Z®810 Color 3D Printer User Manual

Z CORPORATION

Part Number 09524

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Use of Equipment

The Equipment was manufactured under patents licensed to Z Corp. to be used for the fabrication of appearance models and prototypes. Other uses may be restricted; contact Z Corporation for further information.

The Equipment is designed to be used by design engineers and other professionals in the production of early-stage 3D appearance models and prototypes. The Equipment is not to be used to produce, either directly or indirectly, medical or other products that may require precise dimensions or tolerances to ensure the safe and effective operation of such products. You agree to indemnify, defend and hold Z Corporation and its officers, directors and employees harmless from and against any and all claims, losses, damages, costs and expenses resulting from any use of the Equipment other than for the production of early-stage appearance models and prototypes.

If you have purchased all relevant casting-specific products as recommended by Z Corp. (casting-specific service contract, hardware, software, and consumables), as well as a casting license, then you are authorized to utilize the Equipment to fabricate molds for casting.

1 INTRODUCTION

1.1 OVERVIEW

This Z810 Color 3D Printer Manual will speed you along the path towards quickly and inexpensively building parts. The manual contains the following sections:

1. **Introduction**. This section will give you an overview of the principles behind the Z Corporation ("Z Corp.") 3D Printer.
2. **The System Components.** This section will provide a guide for the Z810 System components and features detailed diagrams. It will describe the Z810 3D Printer ("Printer"), ZF8 Powder Feeder ("Feeder"), the ZD8 Depowdering Unit ("Depowderer"), and the optional oven.
3. **Quick Start Guide.** This section will give you a quick breakdown of steps needed to print your part.
4. **Preparing the Z810 3D Printer.** This section will guide you through the steps for preparing the Z810 3D Printer. It includes checking the powder, and fluid levels as well as maintenance procedures such as cleaning the service station.
5. **Using ZPrint™ Software.** This section takes you through a few basics of how to set up your build in ZPrint Software (also referred to as software). For more details on the features available in the Software, please refer to the ZPrint Software User Manual.
6. **Removing the Part.** This section will guide you through removing your part from the Printer and transferring it to the ZD8 Depowdering Unit.
7. **Depowdering the Part.** This section will guide you through using the ZD8 Depowdering Unit.
8. **Infiltrants.** This section offers some recommendations on which infiltrants to use and how to apply them to your part.
9. **Applications.** This section will teach you various ways to maximize the versatility of your printer through the implementation of advanced part processing techniques.
10. **Changing and Aligning Print Heads.** This section contains detailed instructions on how to change and align the HP Print Heads in the Z810 3D Printer.
11. **Changing Material Systems.** This section contains detailed instructions on how to use specific powder systems.
12. **Changing INI Variables.** This section contains detailed instructions on how to change the INI variables to vary the amount of powder metered out by the ZF8 Powder Feeder.
13. **Maintenance.** This section contains recommended periodic maintenance procedures.
14. **Z810 System Details.** This section contains system specifications about the Z810 3D Printer.

1.2 HOW IT WORKS

The Z Corp. Printer Systems are based on the Massachusetts Institute of Technology's patented 3DP™ (3D Printing) technology.

The ZPrint Software first converts three-dimensional data from CAD, or other sources into cross-sections or slices that can be between 0.0035" – 0.009" thick. The Z810 3D Printer then prints these cross-sections one after another from the bottom of the part to the top.

Inside the Z810 3D Printer there is a build piston, where the part is built *(see Figure 1)*. Also represented in the diagrams are the roller, print heads, build area, and cleaning area. The roller moves horizontally across the build area.

When beginning the 3D printing process, the printer first spreads a layer of powder in the same thickness as the cross section to be printed. The print heads then apply a binder solution to the powder causing the powder particles to bind to one another and to the printed cross-section one level below. The build piston descends one layer thickness. The roller then spreads a new layer of powder and repeats the process, until the entire part is printed.

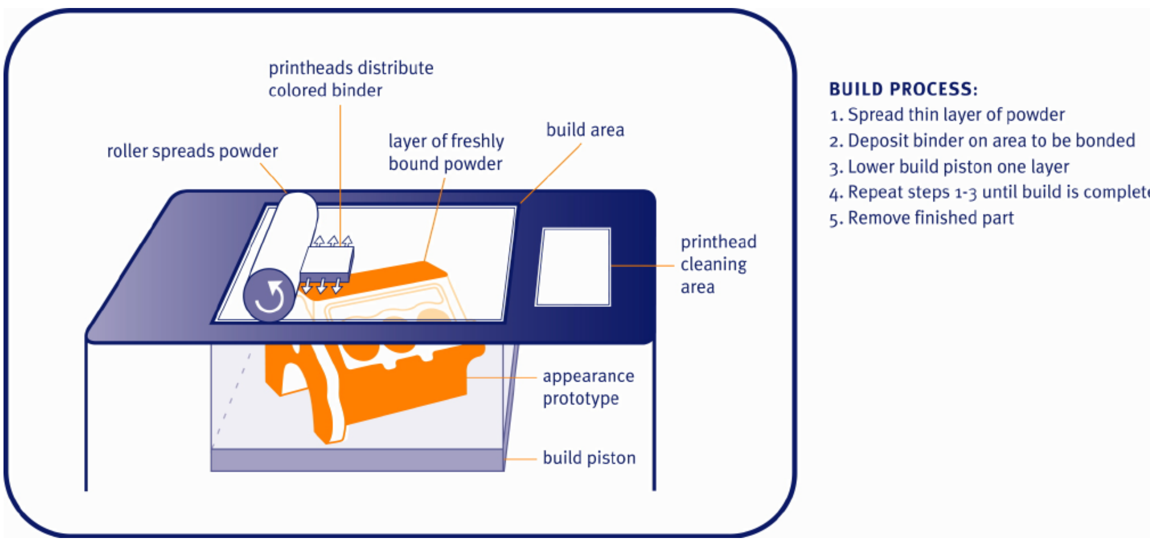


Figure 1: The Printing Process

The Z Corp. Printer System employ several techniques to quickly build parts. First, binder solution is applied in a higher concentration around the edges of the part, creating a strong "shell" around the exterior of the part. Within parts, the Z Corp. 3D Printer builds an infrastructure by printing strong scaffolding within part walls with a higher concentration of binder solution. The remaining interior areas are printed with a lower saturation, which gives them stability, but prevents over-saturation, which can lead to distortion of the part.

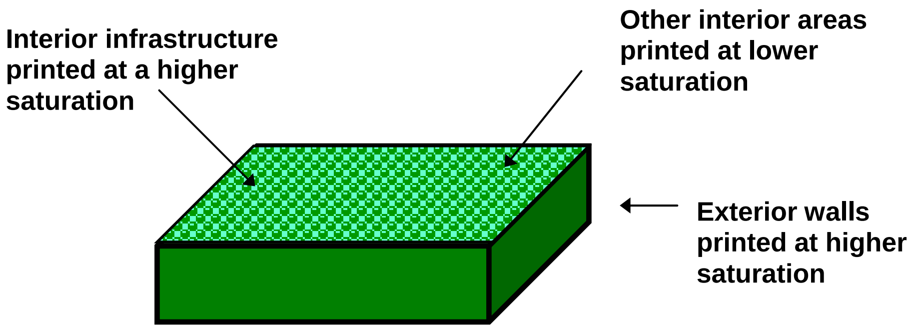


Figure 2: The Shelling and Infrastructure Features

After printing, the part is removed from the powder bed, dried, and depowdered. The part can then be infiltrated with wax, epoxy, or other materials to increase strength and durability. More information on different infiltrants can be found in Section 8, *Infiltrants*.

There are several important issues to consider when preparing a build that will help you print the best parts for your intended purpose.

Part Placement. The ZPrint Software will place the parts within the build box to maximize build speed, the most important criteria for the majority of our users. The ZPrint Software positions the parts with the smallest dimension in the z (vertical) axis. For more information, refer to the ZPrint Software User Manual.

Strength. The ultimate strength of the part will be somewhat affected by its orientation within the print box. The part will be strongest along the x-axis and the y-axis and less strong along the z-axis. This is because the cross sections are printed in continuous strips along the y or the "fast" axis *(the print heads direction of travel)*, bands across the x or the "slow" axis *(the gantry direction of travel)* and laminated layers along the z-axis.

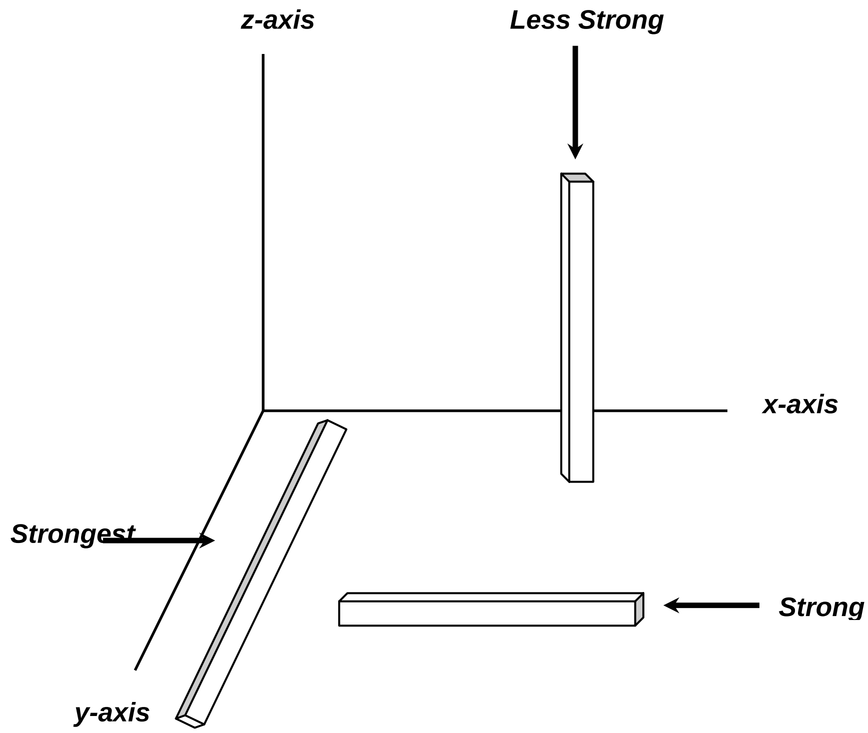


Figure 3: Illustration of Z Corp. System Print Orientations

Accuracy. The accuracy of the printer depends on the materials you choose and the offset and scaling factors used. You can employ the anisotropic scaling feature in the software to adjust for expected shrinkage and bring your parts into true scale. More information on anisotropic scaling factors can be found in Section 5.3.1.1, *Anisotropic Scaling Values*.

2 SYSTEM COMPONENTS

2.1 Z810 PRINTER COMPONENTS

The Z810 System consists of the following hardware components:

2.1.1 Z810 3D PRINTER

Site Requirements:

Power: 100-240 VAC, 50-60 Hz

Dimensions: 46.5 inches (1.18 meters) deep x 64.5 inches (1.64 meters) wide x 54.5 inches (1.38 meters) tall (with top cover closed); 111 inches (2.82 meters) tall with top cover open.

PLEASE NOTE: Left to right (width) dimensions are not additive for the System because the printer and powder feeder overlap by several inches when the feeder is docked.

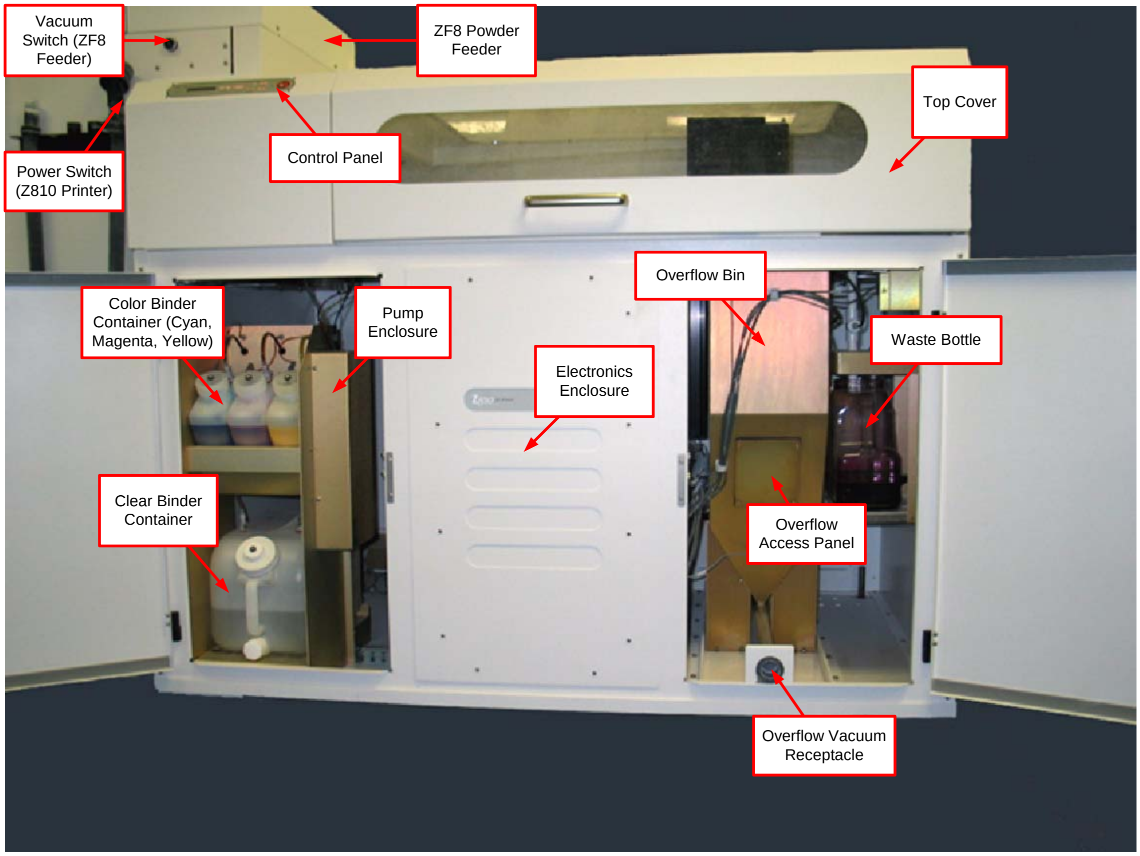


Figure 4: Z810 3D Printer (Front View)

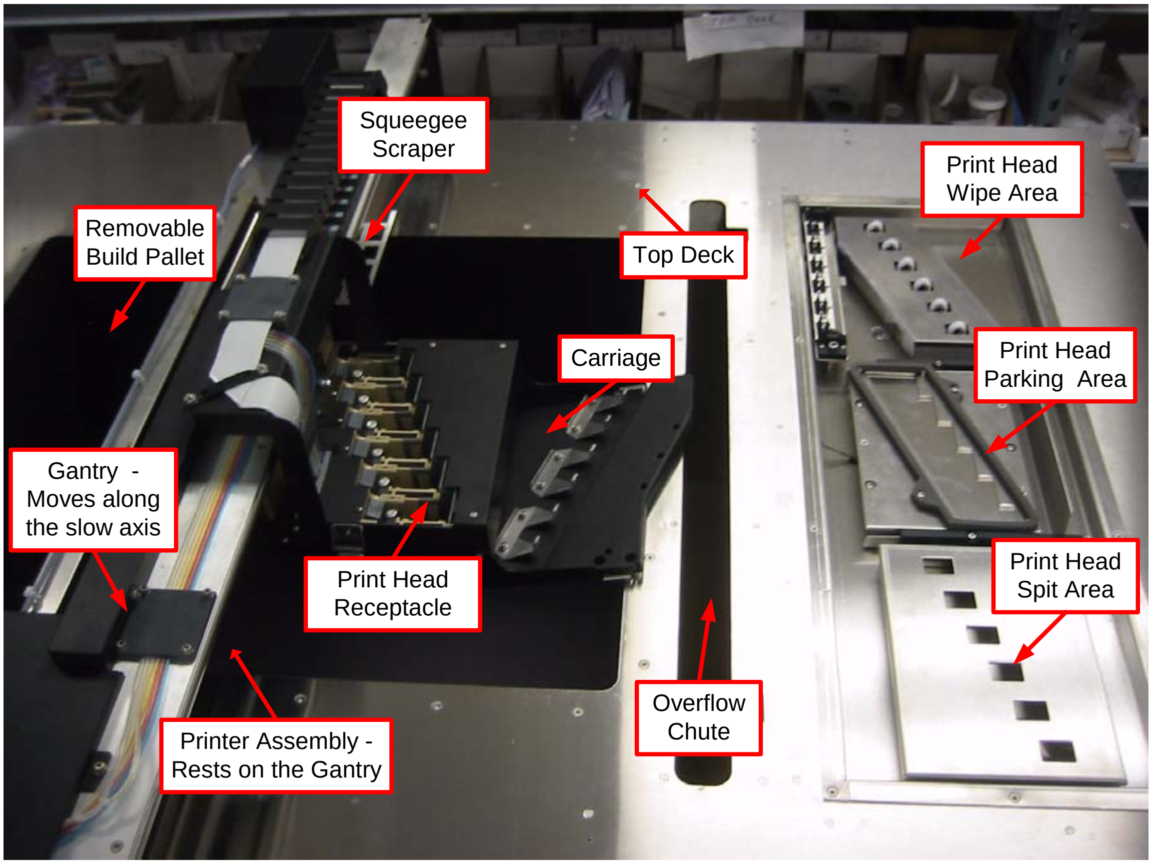


Figure 5: Z810 3D Printer (Top View)

2.1.1.1 Z810 Carriage Assembly

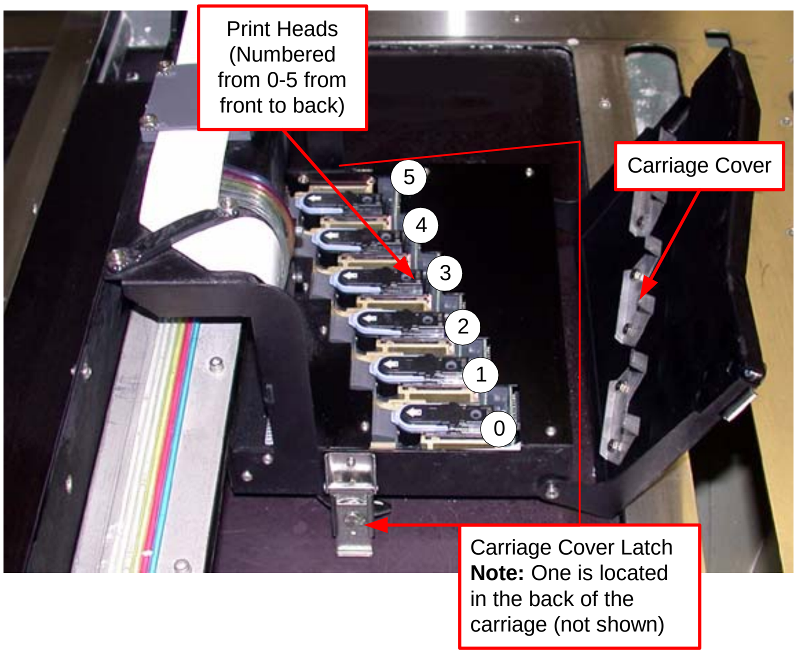


Figure 6: Z810 3D Printer Carriage Assembly

2.1.1.2 Z810 Service Station

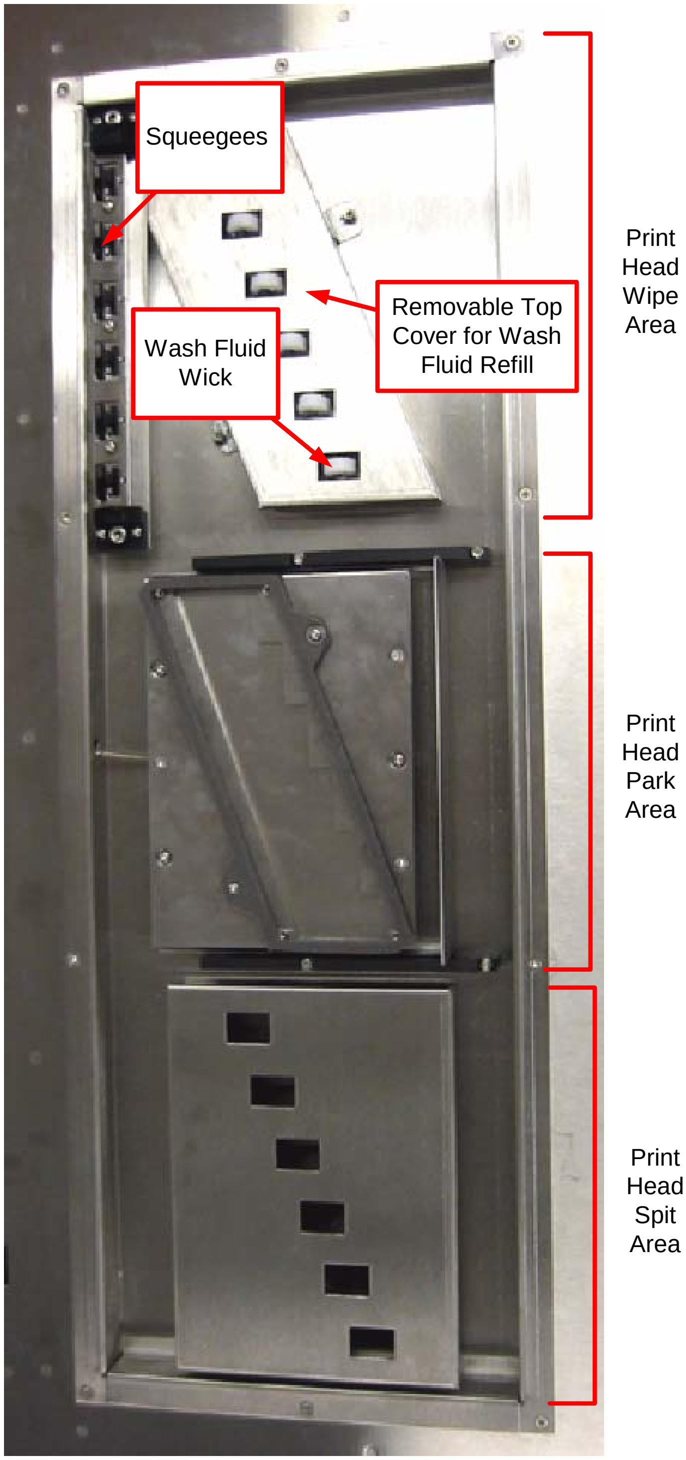


Figure 7: Z810 3D Printer Service Station

2.1.1.3 Z810 Rear Connector Panel

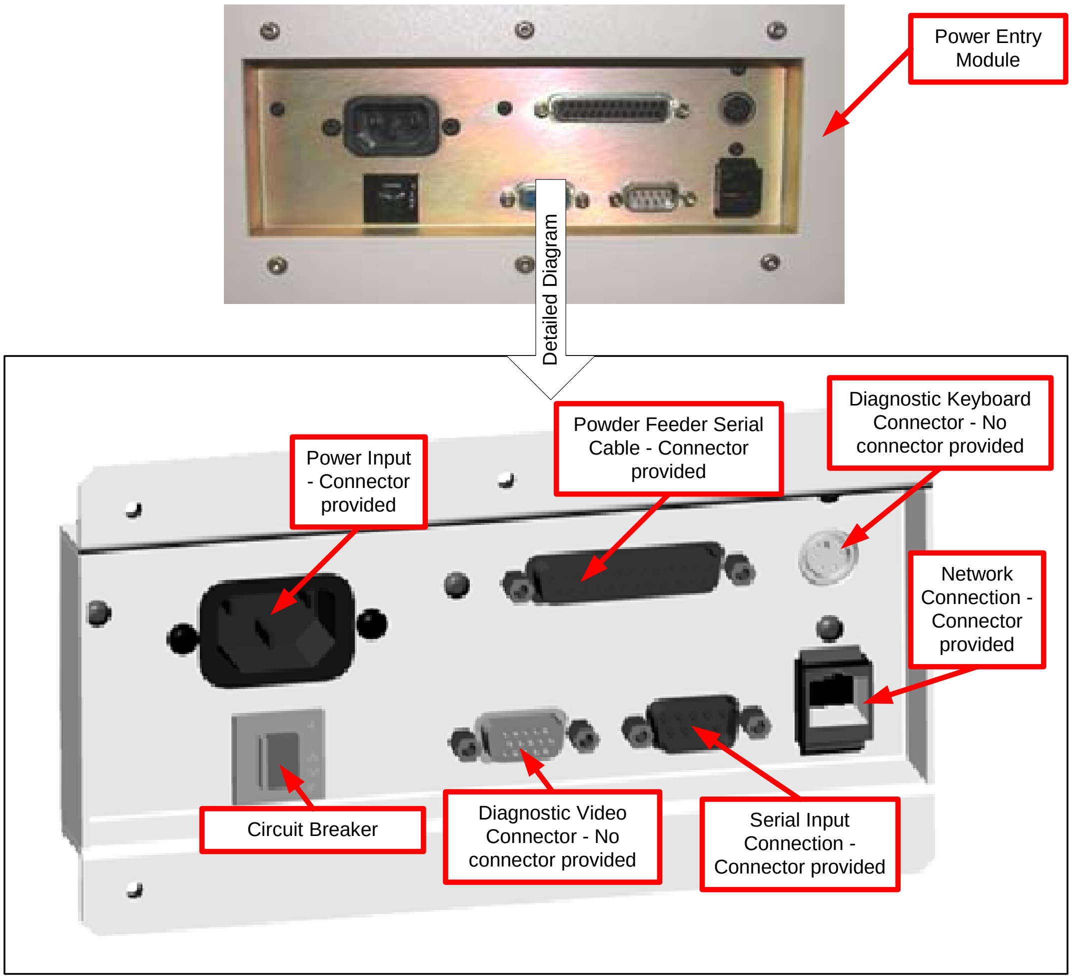
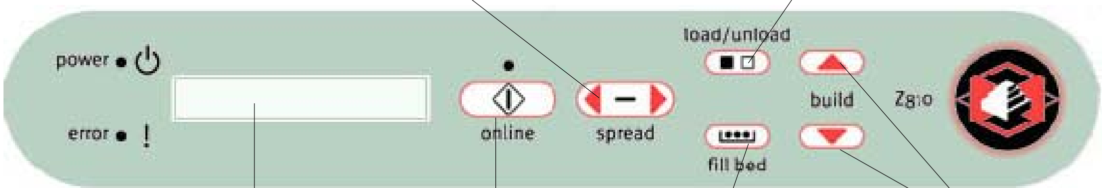


Figure 8: Z810 3D Printer Connector Panel

2.1.1.4 Z810 Printer Control Panel

Spread Button. This button moves the gantry from left to right allowing the user to spread powder over the build piston.

Load/Unload. Lifts build piston to allow for pallet placement and removal.



LCD Panel. Displays the current status of the Z810 3D Printer.

Online Button. Enables and disables printer communication.

Fill Bed. Prepares build area for printing by spreading powder over the build area.

Build Up/Down Buttons. Allows the user to raise or lower the build piston. Briefly pressing this button raises or lowers one layer thickness; holding down the button for five seconds causes the build piston to move all the way down.

2.1.2 ZF8 POWDER FEEDER

Site Requirements:

Power:

Voltage : 100VAC, 50/60Hz, 20A
115VAC, 50/60Hz, 17A
230VAC, 50/60Hz, 10A

Compressed Air: Clean, dry air (dew point 40^{o}F/4^{o}C or below)

Air Fitting: ¼ "Industrial" quick disconnect or other quick disconnect with ¼ inch NPTM pipe thread

Dimensions: 31 inches (0.79 meters) deep x 32 inches (0.81 meters) wide x 78 inches (1.98 meters) tall.

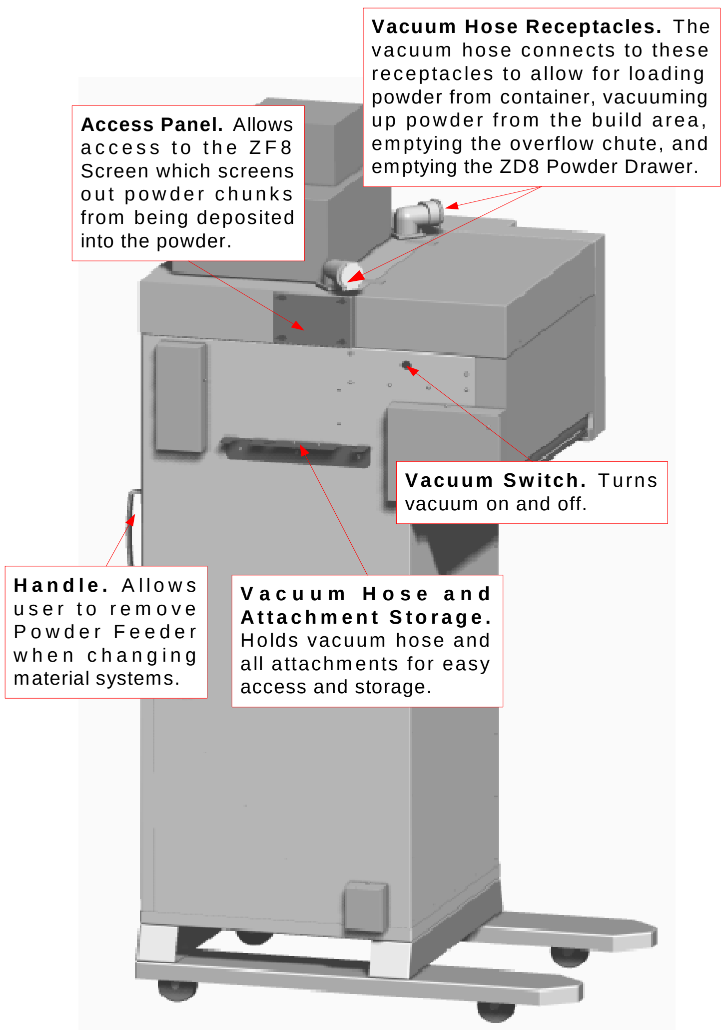


Figure 9: ZF8 Powder Feeder (Front View)

2.1.2.1 ZF8 Rear Connector Panel

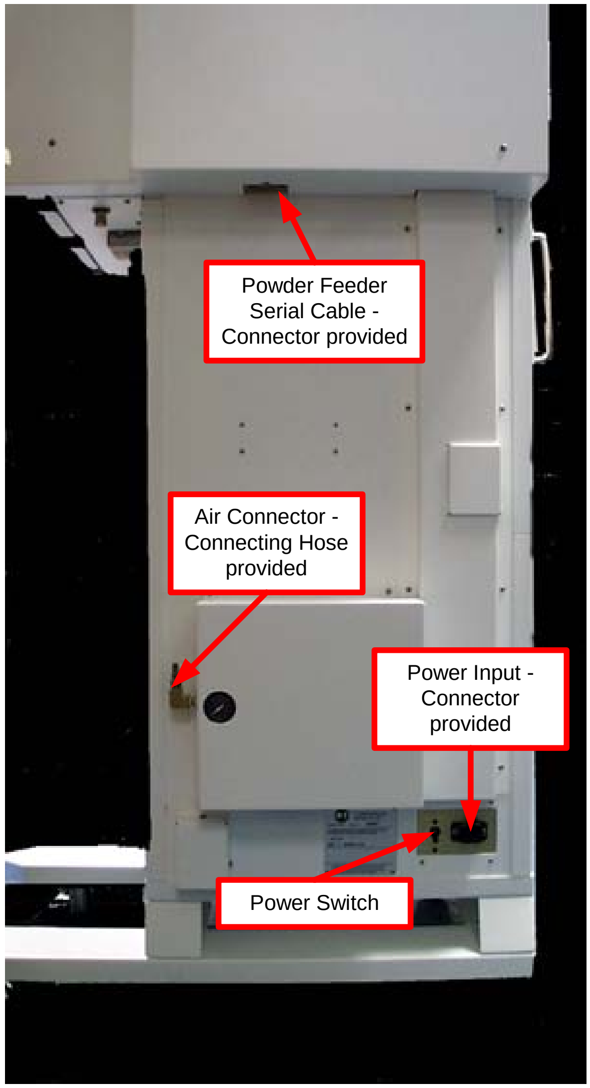


Figure 10: ZF8 Powder Feeder Rear Connector Panel

2.2 ZD8 DEPOWDERING UNIT

Site Requirements:

Power:

Voltage:	Receptacle For Plug Type :
190-200 VAC, 50Hz, 10.5A	IEC 60309-2: RED-6h-32A-3p+N+E
208-230 VAC, 60Hz, 15A	IEC NEMA L15-30 Plug
380-400 VAC, 50Hz, 5.3A	IEC 60309-2 Plug, Red-6h-16A-3p+N+E Plug

Compressed Air: Clean, dry air (dew point 40°F/4°C or below)

Air Fitting: ¼ "Industrial" quick disconnect or other quick disconnect with ¼ inch NPTM pipe thread. *Requires a ¼ NPTM mate.*

Dimensions:

46 inches (1.17 meters) deep x 40 inches (1.02 meters) wide x 105 inches (2.67 meters) tall. *Ceiling clearance of 120 inches (3 meters) is needed to upright the Depowdering Unit from shipping orientation.*

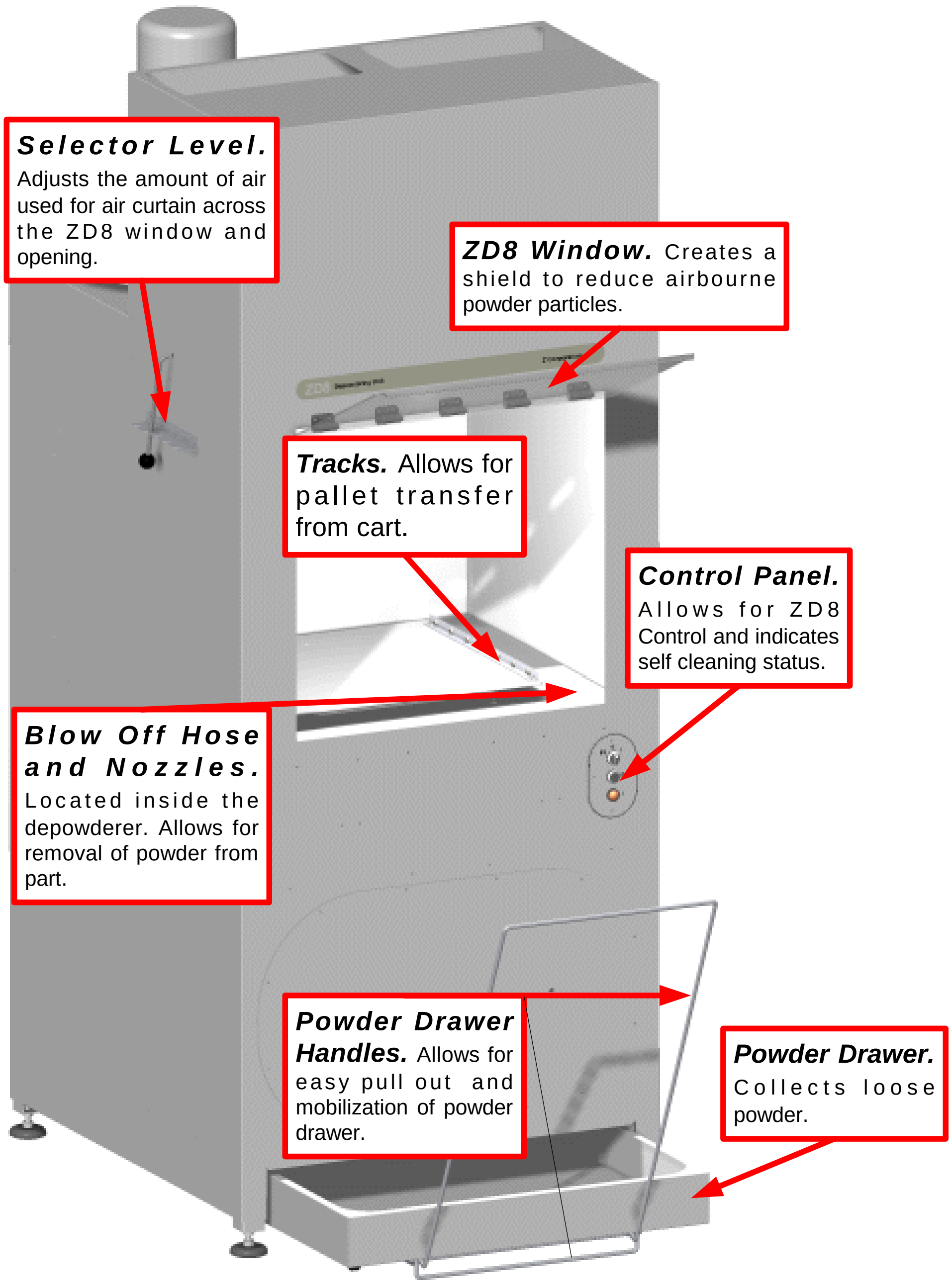


Figure 11: ZD8 Depowdering Unit

2.2.1 AIR CURTAIN

A fraction of the clean air exhausting from the blower is focused into a curtain and directed downward across the ZD8 window and front opening. This air curtain helps powder from being ejected from the part during depowdering.

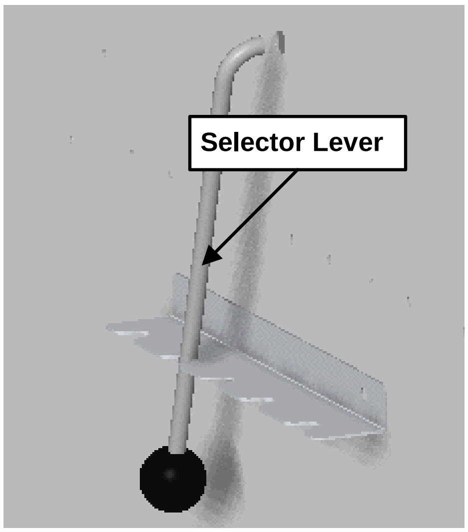


Figure 12: ZD8 Air Curtain Selector Lever

Selector Lever:

The user can adjust the strength of the air curtain - that is, the fraction of the blower exhaust that is recycled into the air curtain - via the selector lever on the left side of the machine. The air curtain is useful for preventing the escape of powder particles and helping the window stay clean. Stronger air curtains more effectively prevent powder jets, reflected off the part, from escaping the booth. However, since the air curtain recycles air within the machine, a strong air curtain reduces the amount of net (fresh) airflow and allows for less visibility. While the air curtain can be adjusted as often as you like, most users will find a single setting they are most comfortable with. The table below summarizes the various positions of the selector lever. Positions 1 through 5 are ordered from the rear to the front.

Pos.	Curtain Strength	Visibility
1	Off	Best
2	Low	Very Good
3	Medium	Good
4	Strong	OK
5	Very Strong	Poor

2.2.2 ZD8 CONTROL PANEL

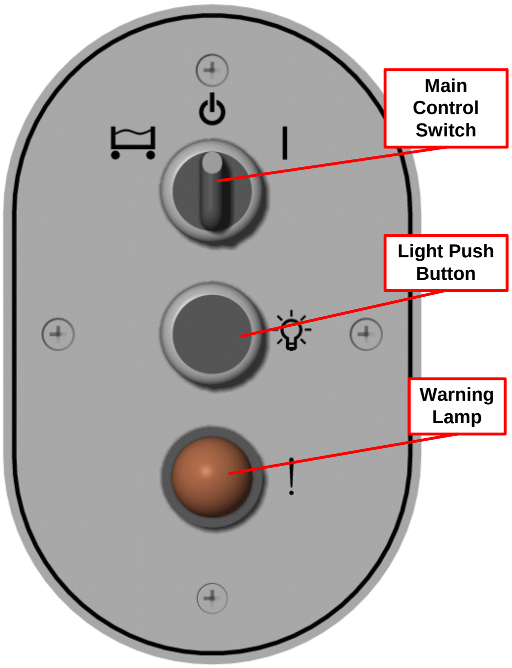


Figure 13: ZD8 Control Panel

> **PLEASE NOTE:** If the warning lamp is illuminated (indicating that the filter cleaning cycle has been initiated) and you would prefer that the cleaning not occur at that time, you can pause the cleaning cycle by turning the main control switch to either Powder-Drawer-Release mode or Power-On mode. The cleaning cycle will restart when the main control switch is returned to Stand-By mode. This is particularly helpful when you want to inspect or unload parts immediately after depowdering.

Main Control Switch:
The main control for the ZD8 Depowdering Unit is a 3-position switch. See the table below for a description of each position.

Position	Symbol	Mode
Left		Powder Drawer Release
Middle		Stand-by
Right		Power On

Light Push-Button:
The light push button serves two functions:

1. Briefly pressing the push-button will toggle the lights in the workspace On/Off. (This feature is only available when the ZD8 Depowdering Unit is in Stand-by mode.)
2. By pressing and holding the push-button until the lamp goes on, the user can initiate the automatic filter cleaning cycle. (While the filter cleaning cycle can be initiated at any time, the cleaning will only start if the ZD8 Depowdering Unit is in Stand-by mode.)

Warning Lamp:
The lamp indicates the status of the automatic filter cleaning cycle. See the table below for description of each lamp state.

Lamp State	Description
Off	Filter cleaning is NOT currently scheduled.
Steady On	**Notice:** Filter cleaning cycle has been initiated. Cleaning is scheduled for next Stand-by mode, and will start shortly thereafter.
Flashing On/Off	**Caution:** Filter cleaning currently in progress. Please stand clear of machine.

2.2.3 POWDER COLLECTION DRAWER

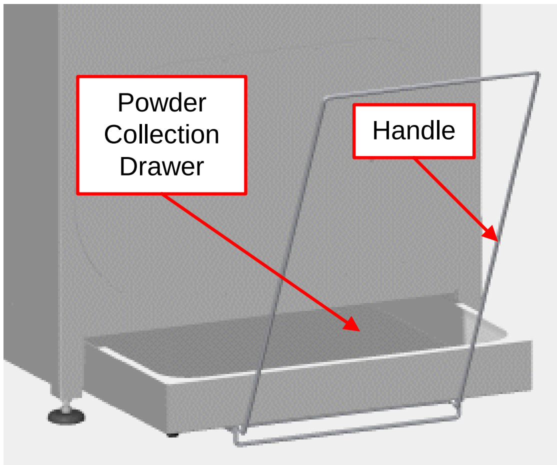


Figure 14: ZD8 Powder Collection Drawer

All of the discarded powder from the depowdering process is deposited in the Powder Collection Drawer at the base of the ZD8 Depowdering Unit. During normal operation, the drawer is actively sealed to the underside of the machine. When the main control switch is in Powder-Drawer-Release mode, the seal is disengaged from the drawer – allowing the user to pull the drawer out from under the machine for emptying.

The extending tow handle stores underneath the powder drawer. To deploy the handle, slide it all the way forward until it reaches the stop on the track. Then, lift the handle to a comfortable walking height. Once the handle is deployed, is can be used to tow, push, and maneuver the Powder Drawer to and from the emptying location. The handle is returned to its stored position by pivoting the handle down to the floor, and then sliding it back under the Powder Drawer.

For information on how to remove powder from Powder Collection Drawer, please see Section 13.13, *Empty Powder Drawer from the ZD8 Depowdering Unit.*

2.2.4 ZD8 CART

- The ZD8 Cart allows for easy transport of parts using the track system.

For information on how to use the ZD8 Cart and Track System, see Section 6.3, *Transferring the Parts to the Depowdering Station.* Also refer to Section 7, *Depowdering the Part*, for instructions on how to depowder your part.

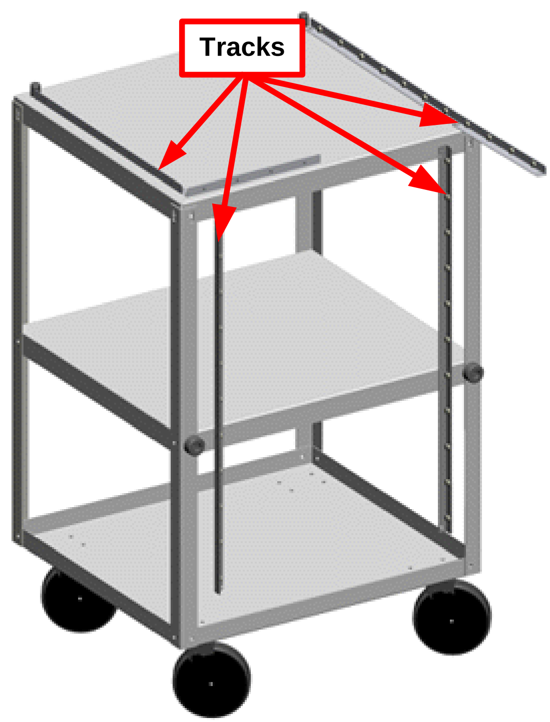


Figure 15: ZD8 Cart

2.3 DESPATCH LBB FORCED CONVECTION OVEN (OPTION)

Key Features

- 42 inches (1.07 meters) deep x 45 inches (1.14 meters) wide x 84 inches (2.13 meters) tall. *Height includes oven stand. Oven alone is 51 inches (1.3 meters) tall.*
- Forced convection
- Temperatures up to 400°F (204°C)
- Precise digital controls
- Stainless steel interior
- Ventable
- Nickel plated shelves
- Five year heater warranty
- UL and C-UL listed
- Optional CE mark
- **Power:** 208/240V, 50-60 Hz

For more information, contact your Z Corp. Sales representative or look on the Despatch website at http://www.despatch.com/.

For information on how to transfer parts from the ZD8 Cart to the Oven, please see Section 7, *Depowdering the Part.*

PLEASE NOTE: Mold preparation and metal pouring requires adequate ventilation to ensure that exposures to dust, particulates, fumes and vapors are controlled below occupational exposure limits. Ventilation designs need to meet each customer's respective governmental health and safety requirements. A reference frequently used by U.S. firms to comply with OSHA regulations is the American Conference of Governmental Industrial Hygienists Industrial Ventilation Manual.

Please review the Material Safety Data Sheet for ZCast® powder.

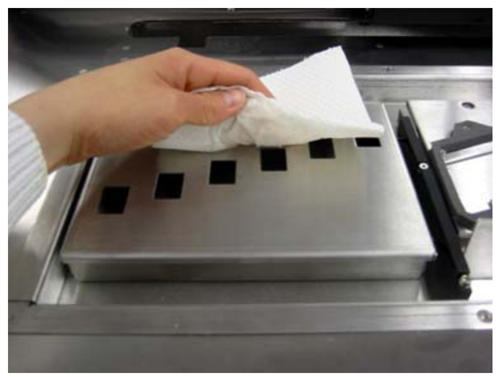
3 QUICK START GUIDE

Here is a quick guide to printing a part in the Z810 3D Printer.

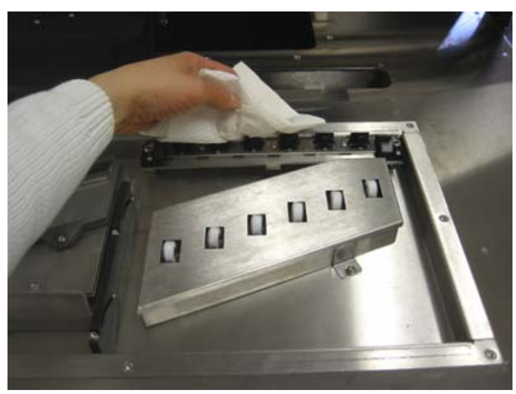
3.1 PRINTER PREPARATION

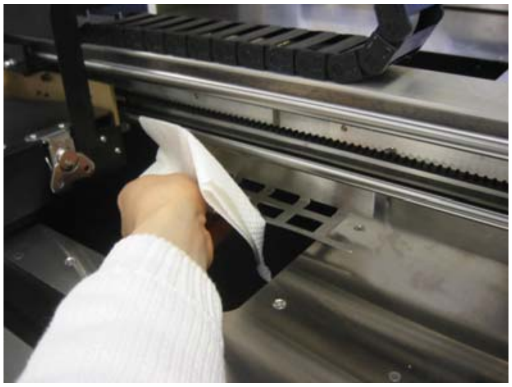
1. Clean the top deck.

2. Clean service station.

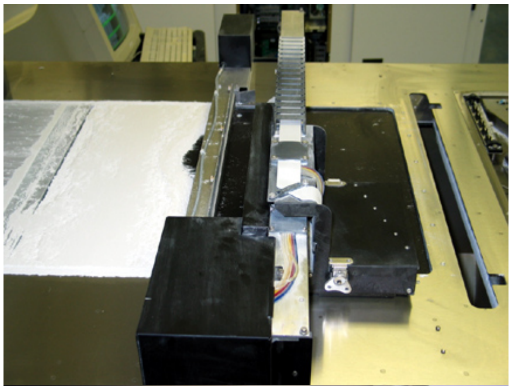


3. Clean the squeegees and wiper scraper with a dry paper towel.





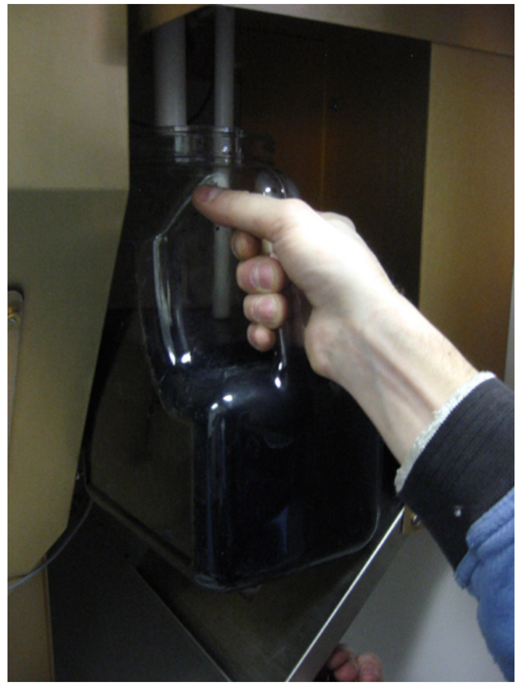
4. Spread powder over the build area using the fill bed feature.



5. Empty powder overflow chute.

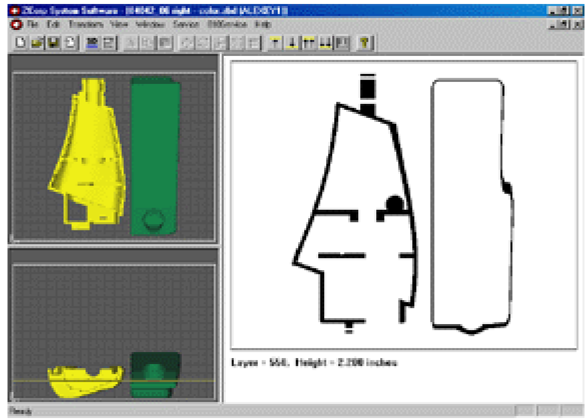
6. Check fluid levels of binder. Fill if needed.

7. Empty waste container.



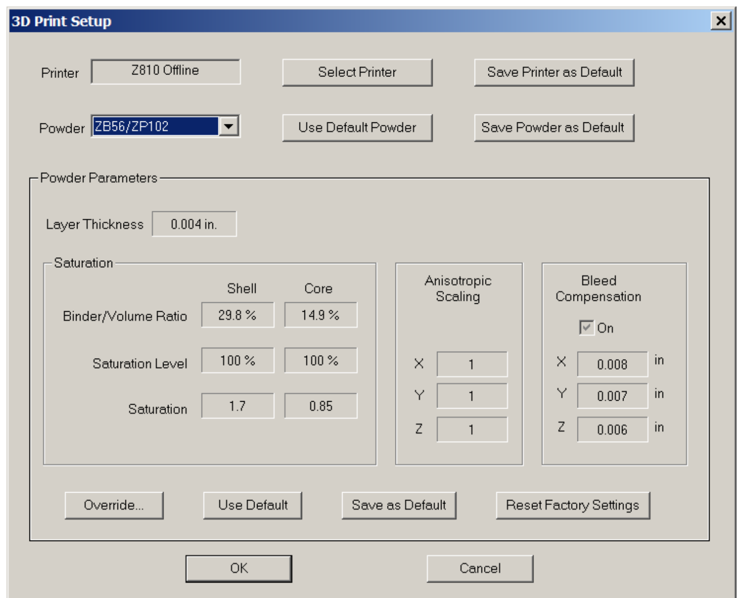
3.2 SETTING UP THE BUILD

1. Set up the build on the ZPrint™ Software.



2. Check 3D Print Setup for build settings and edit as needed.

3. Press 3D Print to begin printing process.



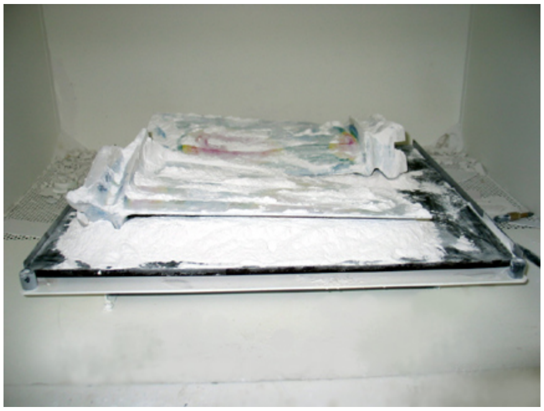
3.3 TRANSFERRING THE PART TO THE DEPOWDERING UNIT

1. Gross depowder the part in the printer, leaving the powder underneath to support the model.

2. Transfer build pallet to cart using track system.

3. Transfer build pallet to depowdering unit.

4. Turn depowdering unit on and leave part in the depowderer to dry.

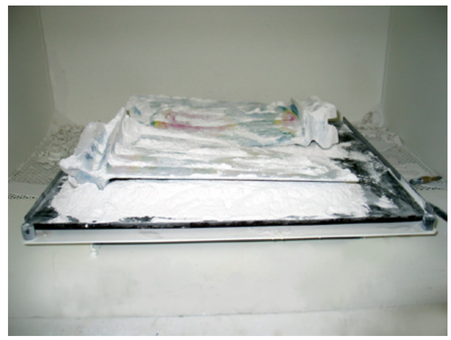


3.4 DEPOWDERING THE PART

1. Turn air gun on and adjust air pressure.

2. Depowder part. Leave supporting powder underneath plaster parts. Depowder starch parts completely.

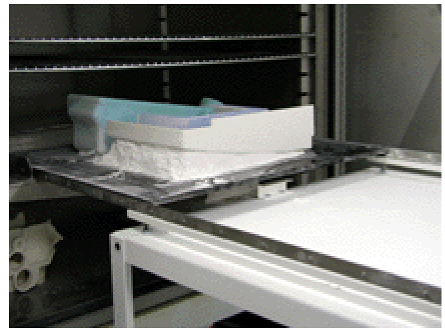
3. Remove part from depowdering unit.



4. Clean depowdering unit.

3.5 TRANSFER TO OVEN

Transfer part to oven for additional drying.



3.6 FINISH PART

Depowder or infiltrate as needed. Infiltrate part with Z Corp. recommended wax or resins. More information on infiltrants can be found in Section 8, *Infiltrants*.

3.7 USER TIPS

3.7.1 SET-UP AND POST-PROCESSING

3.7.1.1 Part Setup, Orientation, and Print Settings

- Do not tightly pack parts into the build. Keep in mind that you will need to depowder and remove them from the build box. Allowing a little bit of room around the part so you can vacuum the powder away and get your fingers around or under it will go a long way.
- Orient parts so delicate features are supported in the z-axis, i.e. keep the attaching feature directly below the fragile features. If a delicate feature is only supported by unprinted powder the chances of breaking that small feature during depowdering is greatly increased.
- When building delicate parts use the “Fixture” function to cradle the part. Raising the part 0.25” (6.4 mm) from the bottom of the build and creating a fixture under the part will produce a cradle that can be handled. The part inside the cradle can easily be transported to an oven or the depowderer.
- Do not enable the bleed compensation feature if you are building a part with features under 0.050” (12.7 mm).
- To increase the strength of thin parts, you can decrease the layer thickness to 0.0035” (0.089 mm) if you are using one of the zp®100 series (plaster-based) powder systems. Then choose to override the saturation values. Input the saturation values used for printing at 0.004” (0.102 mm). This increases the binder to powder ratio and wets more of the resins in the powder system. As you increase the strength of the part in this manner you are also inceasing the amount of time to dry the part. Use of the removable build plate and oven drying the part are recommended.

3.7.1.2 Gross and Fine Depowdering

- Become familiar with where the parts are placed and how they are oriented in the build box so you do not accidentally bump or brush against a fragile part during the depowdering process.
- When performing the gross depowdering (removal of excess powder in the build box) do not plunge the vacuum nozzle into the powder bed. Begin at the outer perimeter of the build box, slowly work your way into the build. Hold the tip of vacuum nozzle approximately 0.25" (6.4 mm) to 0.375" (9.5 mm) away from the powder and allow the vacuum to pull the powder up. Slanting the vacuum nozzle will enable you to control the suction. This will decrease the chance of breaking a part that is hidden beneath the surface of the powder.
- While fine depowdering in the depowderer, always start with a low air pressure and gradually increase the pressure as the fine details and features of the part become visible. When the top and sides of the part are completely depowdered tilt the part onto one of its sides. Handle the part carefully. The part may be fragile and brittle before infiltration. If none of the sides of the part will be able to support the weight of the part you can apply a small amount of resin or epoxy to strengthen it. You want to be careful not to let any of the infiltrant come into contact with any unprinted powder that may still be on the part. Let the infiltrant dry before continuing to depowder.

3.7.1.3 Oven Dry the Part

- Although the part can be handled when it is not completely dried, the part reaches full strength when dried. Placing the part in an oven at temperatures less than 200°F (93°C) for 2-4 hours will increase the strength of the part. This is only recommended for plaster-based powders.

3.7.2 PART INFILTRATION

3.7.2.1 When Using Z-Bond™ Resin

- Always infiltrate the most delicate features of the part first. Z-Bond resin gives almost immediate strength to the area of the part that has been infiltrated. As you handle the areas of the part that have been infiltrated it will be less likely to break it.
- Try to avoid infiltrating the part by applying Z-Bond resin from spot to spot. Pick a good starting place and hold that area upward relative to the rest of the part. With your free hand, place the tip of the Z-Bond bottle against the part and allow the cyanoacrylate (CA) to flow from the bottle. It is important that the CA flows at a uniform rate making it easier for you to judge how quickly it will flow from the tip of the bottle before it wicks into the part. By seeing how quickly it wicks into the part you will be able to judge where and how quickly to move the tip of the bottle while applying the CA, being sure not to apply the CA to the same place more than once.

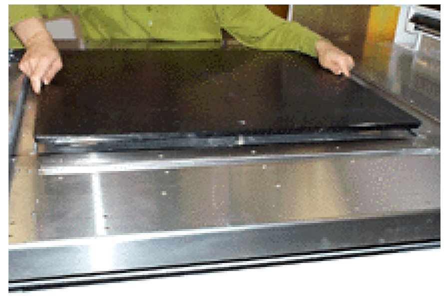
3.7.2.2 When Using a Z-Snap™ or Z-Max™ Epoxy

- If the part has delicate features, infiltrate them last as the feature will be less strong after being infiltrated until the epoxy begins to cure. This will decrease the chance the feature will break from the part if nudged or bumped.
- If the part has multiple delicate features or it is impossible to handle the part without breaking a feature you may infiltrate these features only. Allow the Z-Snap or Z-Max epoxy to cure. Then infiltrate the rest of the part. This will add time to post-processing the part but it ensures that you have a good strong part without any fractures.

4 PREPARING THE Z810 3D PRINTER

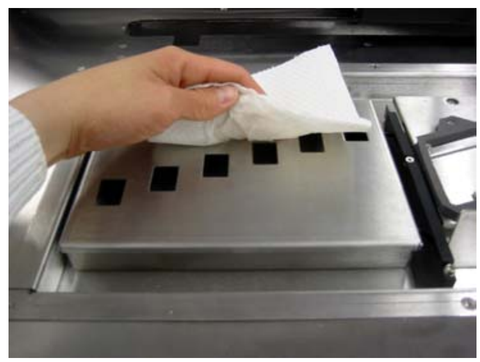
4.1 REPLACING THE BUILD PALLET

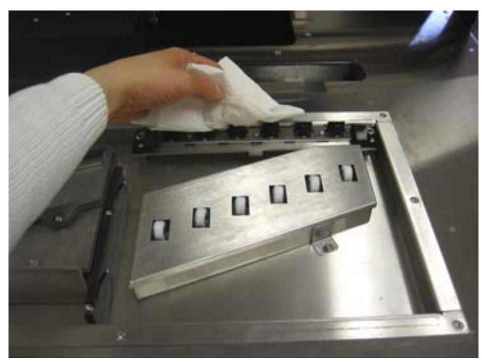
Put the printer offline. If there is no pallet in the printer, replace the pallet by pressing 'Load/Unload' on the control panel to move the build piston up. Once the build piston is in the unload position, place the pallet on the build piston by lining up the pallet holes with the pegs. Press the 'Online' button to return build piston to printing position.



4.2 CLEANING THE SERVICE STATION

1. Put the Printer online. Unpark the carriage using the software by choosing the 'Unpark' option under the 810Service menu. Open the top cover. Once the service station is exposed, wipe the squeegees with a dry paper towel. You may also wipe the other areas of the service station such as the parking cap and the spit station.



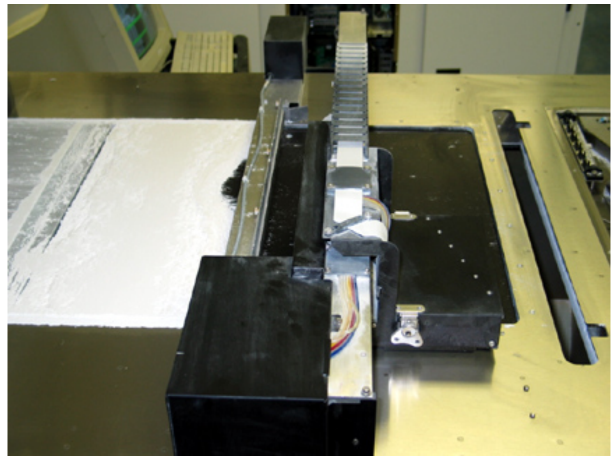


2. Check the zc10 wash fluid reservoir. When the depository is dry, refill with one bottle of zc10 wash fluid.

3. Wipe the squeegee scraper with a dry paper towel.

> *Technical Tip –*
> The cover plates may be detached and cleaned under running water to remove any debris.
>
> Keeping the machine clean will ensure that it works optimally.

4.3 FILL BED



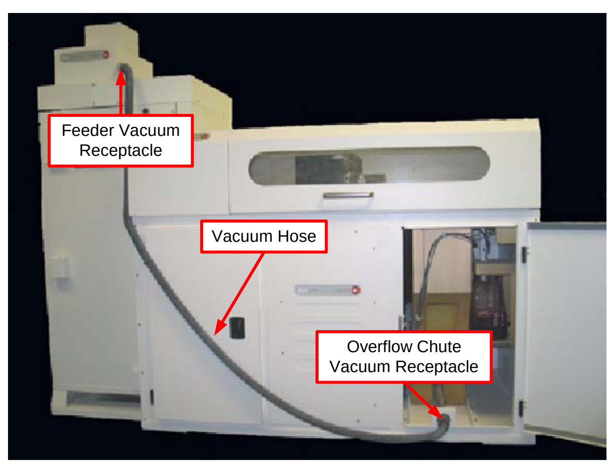
1. Press the 'Fill Bed' button on the control panel. This will prompt the powder feeder and gantry to deposit and spread powder over the build pallet. It will continue spreading until the build pallet is covered.
2. To cancel the operation, press 'Online' on the control panel.

> **PLEASE NOTE:** The powder should spread evenly throughout the build pallet. If it does not spread evenly, manually spread powder over the build pallet by pressing 'Spread' on the control panel.

4.4 REMOVE POWDER FROM OVERFLOW CHUTE

1. Place one end of the vacuum hose into the overflow chute vacuum receptacle.
2. Place the other end of the vacuum hose into the powder feeder vacuum receptacle.
3. From the software select the 'Empty Overflow' option under the 810Service menu. The vacuum and vibrator located on the overflow chute will operate automatically.
4. The vacuum and vibrator will stop when the overflow chute is empty.

To reduce airborne powder particles, turn on the vacuum and remove the vacuum hose from both the overflow chute vacuum receptacle and feeder vacuum receptacle. Then turn off the vacuum.



> **PLEASE NOTE**: The airflow from the powder feeder may stall for a minute while cleaning the filter. The vacuum and the vibrator in the printer will remain on. After cleaning, the powder feeder will resume emptying the overflow chute.

4.5 CHECKING POWDER LEVELS

PLEASE NOTE: Never add powder from container until all powder has been vacuumed out of the build area and overflow chute has been emptied.

If you do not have enough powder to complete your build, you will need to fill the powder feeder. To view how much powder is left in the feeder, choose 'Check Status' under the Service menu or using the control panel raise or lower the build piston the LCD will read "F: X%. B: Y%." (Where X corresponds with the powder level in the feeder and Y corresponds with the build level available.)

The powder levels are given in four-inch increments ONLY.

To fill the feeder:

1. Turn on vacuum.
2. Place vacuum hose into powder feeder vacuum receptacle.
3. Vacuum powder from powder container.
4. The powder feeder vacuum will shut down when it is full.

Technical Tip **–**
Use a nozzle or vacuum at an angle when filling the powder feeder. This will promote airflow through the vacuum hose.

PLEASE NOTE: If the feeder detects that it is full, it will shut off the vacuum and stir the powder in the feeder for 30 seconds. If it no longer detects that it is full after stirring, the feeder will turn the vacuum back on. This continues until the detector reads full after stirring. When the feeder detects that it is full, the vacuum switch will not turn on the vacuum until powder is dispensed from the feeder.

4.6 CHECK FLUID LEVELS

4.6.1 BINDER CONTAINERS

Check the fluid levels on the binder and waste containers. It is good practice to fill the binder bottles when they are half empty.

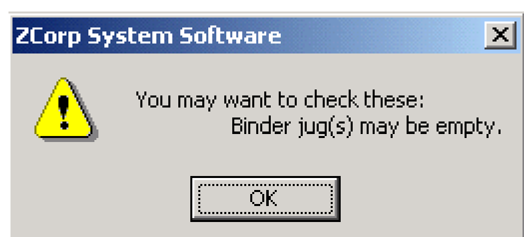
The color binder containers can hold half a gallon (2 liters) of color binder. The large clear binder container can hold up to four gallons (16 liters) of clear binder.

PLEASE NOTE: If the printer will be printing in monochrome mode only, fill color containers with distilled water. See Section 12.2, *Flush System with Distilled Water.*

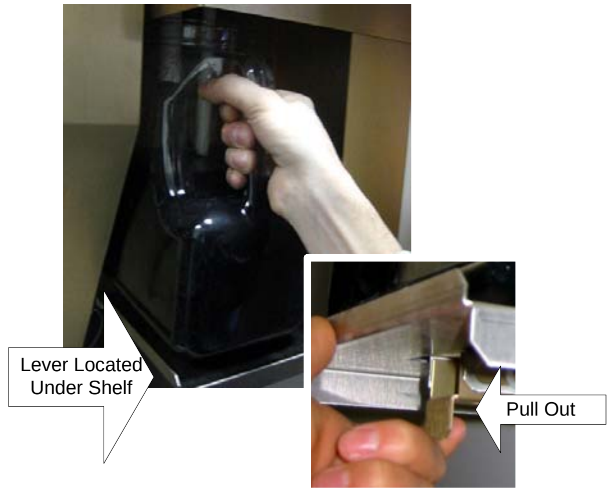
To fill the binder bottles:

1. Unscrew the top cap.
2. Fill container with binder.
3. Replace cap.

PLEASE NOTE: Binder level sensors will indicate via the software when the binder level is low. For color binder, the sensors will indicate a low level when it reaches one liter of fluid. For clear binder, the sensors will indicate a low level when it reaches six liters of fluid. These amounts are enough to complete a large build. The warning will appear before the printer begins a build so that you may fill up the binder bottles to prevent errors in the print job and damage to the printer.



4.6.2 CHECK WASTE CONTAINER



The waste bottle should be emptied before each build.

To empty the waste container:

1. Hold and lift waste container.
2. Release the latch on the bottom of the waste container shelf.
3. Remove bottle.
4. Empty out waste fluid.
5. Replace waste container.
6. Replace shelf to original position.

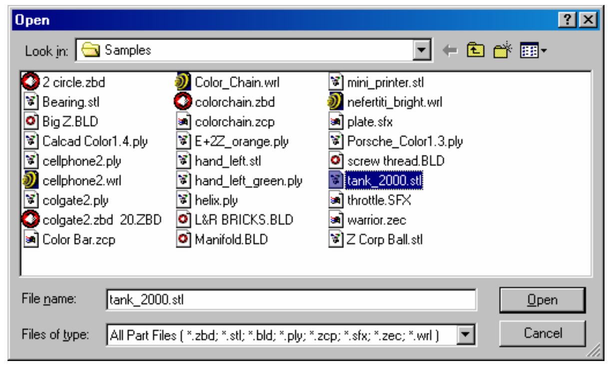
5 USING ZPRINT™ SOFTWARE

This chapter will briefly explain how to set up the build, check the settings, and print. For more information about features in the ZPrint Software, please refer to the ZPrint Software Manual.

PLEASE NOTE: If the ZPrint Software has not been installed, install the software. Instructions are located in Section 1.2 of the ZPrint Software Manual.

5.1 OPEN OR IMPORT THE FILE

1. Open the ZPrint Software. The open dialog box will appear.
2. Choose the file you wish to open.
3. Click ‘Open’ or double-click the file.
4. Choose the dimensions and powder type you will be using.
5. Click ‘OK’.
6. The file will be brought into the software and sliced.



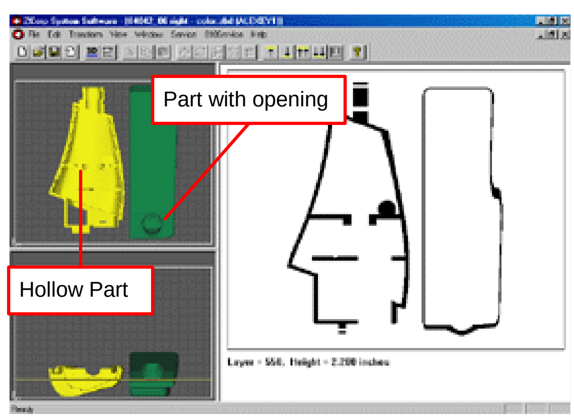
If you would like to open additional files, choose the ‘Import’ option under the File menu.

5.2 ORIENTING THE PART

- We recommend that only one level of parts be printed. All parts should be seated on the build pallet.
- Place parts in the center of the build pallet by choosing either ‘Justify’ or ‘Justify Group’ under the Transform menu and select center justify for the left and right and front and back options.
- Parts that need to be built separately and then mated are dependent on part geometry. If you need assistance for best accuracy with mating parts, please contact the Applications Engineering Team at applications@zcorp.com.

5.2.1 PART CONTAINING AN OPENING OR HOLLOW AREA

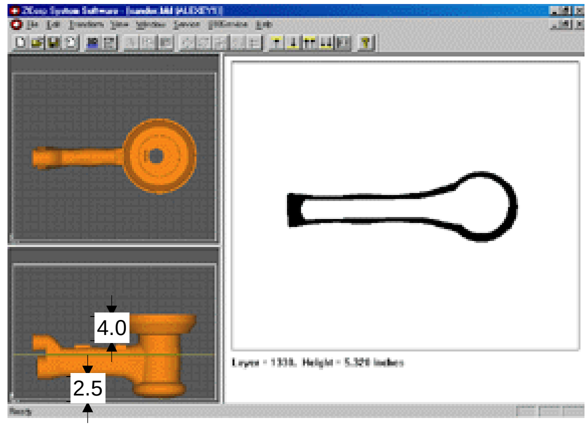
- If the part has an opening or is hollow, place the opening or hollow side up. This will allow for the removal of powder during the gross depowdering process.



5.2.2 PART CONTAINING OVERHANGS

▪ Unsupported overhangs should be placed on the left hand-side and as close to the build plate as possible. The plaster powder, being extremely fine, is more fluid in the build. Placing a small solid piece underneath overhanging surfaces would reduce the movement of the overhang.

▪ Cylindrical features will be more accurate when their axis is parallel to the z-axis. For example, if you were to print a bottle, the bottle would best be printed standing up, with the mouth of the bottle facing the top of the printer.

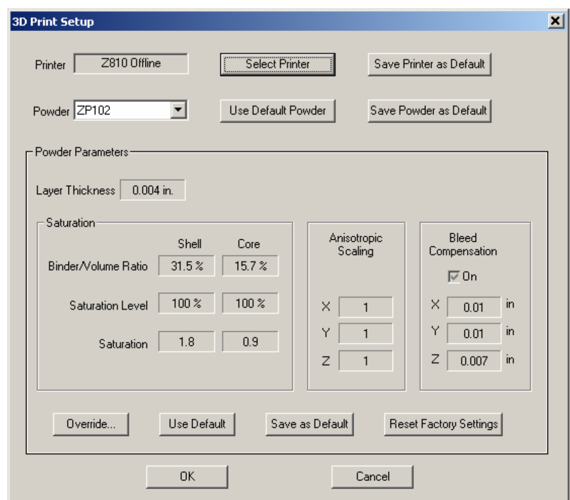


5.3 CHECKING BUILD SETTINGS

ALWAYS check build settings before printing:

1. Choose the '3D Print Setup' option from the File menu (or toolbar).
2. Check that the selected printer, powder type, and powder settings for the build are correct. The ZPrint Software settings are the recommended values.
3. If the settings need to be changed, select 'Override'. Press 'OK' to confirm.

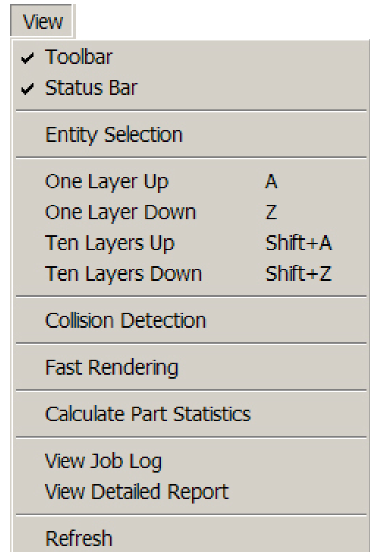
For more information on how to change the settings, please refer to the ZPrint Software Manual.



It is also strongly recommended that slice viewing and collision detection (if more than one part is being printed) be used before beginning the build. These features are found under the View menu of the software.

Slice viewing allows you to view the cross sections of the part to identify any slice errors.

Collision detection will scan through the slices and report the layer in which part overlapping is found.



5.3.1 POWDER SETTINGS

5.3.1.1 Anisotropic Scaling Values

Anisotropic scaling values scale the model to accommodate any shrinkage or expansion of the part either due to characteristics of the material system or infiltrant system. A scaling value of one (1) is equal to 100% of the part in a specific axis. If the part shrinks 1% in a certain axis, the correct anisotropic scaling value would be 1.01 in that axis. The ZPrint Software will display the recommended values for each powder type. The scaling factors may differ according to wall thickness and geometry of the part.

A higher accuracy level may be obtained by measuring the part and adjusting anisotropic scaling values as needed. To obtain new anisotropic scaling factors that are part specific, print the part with scaling factors of one (1) in all axes. Once the part is completed, post-process the part. Measure the x-, y-, and z-axes. Divide the nominal value by the measured value. For example, if the printed part had a nominal value of 1 and had a measured value of 0.98, the scaling value would be 1.02. After calculating the anisotropic scaling values, input them into the software and reprint the part and follow the post-processing procedure.

1. Plaster Material System
The plaster material system has been found to remain dimensionally accurate during printing and thus, the recommended anisotropic scaling values are one (1) in all axes. If the infiltrant system being used changes the accuracy of the part, please alter the values as needed.

2. Starch Material System
The shrinkage found in the starch material system is proportional to the part geometry and the drying time of the part. The longer the part is left to dry, the larger the shrinkage value. The part is most stable in the x and y-axis and shrinks more in the z-axis. Thus, the anisotropic scaling factor of the z-axis will always be greater than the values for both the x- and y-axes.

3. ZCast Material System
The ZCast material system has been found to remain dimensionally accurate during printing and thus, the recommended anisotropic scaling values are one (1) in all axes.

5.3.1.2 Saturation Values

The saturation values determine how much binder is placed on the powder to print the part. The part is made up of two areas, the shell and the core, as described in Section 1.2, *How It Works*. Thus, there are two saturation values, one for the shell and core. In general, the shell saturation is higher than the core saturation. The ZPrint Software will display the recommended values for each powder type.

1. Plaster Material System

The shell and core saturation values for the plaster material system are generally constant values, meaning that there is only one value for all geometry types.

> **PLEASE NOTE:** When printing parts that are thinner than 1/8 of an inch (3 mm). Increase saturation values:
> Shell Saturation: 2
> Core Saturation: 1

2. Starch Material System

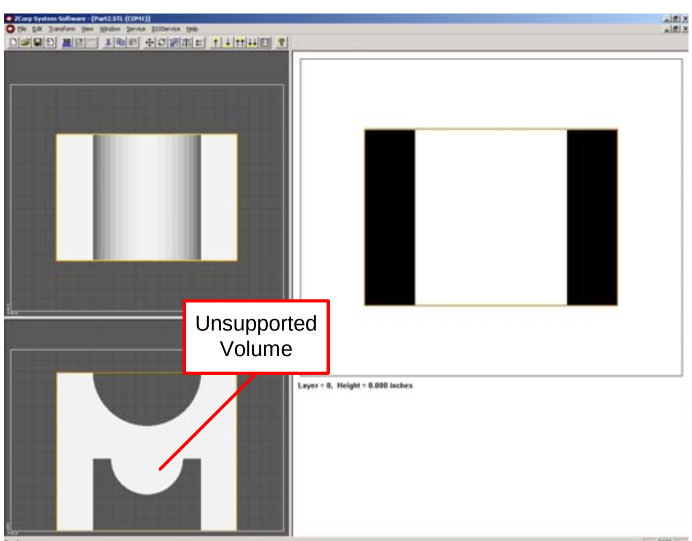
The shell and core saturation values for the starch material system depend on part geometry. A thick walled part will have lower shell saturation than a thin walled part. Core saturation is dependent on the wall thickness of the part. The thinner the wall thickness the higher the core saturation; the thicker the wall thickness the lower the core saturation.

3. ZCast Material System

The shell and core saturation values for the ZCast material system are generally constant values, meaning that there is only one value for all geometry types.

The ZPrint Software will recommend shell and core saturation values based on the part geometry. These values will work for most parts except the following:

- Parts where a large volume will be unsupported when the part is fully depowdered need to have their saturation values manually set. These parts should be printed with a very low core saturation value and the highest shell saturation possible without affecting depowderability (cakiness).



5.4 PRINTING THE BUILD

It is strongly recommended that the build settings be confirmed before printing. To check build settings, choose '3D Print Setup' under the File menu or click on the icon located on the taskbar.

After all build settings have been confirmed:

1. Choose '3D Print' under the File menu.
2. A dialog box will appear asking that powder and fluid levels be checked.
3. Press 'OK' to confirm that these have been checked to begin the build.

Once the build has begun, a dialog box will appear reporting the status of the build.

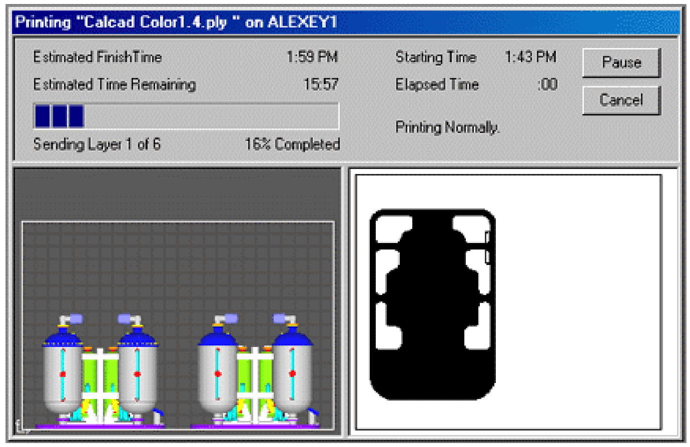


Figure 16: Printing Status Dialogue Box

6 REMOVING THE PART

6.1 SET TIMES

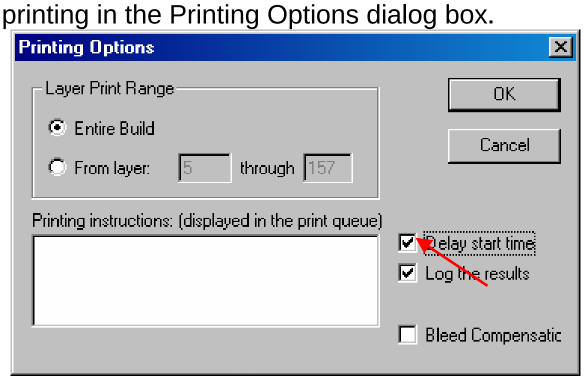
Once the build has completed, let the part sit in the printer to set. This will allow the part to dry while being supported by surrounding powder.

Recommended Set Times

Material System	Set Time
Plaster Material System	60 minutes or more
Starch Material System	No more than 60 minutes ▪ Leaving the part in the build area for a longer time period may lead to part damage due to shrinkage. Parts that enclose loose powder may be susceptible to cracking due to the pressure from shrinkage around the volume of loose powder. ▪ Leaving the part in the build area for a longer time period may cause “caking” of the part. Caking is characterized by adhesion of loose powder onto the printed part.
ZCast Material System	60 minutes or more

Technical Tip –

- To control the amount of time that starch parts sit in the build area, use the print time delay feature in the ZPrint Software. This will allow you to start your build at a later time and thus, finish at a designated time. To use the print time delayer, choose this option before printing in the Printing Options dialog box.

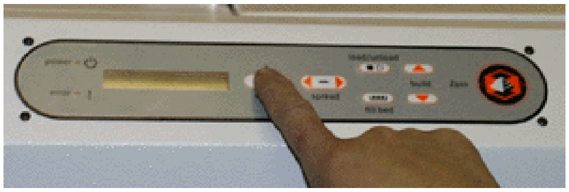


- To speed up the setting process, vacuum off the excess powder surrounding the part, which will allow air to circulate around the printed part. See Section 6.2, *Gross Depowdering*. After gross depowdering, leave part to sit in build area for approximately 30 minutes.

6.2 GROSS DEPOWDERING

Gross depowdering is the initial removal of excess powder from the build.

1. Put printer 'Offline'.



2. Turn on the vacuum.

3. Insert the vacuum hose into a vacuum receptacle in the powder feeder, and turn on the vacuum.

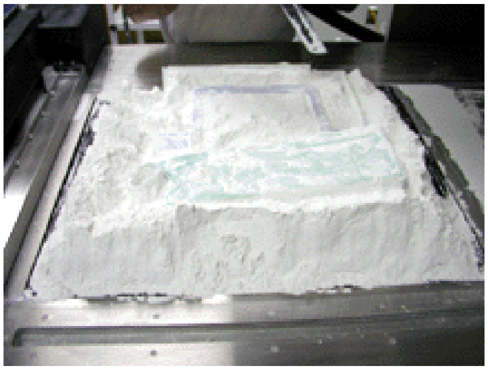
4. Lift the top cover of the printer to gain access to the build area.

5. Vacuum powder around the edges of the build area and part.

> *Technical Tips* -
> - Place the vacuum nozzle at an angle to facilitate airflow into the powder feeder and improve suction control.
> - Use the vacuum attachments to control suction and for ease of vacuuming powder in tight areas.
> - Use the second vacuum receptacle located in the back of the powder feeder to access the rear of the build area.

6. Carefully vacuum around the part from the top to the bottom and from the outside edges of the build area to the inside.

7. Raise the build piston as needed for easier access to the part.



8. Leave powder underneath the part to support any overhanging surfaces.

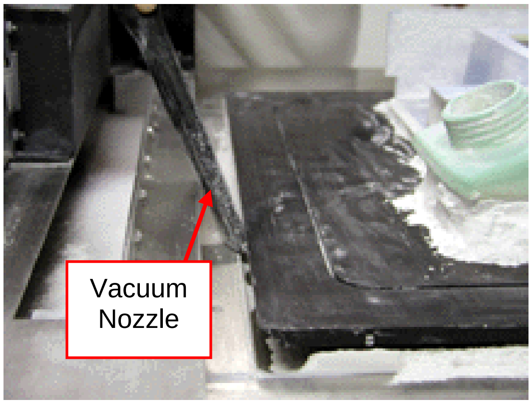
9. Carefully vacuum around the part to remove as much powder as possible.

> *Technical Tip –*
> Leave enough powder around the part to cradle the part during build pallet transfer.

6.3 TRANSFERING THE PARTS TO THE DEPOWDERING STATION

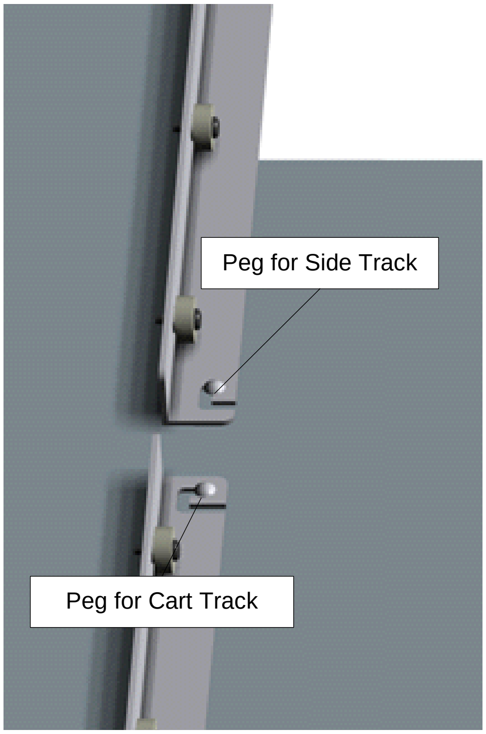
1. Put printer 'Offline'. Press the 'Load/Unload' button on the control panel to raise the build pallet.

2. Vacuum off any surrounding powder.

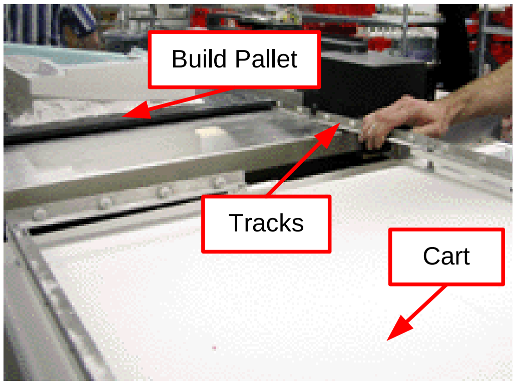


3. Place the tracks on each side of build pallet.

4. Secure the tracks to the top deck by interlocking the “j-shaped” slots with the track pegs.



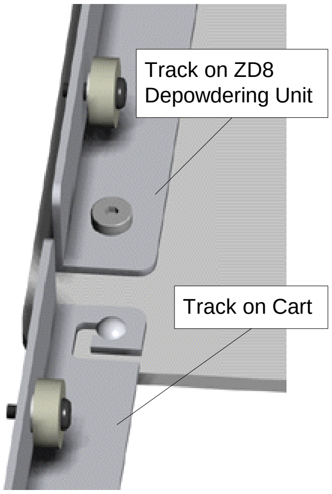
5. Place ZD8 Cart in front of printer and attach tracks from cart to top deck.



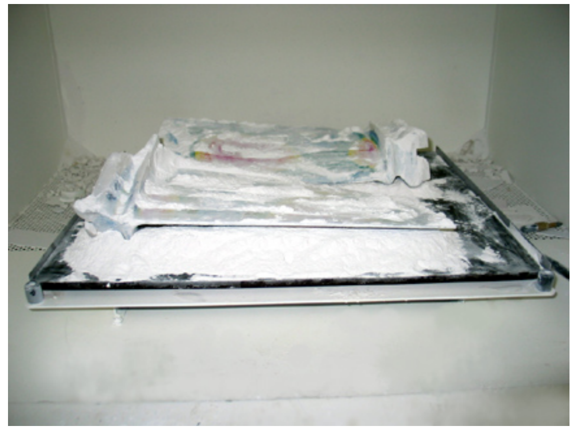
6. Press ‘Online’ on the control panel to lower build pallet.

7. Push or pull pallet onto cart. Remove tracks and replace in storage position on cart.

8. Lift ZD8 Window.
9. Move cart in front of ZD8 Depowdering Station.
10. Orient the ZD8 turntable so that the track pegs are towards the front of the depowdering unit.
11. Attach the tracks.
12. Push build pallet into depowdering unit.
13. Detach tracks from turntable and move cart to a convenient storage location.



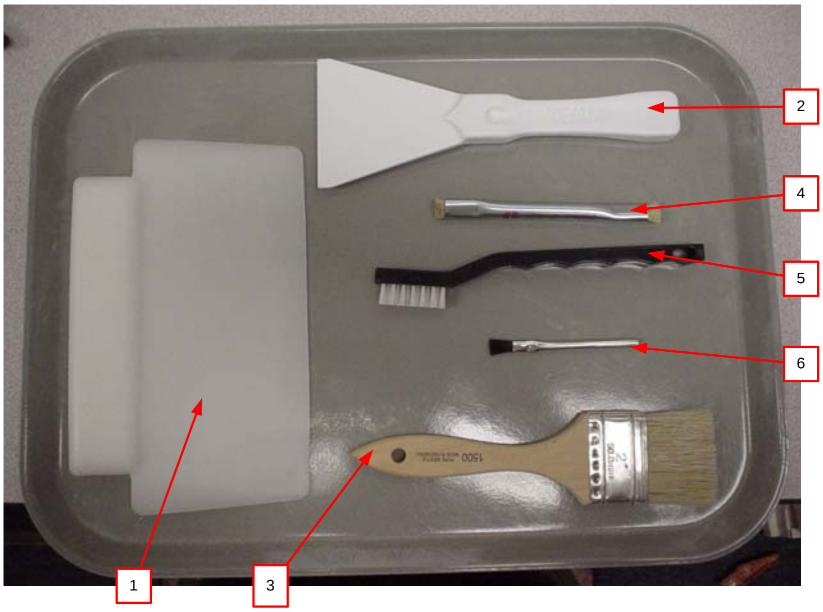
14. Turn depowdering unit on and leave parts to dry for 45-60 minutes. The circulating air will allow the parts to dry before depowdering the part.



> **PLEASE NOTE:** If the depowdering unit is on, and the warning lamp is illuminated, turn the machine off. This will allow the depowdering unit to complete the filter cleaning cycle before you begin depowdering.

6.4 POST PROCESSING TOOLS

There are six tools included in the accessories kit that are used to assist the user with gross depowdering and cleaning of the part.

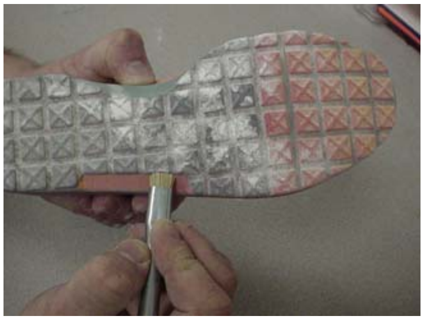


1. Wide Blade Utility Scraper: This tool is used in ZPrinter® 310 and Z406 3D Printers only.

2. Polypropylene Scraper: This tool is used in ZPrinter 310 and Z406 3D Printers only.

3. Soft Horsehair Brush: This brush has very soft bristles and assists the user with the gross depowdering process. Brushing powder away from a delicate part to expose the area may be useful prior to vacuuming.

4. Stiff Detailing Brush: This brush has very stiff bristles, which are useful for scrubbing caked powder out of tight areas of a part. The brush is also very helpful when removing fringing from color part surfaces.

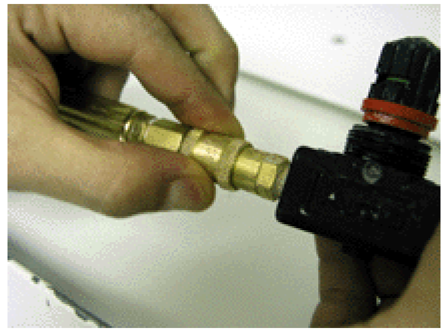


5. Stiff Handle Brush: This tool serves the same purpose as the Stiff Detailing Brush but is slightly larger and is more useful when working with a larger surface area.

6. Soft Acid Brush: This part can also be used to remove caked powder from hard to reach areas and the soft bristles make this brush perfect for delicate features.

7 DEPOWDERING THE PART

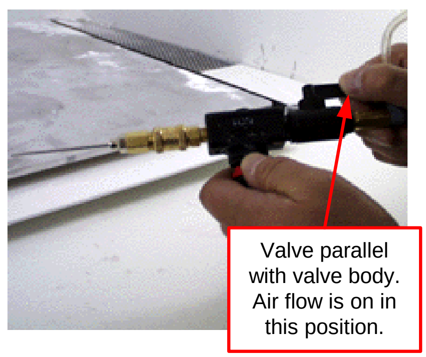
7.1 CHANGING AIR NOZZLES



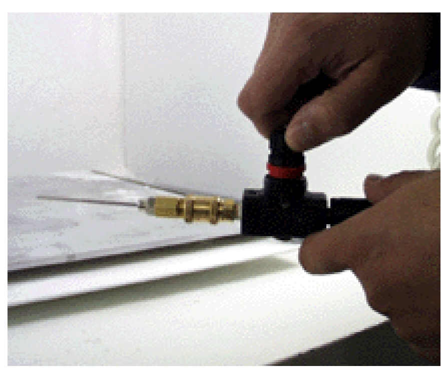
You may choose to use different air nozzles for different stages of depowdering. For rough depowdering, use the large nozzle. Use the fine point nozzle for depowdering detailed areas.

1. To remove nozzle, slide the outer sleeve of the socket towards the nozzle.
2. To connect a nozzle, press the plug-end of the nozzle into the quick disconnect socket until it "clicks".

3. Turn air gun on by opening the 1/4 – turn valve at the end of the coiled blow-off hose. The valve is open when the thumb-lever is in alignment with the valve body and closed when the thumb-lever is perpendicular to the valve body.



4. Adjust airflow by using the control valve. Slide the red ring down to lock the settings.



PLEASE NOTE: When depowdering thin walled or fine detailed areas, use lower air pressure.

5. Depowder the part beginning from the top surface area and working downwards. Rotate turntable as needed. Remove as much powder from part as possible. **For plaster parts do not remove the supporting powder. For starch parts remove supporting powder. For ZCast parts, remove all loose powder.** Leave part in the depowdering unit and let it sit for 15 minutes with the depowderer on.
6. You will need to lift the starch part up to depowder the bottom surface of the part.

> *Technical Tip* – Spin the turntable so that the part face you are depowdering is aimed away from the front opening. This will direct most of the air jet reflection toward the wall – allowing you to use a lower setting on the air curtain.

7. Transfer part into oven. The oven removes any moisture left in the part. The requirement for this step will be dependent on application and infiltration needs.

Drying times are dependent on wall thickness.

Material System	Drying Temperature
Plaster	130^{o}F / 54^{o}C
Starch	100^{o}F / 38^{o}C
ZCast	400^{o}F / 200^{o}C

Average drying time for plaster and starch parts:

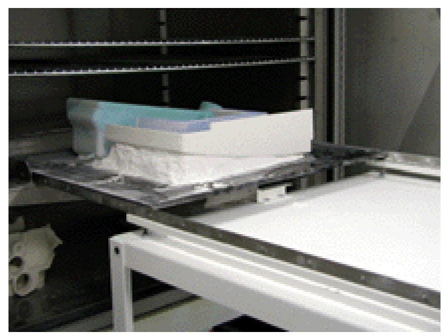
- 0 - 0.25” (0 - 6 mm) – 60 minutes
- 0.25” - 0.50” (6 - 13 mm) – 90 minutes
- 0.50” - 1.00” (13 – 25 mm) – 120 minutes
- More than 1.00” (More than 25.4 mm) - 180 minutes

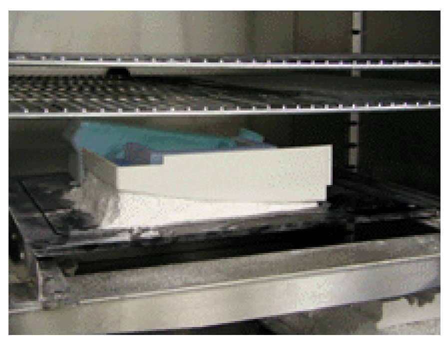
> **PLEASE NOTE:** Drying starch parts at a higher temperature may distort and damage the part.

Average drying time for ZCast parts:

- 4-12 hours
- Drying times will depend on the volume and surface area of the part(s) and oven temperature. The parts need to dry in an oven with a constant air temperature of 400^{o}F (204^{o}C). If you would like to reduce drying time, hollow

> **PLEASE NOTE:** Remove all loose powder from the starch part. Any powder left on the part will adhere to the part during oven drying.

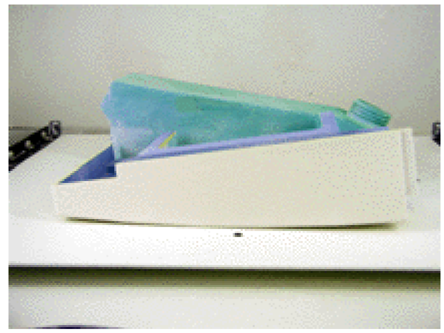




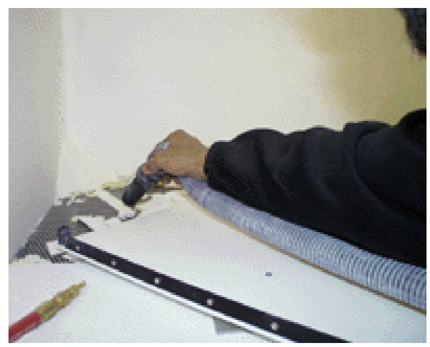
> **WARNING:** Mold preparation and metal pouring requires adequate ventilation to ensure that exposures to dust, particulates, fumes and vapors are controlled below occupational exposure limits. Ventilation designs need to meet each customer’s respective governmental health and safety requirements. A reference frequently used by U.S. firms to comply with OSHA regulations is the American Conference of Governmental Industrial Hygienists Industrial Ventilation Manual.

out certain sections of your part using your respective CAD software package to decrease volume. For more information, refer to the ZCast Design Guide located in the appendix of this manual or found on the User Group Website at www.zcorp-users.com.

8. Remove part from oven and complete depowdering (for plaster and ZCast parts only).
9. Remove part from depowdering unit.



10. Clean depowdering unit by using the external vacuum to remove any debris.



8 INFILTRANTS

INFILTRANT	MATERIAL SYSTEM	APPLICATION
Z-Max^{TM} Epoxy	Starch and Plaster System	Spray or Brush
Z-Bond^{TM} Cyanoacrylate	Starch and Plaster System	Spray, Brush, Drizzle
Z-Snap^{TM} Epoxy	zp250 Material System	Spray, Brush, Drizzle
Wax	Starch and Plaster System	Spray or Dip

For an updated list, please visit the Z Corp. Users Website at www.zcorp-users.com

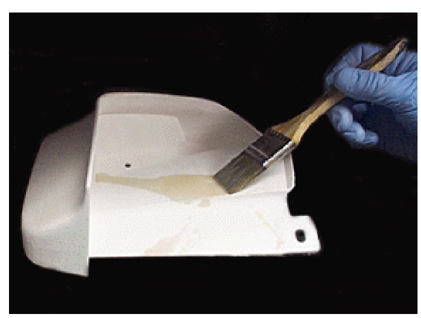
All parts can be infiltrated with a variety of resins to produce a range of material properties. As an early stage design tool, it may not be necessary to infiltrate the parts at all. However, the true versatility of the Z810 System is derived from the spectrum of material properties that can be achieved by applying one of our infiltration materials to parts that will be exposed to a variety of product testing environments. For additional information on how Z Corp. customers are utilizing our line of infiltration products, call us at Z Corporation, or visit our user group website at www.zcorp-users.com. You will also find other ways to finish your part in the next chapter, *Applications*.

8.1 USING Z-MAX^{TM} EPOXY

SAFETY PRECAUTIONS

- Wear lab coat, gloves (we recommend PVC Examination Gloves), face shield or goggles. Face shield is required if spraying. Apply in ventilated hood.
- Use specialized containers recommended for dispensing and application. A system for avoiding spills includes: Catch pan, waxed paper, or plastic drop cloth.
- Label disposal materials.
- Wear dust mask when sanding finished parts.
- Read the Material Safety Data Sheet for Z-Max epoxy **prior** to the use of this material.

MIXING INSTRUCTIONS



- When using the 250 gm Z-Max kit simply pour the entire contents of the Z-Max Hardener container into the Z-Max Resin container and mix the two parts thoroughly for two minutes prior to application. If less than 250 grams is desired, follow the instructions for mixing by weight or volume.
- Mix 100 parts Z-Max Resin to 37 parts Z-Max Hardener by weight or 100 parts Z-Max Resin to 41 parts Z-Max Hardener by volume. Mix the two parts thoroughly for two minutes before application. The material has a working time of 35 minutes in a 425 gram mass. Please be aware of the gel time while preparing quantities of material as the gel time decreases as the quantity of material increases. It is recommended not to mix quantities over 425 grams.

GENERAL APPLICATION NOTES

- Material can be brushed or sprayed.
- Material will penetrate between 0.079-0.28 inches (2 – 7 mm).
- Material will pool off the part during curing, if it is over-applied.
- Better penetration depth is achieved by applying several light coats of material.
- Allow all mixed materials to cure prior to disposal.

SPRAYING INSTRUCTIONS

- Use **Gravity Feed High Volume Low Pressure Sprayer** (Z Corp. Part # 14206). We recommend Devilbiss Sprayer with 14 – 18 mm tip. Other sprayers are compatible, however the use of a HVLP sprayer will minimize the amount of overspray generated. The Devilbiss Sprayer is available with disposable canister liners (Z Corp. Part # 14207). and will minimize the amount of cleanup.
- Have the sprayer, parts and materials ready before mixing the resin.
- Mix resin and pour into the disposable liner in the canister.
- **Always spray in a vented hood. Use of a respirator is also recommended.**
- Spray resin between 15 – 20 psi.
- When finished, remove the disposable liner and clean sprayer with ethyl alcohol or acetone.
- Remove the tip and thoroughly clean by hand to avoid resin build up. (Cleanup takes approximately 15 minutes).

CURING INFORMATION

- **Allow the part to cure for 1 hour at ambient temperature to avoid outgasing of part which can result in bubbling on the top surface of the part.**
- The resin can be cured at an accelerated rate in an oven. **The oven must be vented.** Ventilation designs need to meet each customer's respective governmental health and safety requirements. A reference frequently used by U.S. firms to comply with OSHA regulations is the American Conference of Governmental Industrial Hygienists Industrial Ventilation Manual.
- At 160°F (71 °C) your part will reach full strength in 2 hours.
- The part should be placed on a non-stick, material (wax paper, Teflon, etc.) to prevent it from adhering to the surface it is sitting on while curing.
- Wear gloves when handling the parts when they are still at an elevated temperature. Parts will attain full strength and be safe to handle once they cool to room temperature.
- The resin will cure at room temperature after 24 hours.

For more information on the uses of Z-Max epoxy, please refer to the technical data sheet that can be found on the User Group Website at www.zcorp-users.com.

8.2 USING Z-BOND™ CYANOACRYLATE

Z-Bond cyanoacrylate is an extremely fast setting, low viscosity, general-purpose infiltration resin. This resin is designed to rapidly strengthen parts. Z-Bond is a one part, user friendly, no-odor, non-blooming resin that may eliminate the need for special ventilation. This resin is easily sanded and enhances the vibrancy of color parts. Z-Bond 10 (which can be used with starch models) is available in 0.5 lb bottles and Z-Bond 100 (which can be used with plaster models) is available in 3.5 ounce bottles and 24 ounce spray bottles.

8.2.1 SAFETY PRECAUTIONS

- Do not use or handle this product until the Material Safety Data Sheet has been read and understood.
- Wear lab coat, gloves (we recommend Nitrile Examination Gloves), face shield or goggles. Face shield is required if spraying. Apply in ventilated hood.
- Specialized containers recommended for dispensing and application. System for avoiding spills: Catch pan, waxed paper, or plastic drop cloth.
- Label disposal materials.
- Wear dust mask when sanding finished parts.

8.2.2 GENERAL APPLICATION NOTES

- Part should be fully dried before applying resin. Resin reacts with water and produces heat. If the part is not dried, it will heat up the part and produce gas that may be an irritant to the mucous membranes.
- Material can be brushed, dripped or sprayed.
- Material will penetrate between 0.8 - 0.12 inches (2–3 mm).
- Do not over apply the material, as it will pool off the part during cure cycle.

8.2.3 SPRAYING INSTRUCTIONS

- Always spray in a vented hood.
- While wearing all protective equipment, insert the spray trigger nozzle into bottle.
- Use cardboard or wax paper to protect the spraying area from overspray.
- Spray Z-Bond 100 only onto parts that have been oven dried and are free from moisture (this ensures deepest available penetration and decreases smoking from reaction with water).
- Keeping the tip of the spray bottle 4 – 6 inches (10 -15 cm) away from the top of the part begin squeezing the trigger.
- Adjust the tip of the sprayer until the desired spray pattern is reached.
- Apply the Z-Bond 100 to all upward facing surfaces and sides of the part. Be sure not to spray the base of the part, as it will stick to the surface it is sitting on.
- Wait for the top of the part to cure or speed up the process by using an approved Z-Bond 100 accelerator.
- Turn your part over and apply to any uninfiltrated surfaces.

8.2.4 CURING INFORMATION

- The part should be placed on a non-stick material (wax paper, Teflon, etc.) to prevent it from adhering to the surface it is sitting on while curing.
- Wear gloves when handling the parts to avoid contact with uncured resin.
- Parts will attain full strength in two minutes.

For more information on the uses of Z-Bond resin, please refer to the technical data sheet that can be found on the User Group Website at www.zcorp-users.com.

8.3 USING Z-SNAP™ EPOXY

Z-Snap epoxy is a flexible, toughened epoxy infiltration system specifically formulated for Z Corporation for use with zp®250 powder. Parts made from zp250 powder and infiltrated with Z-Snap exhibit the appearance and snap fit characteristics of plastic. These parts can be easily sanded and finished. For detailed instructions on how to use Z-Snap epoxy with zp260 parts see Section 11.2.3, *Part Removal and Post Processing of zp250 Parts*.

8.3.1 GENERAL APPLICATION NOTES

- All part surfaces should be clean, dry and free of contaminants prior to applying Z-Snap epoxy.
- The part should be oven dried for 2-4 hours at 150°F - 200°F (65°C - 85°C), depending on part volume and wall thickness, to drive off any excess moisture that remains in the part after depowdering.
- Z-Snap epoxy can be sprayed, brushed or drizzled onto parts. Multiple thin coats applied liberally during the resin's working time will produce maximum infiltration depth.

8.3.2 MIXING INSTRUCTIONS

- In a clean, plastic, non-porous, container mix Z-Snap Resin to Hardener in a 2:1 ratio by volume, 100:47 by weight. Mix the two parts thoroughly for 2 minutes, stirring in a figure eight pattern, being sure to scrape the sides and bottom of the container.
- The material has a working time of 85 minutes in a 450 gram mass at room temperature. Mix only what you need. Please be aware that the mixed solution will increase to a maximum temperature of 122°F (50°C) after 40 minutes.

PLEASE NOTE: The gel time decreases when preparing quantities of material greater than 450 grams.

8.3.3 CURING INFORMATION

- Infiltrated parts should be pre-cured at ambient temperature for 30 minutes.
- Cure the infiltrated part for 30 minutes at (120°F) 50°C then 2 hours at (165°F) 74°C on a non-stick (wax paper, Teflon, polyethylene, etc.) material or it will adhere to the surface it is sitting on while curing.

PLEASE NOTE: Z-Snap epoxy should not be cured at temperatures greater than (165°F) 74°C and longer than 3 hours because flexibility may decrease, making the parts more brittle.

8.3.4 CLEAN UP

- Any remaining mixed infiltrant beyond the working time should be kept in a well-ventilated area to avoid fumes. Clean up of the spraying apparatus is simple with solvents found at a local hardware store such as acetone or denatured alcohol.

For more information on the uses of Z-Snap epoxy, please refer to the technical data sheet that can be found on the User Group Website at www.zcorp-users.com.

8.4 USING PARAPLAST X-TRA WAX

Paraplast X-Tra is a low viscosity, general purpose, infiltration wax formulated to melt at very low temperatures (122°F or 50°C) and strengthen both starch and plaster powder parts. This material cures rapidly and enhances the vibrancy of color parts. PARAPLAST is available in a case of eight 2.2 lb. (1 kilogram) bag of chips.

8.4.1 SAFETY PRECAUTIONS

- Liquid wax is hot and may cause burns. Follow all manufacturer recommended safety precautions for your dip tank prior to use.
- Wear gloves when handling hot parts.

8.4.2 GENERAL APPLICATION NOTES

- Parts should be dried in an oven at 100°F (38°C) prior to infiltrating with wax for deeper wax penetration.
- If the part is bulky, you may preheat it at 150°F (66°C) for up to 30 minutes.
- Soak part in the liquid wax tank (follow all tank manufacturer's instructions).
- Remove infiltrated part from dip tank.
- Place part in an oven at 150°F (66°C) until the wax has penetrated or melted off your part (usually around 15 minutes).
- Be aware that these are simple guidelines. Your specific applications may require additional steps.

8.4.3 CURING INFORMATION

- Allow your parts to cool after removal from the oven until the part is no longer warm to the touch.

Below is a list of links to websites of leading wax dip tank suppliers:

http://www.3candles.com/commercial.htm
http://www.dccoopertanks.com/directlyheated.html
http://www.wenesco.com/wax2.htm#waxtop

9 APPLICATIONS

In this section, you will learn various ways to maximize the versatility of your Z Corporation 3D Printer through the implementation of advanced part processing techniques. Please visit the User Group Website at www.zcorp-users.com for more information. If you have an application you wish to share or have questions regarding any of these applications, please contact the Z Corporation Applications Team at applications@zcorp.com.

9.1 GLUING MULTI-PIECED PARTS

Instructions:

1. Remove and depowder the part as described in Section 6, *Removing the Part*, and Section 7, *Depowdering the Part*.

2. Sand seams prior to gluing and check fit of any assemblies. Sanding small parts or parts with curved surfaces can be made easier with a small, air-powered glass air etching/sanding kit.

3. Glue seams – use of clamps can assist in the bonding process.



4. Sand the seams after they have cured to blend and smooth the edges. You may also fill the seams with loose powder.

5. Priming, filling, and sanding before painting are critical steps in the process. Achieving the best results sometimes requires application of two coats of primer. A wide variety of paints and primers have been successfully used for hi-quality finishes:

   SEM products (www.semproducts.com)
   Bondo (www.bondomarhyde.com)
   Rustoleum Acrylic (www.rustoleum.com)
   Interlux Brightside Polyurethane

6. You may proceed with painting the part. See instructions below for more information on painting.

Follow all safety recommendations regarding handling, storage, venting, and personal protection equipment when using these kinds of materials. This information can be found on the Material Safety Data Sheet of each material.

9.2 PAINTING PARTS

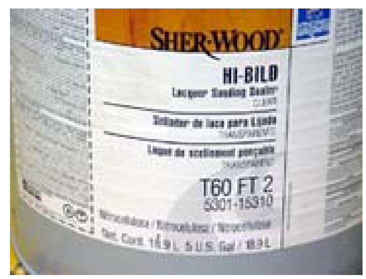
This procedure reduces the amount of sanding needed to produce a nice, smooth surface on Z Corporation parts.

1. Depowder and dry the part.

2. Hand sand the part with 230 grit sand paper lightly.

3. Mix BCC Proto-Kast (**BC8163 Proto-Kast - White)** urethane. Proto-Kast is a 2-part urethane. Mix with a third of lacquer thinner. This thins the mixture and retards the hardening process. For example, if you were to make 150 grams of the mixture, take 50 grams of part A, 50 grams of part B, and 50 grams of lacquer thinner. (BCC products can be found at http://www.bccproducts.com/p3.html).

4. Infiltrate with one coat of BCC Proto-Kast urethane mixture by dipping, dripping, or brushing.



5. Apply 10 light coats of Sher-Wood sanding sealer by spraying.

6. Apply lacquer primer by spraying. A hand-held, air sprayer will be necessary for the highest quality surface finish.

7. Apply colored lacquer gloss paint to achieve the shiny, plastic-like finish.

9.3 POLYESTER RESIN

Many types of transportation equipment require the use of geometrically complex ducting for heating, ventilation and air conditioning (HVAC) of the interior space. Prototype ducting produced on the Z Corporation 3D Printer can be used for form and fit testing, as well as air-flow testing across a range of temperatures and humidity. The parts can be prepared to have sufficient toughness and resiliency to survive bench testing and functional testing in an automobile.

The basic parts are produced in zp15e starch powder. It is recommended to print a sample part first to practice all the process steps if you are a new user. This step is worthwhile, especially when dealing with large parts because it will help to minimize waste and to increase efficiency.

Infiltration Details
This application requires use of a marine-grade, thixotropic, low viscosity polyester resin. This resin is widely available at hardware stores and industrial supply centers. Some common manufacturers are Evercoat, Fibre Glast, and/or FiberLay.

Materials Required

Polyester resin and catalyst
Plastic container for resin
Disposable brushes
Fiberglass mat (optional) Kevlar, E-, S-glass mat
CA or equivalent glue for joining assemblies
Personal Protective Equipment (Gloves, Eye protection, Apron)

Application Time
Highly dependent on part 5-30 minutes

Application Technique
Applied by brush

Working Life
15 Minutes

Set Time
4 hours min.

Environmental Setting
Please read the Material Safety Data sheets for these products carefully. This operation should be conducted in a well ventilated area with protective eyewear.

Instructions:

1. Depowder and air dry parts for a minimum of four hours.
2. Apply the resin by brush to individual parts per the material's directions and allow them to cure.
3. Sand as needed and check any critical dimensions. Finally, use cyanoacylate (resin) to construct any multi-part assemblies as required.
4. Apply polyurethane resin.

9.4 ELECTROPLATING

Parts printed on the 3D printer on either starch or plaster can be easily prepared and electroplated for the look and feel of a metal part**.**

Preparation

Preparation is the most important step in producing a good electroplated surface.

1. Both starch and plaster-based powder parts can be used as the base parts for electroplating. Parts should be well infiltrated with cyanoacrylate resin or epoxy and sanded with 220-grit sandpaper. **Do not wax the parts.**

2. Spray parts with a sandable primer (such as Rust-Oleum Auto Primer), let dry, and sand again. In order to create a smooth metal finish, the part must be sanded as smooth as possible.

3. Once sanded to satisfaction, clean the part with a damp paper towel.

4. To aid in the spraying process, and make it easier to get a good contact when plating, it is a good idea to attach wire before painting the parts. Wire can be attached to any non-visible surface with cyanoacrylate resin.

5. After the wire is securely attached, spray the entire part, including the wire, with a conductive paint. There are a variety of conductive paints on the market such as Agri Systems Non-Stick Graphite Paint, or Dalmar Easyplate Copper Conductive Paint.

6. The conductive coating is critical to good plating. Spray all parts well and evenly. Do not leave any surface un-coated. Be especially careful of where the part is held while you spray it. Do a second coating to cover these spots.

Plating

- While any electroplating shop should be able to plate the parts at this point, it is a good idea to find a shop that has experience with plating nonconductors, when possible.

During the plating process, the first bath will be a copper strike. This bath will use a relatively low current. The paint you use may come with directions for the current and voltage that should be used for this coating. If not, a good guideline is to start at 1 to 2 amps/square foot and increase that amount as the part starts to plate. Once this first layer has been plated, the following coats can be plated as normal. If the surface is not leveling, it can be sanded in between baths to help get a shiny finish.

Contacts

If you would like to have a part plated, we recommend contacting Associated Electroplaters, Inc. at (248) 547-5520.

9.5 WATER TRANSFER PRINTING

Water transfer printing is a process that enables 2D printed patterns to be applied to three-dimensional objects. The process is suitable for production as well as prototyping. Currently, the most prevalent use of water transfer printing may be in auto finishing. As shown in the picture below, many trim packages utilize the process to mimic high-end wood finishes on plastic or metal components. The process is also often used on small electronics equipment, decorative items and architectural trim.

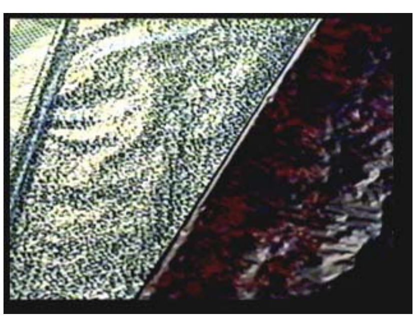
The process transfers a 2D image onto a 3D object by floating the image on the surface of a heated water bath and dipping the 3D object, through the image, into the bath. A subsequent sealing step with a spray lacquer gives the part durability with a wide range of surface finishes. Any part that can be primed and spray-painted can be dipped. Equipment manufacturers, such as Dips 'n' Pieces, claim that virtually any geometry can be dipped. With proper masking, parts can be dipped from all directions to give a near continuous pattern on every surface of a part.

There is some equipment to purchase and set-up to be able to perform this printing process in-house, however there are several service bureaus that will dip parts for a fee. Any image can be transferred to the object, however, standard patterns and color combinations prevail at most service bureaus. The process is also referred to as: Dip Printing, Immersion Printing, 3D Printing, or Cubic Printing.

Process Description

Part preparation: Print the chosen part using any Z Corporation plaster series powder. The part should be infiltrated with cyanoacrylate or epoxy resin. Sand the part prior to dip printing. For an improved finish, the part can be sprayed with a spray-filler (such as Plasti-kote Sandable Primer or Spraila AutoK) and sanded again. Make sure to remove any dust. NOTE: Many service bureaus capable of water transfer printing will take an infiltrated part and do all of the sanding and finishing for you - included in the fee.

Film Printing: The decor or pattern is printed on a special, high-molecular, water-soluble film. Any image can be printed. Common images include realistic wood grains, carbon fiber patterns, metals and metalics, stone, camouflage and decorative images.

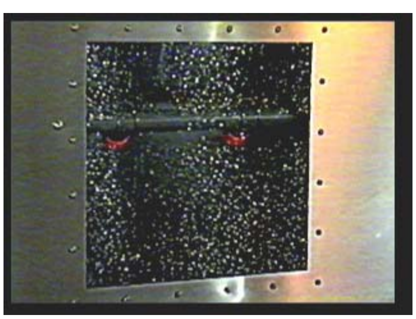


Priming: Z Corp. parts should be primed and painted in a base color (e.g. brown for parts which are to be printed in a wood grain decor).

Spreading Film: The film is spread out on the water surface of the dipping basin. The water bath is heated and kept at a constant 86°F (30°C). The film dissolves and only the ink image remains floating on the water.

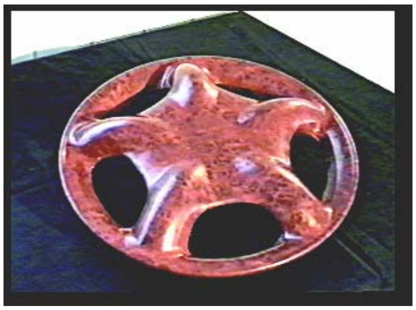
Activating: The ink is sprayed with an activating material so that it becomes adhesive. After spraying with activator, the ink must sit for 3 minutes.

Transferring: The parts are dipped into the water through the layer of liquefied ink. The image is pressed to the parts evenly by the pressure of the water. If there are several parts to be dipped, they are mounted to a fixture and dipped simultaneously.



Washing and Drying: The printed parts are washed to rinse off remaining pieces of film, and dried. Due to the exposure to water here, Z Corp. parts must be well infiltrated and finished completely with the primer, even if the image is to be partially applied.

Top Coating: The parts are clear coated or varnished to protect the printed surface. A varying degree of gloss can be achieved by using different top coats. Polishing completes the process.



Presenting: The finished parts can now be used. The surface can be very durable and scratch resistant – depending on the top coat used, so the finish will stand up to many functional applications.

Typical Site Requirements (from www.dips-n-pieces.de)

- sufficiently sized and ventilated room with a humidity of less than 60% and with a waterproof and solvent agent resistant floor
- dip printing system with suitable power requirements
- water supply for filling and refilling the basins
- drainage for used water
- compressed-air supply for the activator pistol
- dry and dark place for storing the printing films
- suitable painting facility for priming and clear coating/varnishing the parts
- protective clothing such as breathing masks and gloves

Suppliers / Service Bureaus

There are a limited number of companies that provide this service. Below is a list of websites for several service bureaus and manufacturers around the world. Many of these companies were found with an Internet search: they have not all been qualified.

Dips n Pieces – Located in Germany. They manufacture and sell water transfer printing equipment and also operate a service bureau. They have worked with Z Corp. parts before. Website: **www.dips-n-pieces.de**.

Alsa Corp. – Located in the United States. They are a service provider, capable of prototype to production quantities. They also offer other finishing services and equipment. Website: **www.alsacorp.com**.

Deco-Tech – Located in the United States. They are strictly a service provider, capable of prototype to production quantities. They have worked with Z Corp. parts before. Website: **www.xfinishes.com**.

Yuan Heng Tai Water Transfer Printing – Located in Taiwan. They manufacture and sell water transfer printing equipment and provide finishing service. Website: **www.yht.com.tw**.

Master Approach Sdn. Bhd. – Located in Malaysia. They offer dip printing as a service. Website: **www.maproach.com**.

Dorchase Industrial, Ltd. – Located in Hong Kong. They provide dip printing as a service. Website: **www.plasticscommerce.com/dorchase**.

Cubic Co., Ltd. – Located in Japan. This company manufactures dip printing equipment. Look at the "network" page on their website to find a comprehensive list of owners of their equipment throughout the world. Website: **www.cubic.co.jp**.

9.6 INVESTMENT CASTING

Z Corp. parts can be used as investment casting patterns to quickly get metal parts. Starch-based parts can be infiltrated with cyanoacrylate resin or wax and used instead of a standard wax pattern in the investment casting process. The parts burn out well and do not have any expansion problems that would lead to shell cracking. Investment casting of Z Corporation parts is a good way to get a final prototype, or a near-net shape part made of the specific alloy your application requires. It can also be used for short-run production when time is extremely important. 25% of Z Corp. users have had a part cast at some point in their design process.

General Notes

- Consult with experienced foundry personnel to incorporate best practices in casting design when designing your pattern. They will help the designer or engineer to design their part with the gate, runners and secondary operations in mind. Operations and equipment vary from foundry to foundry. Success has been achieved consistently in a variety of situations and locations using the notes below as a guide. Steps that have been varied to achieve success are noted.

Preparation

1. Starch-based powder parts should be used. Oven-drying the part at 104°F (40°C) after removal has been included in the process at some locations, especially where humidity may be an issue with 'green' part characteristics. Additional gate(s) may be incorporated in the set-up of the mold to increase air flow during burn-out of the casting pattern.

2. Patterns should be infiltrated with either wax or resin. Wax infiltration is an excellent treatment for investment casting patterns. Wax infiltrated parts will behave similarly to common wax patterns when they expand. The ZW4 or ZW3 Waxer and hand application methods have both been successfully used on Z Corp. parts. Some users briefly blast their parts with a consumer hairdryer or heat gun to quickly heat and re-cool the wax to improve surface finish.

   Patterns can also be infiltrated with resin for increased strength. Surfaces should be sanded to their desired finish after this step. Then coat with wax.

Casting

1. Z Corp. patterns can be assembled on standard wax gates and runner systems. They should be coated with the normal 6-8 shell layers of slurry.

2. When using wax patterns assembled on wax runners, the tree assembly should go though an autoclave process for 10 minutes before being put in the firing oven. The autoclave should be 380°F (193°C) and 130 psi (9 bars). The pattern should then be put in the burnout oven. Note: this process has been omitted by some users to their satisfaction.

   Patterns infiltrated with resin should skip the autoclave process and go directly to the burnout oven.

3. Z Corporation patterns should be burned out at 1750-1800°F (954-982°C) in an oxygen rich environment. Burnout time will depend on the part volume and air circulation. If the part is an inch thick or less, it should burn out completely in two hours. For larger parts, a longer burnout time should be expected. The patterns will burn out completely if they are left in the oven for a sufficient amount of time.

   Low-temperature furnaces with air treatment devices using ionized air have also been utilized successfully to burn out Z Corporation patterns. Refer to the furnace manufacturer for guidelines for this process.

4. After burn-out, allow the shell to return to room temperature. In some cases, a small amount of residual ash may remain (less than 1%). This can typically be washed or blown out of the mold. Wash the shell out with water. Allow the shell to dry and thoroughly pre-heat shell before pouring metal to entirely eliminate any water vapor that may remain.

Results

- 2% shrinkage should be expected when going from the Z Corp. pattern to a cast part. The surface finish will depend on the surface of the original pattern, but can be expected to be around 3-5 mils.

9.7 FLEXIBLE PARTS

Material

- Por-A-Mold 2030

Preparation

- Read and understand the Material Safety Data Sheet, as well as any directions.

- zp15e parts should be used.
- Be sure the parts are completely dry.
- Wear impervious rubber gloves, glasses, and a lab coat.
- Use adequate ventilation when mixing and applying the material.

Instructions

1. Material should be mixed well at an exact 1:1 ratio.
2. Apply generously. For thin parts, use a brush or syringe. Thicker parts can be dipped.
3. If the material soaks completely into the part within a minute, apply another coat. Multiple thin coats of elastomer will enable the part to be best infiltrated.

4. A vacuum chamber will help the material to soak deeper into the part, but is not required.
5. Excess material can be removed with a paper towel.
6. Let the parts sit on wax paper to cure. Make sure excess material is not dripping into a puddle on the wax paper. This will be difficult to remove after it cures.

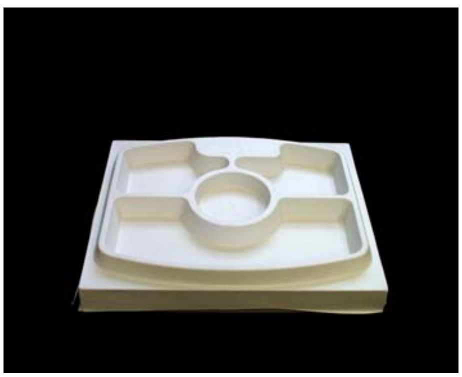
9.8 THERMOFORMING

This process consists of heating a thermoplastic sheet to a formable plastic state and then applying air pressure and/or mechanical assists to shape it to the contours of a mold. In this process, the air pressure may range from almost zero to several hundred psi. ‘Vacuum forming’ is the term given when a pressure differential of up to approximately 14 psi (atmospheric pressure) is used. The pressure is obtained by evacuating the space between the sheet and the mold in order to utilize this atmospheric pressure. Vacuum forming will give satisfactory reproduction of the mold configuration in the majority of forming applications. Manufacturers can use all types of thermoplastic materials – PVC, polystyrenes, polyesters, acrylics etc. in this process.

Making light gauge (plastic less than 0.060”) thermoforming molds for prototype parts is an ideal use for Z Corporation 3D Printers and plaster powder.

For more information regarding the process and the industry, check out SPI’s website: www.plasticsindustry.org/index.htm where you can search SPI's Membership Directory & Buyer's Guide for thermoformers.

In the example below, the industrial designer wanted to get a feel of his design in the actual material. He was able to generate a mold and produce a sample in a period of days.



MOLD

PROTOTYPE

The packaging company that produced the prototypes below uses the parts to generate samples for their sales department, who then use them to collect customer feedback.

The instructions below are specific to molds produced on Z Corporation Printers. It is assumed that the user currently owns a thermoforming system and is familiar with using molds created from other techniques for creating thermoformed parts.

The process for making molds is straightforward. Good design of the molds will be the first and most important step in the process.

Design Considerations

1. Material – Plaster
2. Thickness - Capital equipment (presses) will vary from plant to plant. The optimum thickness (minimum material use = minimum cost) for the mold will vary as well, but we recommend beginning with a minimum thickness of 1.5" (38 mm).
3. Printing the small size holes needed for the vacuum is unrealistic. The tool designer may place 'guide' holes or marks in the part to act as guides for drilling, but the process will require the use of a mechanical drill to fully incorporate the hole into the mold. Drill diameters should be the same as used when creating molds from aluminum or other non-permeable materials.
4. Drying – the molds will need approximately four hours minimum of drying time at 150^{o}F (66^{o}C) to maintain a usable strength.
5. It is often useful to use STL editing features to improve the accuracy of the final mold. If using the Magics RP software for STL file editing, read the help section regarding the offset function. In summary:
    a. For applying correction to the part on flat faces of the block, use the Extrude command on each face. For the faces of the part that have curved features, use the offset command.
6. Resin
    a. Epoxy resin works best in terms of speed, ease of use, and strength.
7. Sanding is optional – some users are satisfied with the surface finish as is.
8. Usage life - Individual molds have consistently produced 10-20 parts successfully without the use of a release agent.

9.9 RTV MOLDING

Room Temperature Vulcanization (RTV) molding, also known as Silicone Rubber Molding (SRM), is an inexpensive soft molding solution for creating dozens of prototypes accurately. The benefit of RTV molding is that anyone can do it because of its simplicity. Factors such as draft[1], complex parting lines[2] and undercuts[3] are not factors in building effective molds as they are when using hard tooling. Additionally, hard tooling may not be practical during the design process due to cost, production time, and likelihood of design changes. RTV molding effectively bridges the gap between one off prototypes and hard tooling in a fraction of the time.

RTV molding requires the production of a single master pattern, which is encased in low durometer[4] silicone rubber. Using a part printed on a Z Corporation 3D Printer is the fastest and least expensive method for creating a pattern for RTV molding. Once the silicone rubber, encasing the pattern, cures (2 – 48 hours depending on chosen material) the master is cut out, leaving a cavity. The cavity is used as a soft rubber tool for molding investment casting wax, epoxy, foam, or in most cases polyurethane or a similar thermoset material that has physical properties similar to injection-molded themoplastics. Cast prototypes will have the look and feel of a production piece.

Additional Resources for the Novice Mold Maker
www.build-stuff.com/002book.htm
www.bare-metal.com/articles/gremlins_how_to.htm
www.smooth-on.com/moldmaking.htm
www.eagerplastics.com/intro.htm
www.theminiaturespage.com/ref/fgmolds.html
www.micromark.com/part_mold.html

The quality of the pattern directly affects the quality of the part from the RTV mold because RTV rubber molds will pick up details as fine as a fingerprint from the master pattern. Master patterns are classically sanded and polished regardless of the method of their production. This makes parts printed using Z Corporation technology a perfect fit due to the ease in which their surface finish can be enhanced.

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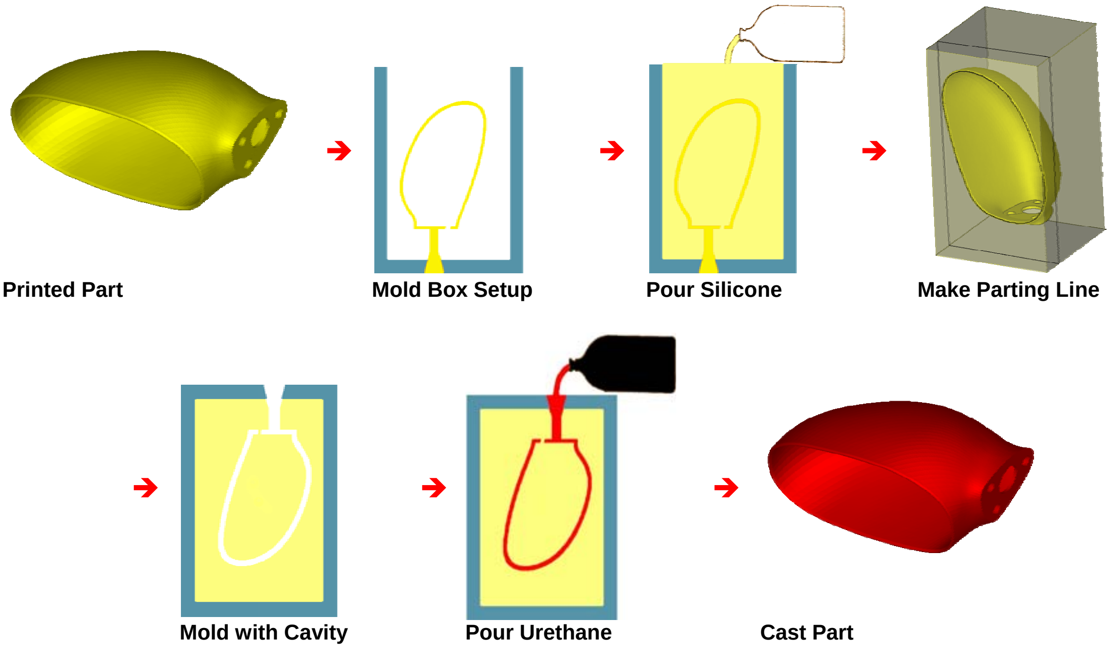
[1] Draft Angle – A slight taper to the shape of a cast part to allow it to be easily removed from its mold. Draft angles should be used on interior or exterior part walls in the direction of draw. A minimum 1° draft angle per side is recommended for parts having no textured surfaces. Textured surfaces need additional draft to easily release the part, and eliminate drag marks or scuffing of the part surface.

[2] Parting Line – Line in which two halves of a mold will separate. Parting lines should be located to provide good part appearance and function.

[3] Undercut – A protuberance or indentation that impedes withdrawal from a two-piece rigid mold.

[4] Durometer – The hardness of a material. RTV molds typically use a material with a Shore A hardness <50.

Process Overview



Master Pattern Production

Preparation of the master is the key to successful mold making and part casting. Every detail of the master's surface finish will translate to the cast pieces. The polished appearance of an injected molded part is often the goal when prototyping with RTV molding. To achieve the polished appearance, prepare the surface finish of the master pattern by following the seven steps listed below. Note that it is only necessary to follow these steps to achieve the appearance of an injected molded part with an ultra-smooth finish.

Instructions:

1. Remove, post-process and infiltrate the printed part from the Z Corporation 3D Printer. Infiltration with cyanoacrylate or epoxy is recommended. The use of wax is not recommended because the part will not accept a primer later in the finishing process and is not easily sanded.

2. Sand the part with 100-grit sand paper after it has been infiltrated with either epoxy or cyanoacrylate. Sand the part so there are no pits in the surface.

3. Coat the part with a filler, such as Bondo® No. 907 Glazing & Spot Putty, being sure to fill in any remaining pits. You can also use a fast curing spackling putty. Both putties are applied wet and dry quickly at ambient temperatures.

4. Sand the filler with 220-grit sand paper. The finish at this point should be completely smooth with no surface defects.

5. Prime the part with a sprayable / sandable primer. Z Corporation recommends Plasti-kote® Sandable Primer for parts infiltrated with cyanoacrlylate and Dupont® Corlar® Epoxy Primer for parts infiltrated with epoxy. Apply 2-3 thin coats.

6. Allow the part to dry. Wet sand the pattern with 400-grit sand paper. Wet sanding the part re-wets the primer making it extremely smooth and fills in any remaining pits.

7. Dry sand the pattern with 400-grit sand paper. This step will remove any residual surface defects such as drips in the primer.

A gate to feed the casting material into the mold must be set up prior to creating the mold. The gate also acts as a vent to allow air to escape the mold cavity. If the part is complex the master pattern may require numerous vents. The master pattern usually has the gate mounted to the highest feature and is almost always oriented in a manner such that air rising up through the mold will not be trapped. If the pattern cannot be oriented to prevent trapping air, additional vents will need to be added to allow the air to escape. Gates and vents are usually attached permanently to the pattern using an adhesive but Klean Klay and wax can also be used.

It is common to draw a line on the part where the desired parting line will be. This serves as a reference when removing the master pattern from the mold as to where two pieces of the mold should be separated.

A mold release may need to be applied to the master pattern to prevent it from bonding to the mold depending on the silicone chosen. Use a dry mold release if cast parts are to be painted. A part cast after using a dry mold release will be easier to clean in preparation for painting. Use a mold release that is recommended by the manufacturer of the silicone used to create the mold. Mold releases can be purchased through most silicone distributors.

Choosing a Silicone

There are several aspects to consider for the novice mold maker when choosing a mold material. The foremost aspect should be whether to use a silicone with a tin or platinum-based catalyst. A catalyst is a substance that initiates or accelerates a reaction.

Tin catalysts work extremely well for the beginner because they generally have a low durometer, cure at room temperature, and are virtually inhibition free[5]. Low durometer materials make it easy to create a parting line and remove the master without damaging it. Inhibitors can be powder from gloves, rubbers, plastics, or chemicals not cleaned from the surface of the master pattern.

Platinum catalysts have a cure cycle that can be accelerated with heat and have virtually no shrinkage, however they have a higher durometer.

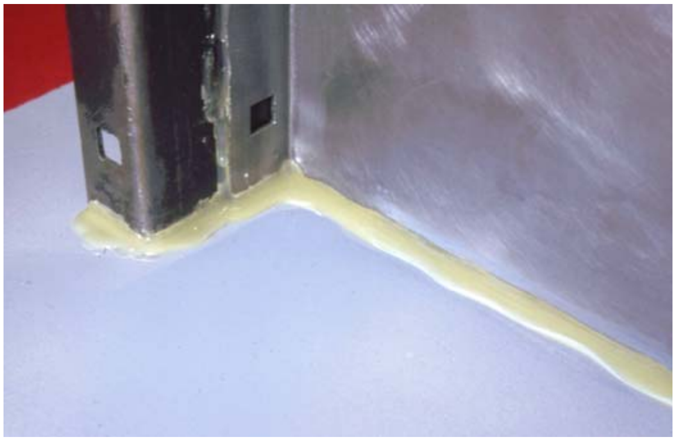
Patterns used to create molds with higher durometers may need draft and must have an excellent surface finish to de-mold cast parts. It is also recommended that the novice mold maker use a translucent mold material so the pattern is visible within the mold, making it easier to direct where the parting line is located.

Manufacturers of Molding Silicone

Hapco (www.hapcoweb.com/)
Dow Corning (www.dowcorning.com)
General Electric (www.gesilicones.com)
Innovative Polymers (www.innovative-polymers.com)
US Composites (www.shopmaninc.com/moldmaking.html)
Ebalta (www.ebalta.de)

Building the Mold Box

The purpose of a mold box is to contain the silicone rubber (after it is poured over and around a master pattern) until the silicone turns to a solid. A mold box does not have to be a complex structure, depending on the size and configuration of your part; often a can, small plywood box, pan or plastic bucket will get the job done. For ease and convenience, plywood, Plexi-glass, plastic or sheet metal work extremely well. Be sure not to use a material that will inhibit the curing of the silicone. Consult your silicone vendor for a list of these substrates.



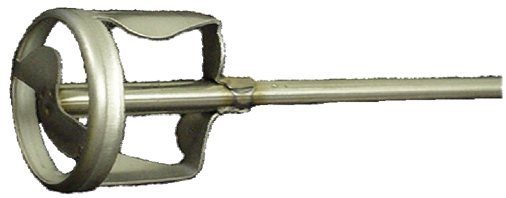
The box must have four sides, all of which must stand higher than the master pattern when mounted to the gate. The box can be screwed or nailed together, but clamps are used in most cases for easy disassembly of the mold box. All seams of the mold box must be sealed to ensure the liquid silicone does not leak. Hot melt glue, silicone caulk or clay are effective choices, again be sure the material chosen will not inhibit the cure of the silicone.

5 Inhibition – The failure of silicone to cure within the recommended cure time. Surfaces of the mold will typically remain gummy, uncured or stick to the master pattern.

Preparing and Pouring the Silicone Mold

Preparing the silicone is relatively easy but must be performed properly to ensure a good mold. Pay close attention to the mix ratio of the two components of the silicones. Be sure to prepare a large enough volume to completely encase the pattern. The open time[6] of RTV silicone is typically 1-2 hours (see your product's Technical Data Sheet for specific information) allowing enough time to carefully mix and prepare the liquid rubber.

Though mixing can be done by hand, it is difficult to determine if both components are thoroughly combined in large volumes. The use of a Jiffy® Mixer is recommended. Mixing the components together will whip air into the mixture. Air trapped in the mixture must be degassed, which separates the air out of the silicone mixture. Place the mixture in a vacuum chamber and degass. Removing the air until a minimum of 27" Hg has been reached (vacuum chambers and casting systems are commercially available for a range of budgets). Note that the volume of the mixture will increase dramatically until all of the air has been removed. Choose a container that holds approximately 3 times the volume of the mixed silicone.



Once the de-gassing is complete; pour the silicone mixture slowly into the mold box, letting it run smoothly around the pattern. Take your time to decrease the chance of air being trapped anywhere. Best practice is to de-gas the mold after the silicone has been poured to remove any air that was introduced.

Manufacturers of Vacuum Chambers and Casting Systems

BJB Enterprises (www.bjbenterprises.com/equipment)
Innovative Polymers (http://www.innovative-polymers.com/)
MCP Equipment (www.mcp-group.com)

Removing the Master Pattern and Creating the Parting Line

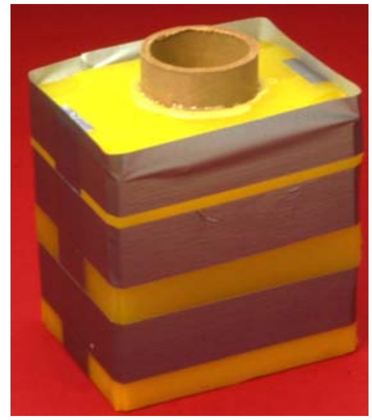
Remove the mold box from around the mold. Using a razor blade or scalpel, begin to cut the mold open at the gate and vent. This will begin to create the parting line for the mold. Cutting in a smooth zigzag motion will make the mold halves easier to re-assemble in preparation for urethane casting. Slowly cut deeper to the edge of the pattern. Keep in mind where the mold parting line will be on the pattern. The parting line should be placed on an edge of the part to avoid witness lines (flash[7] from the cast urethane).

When the cut is finished, the mold halves should easily separate and the master pattern can be removed.

[6] Open Time – The amount of time it takes to gel or double in viscosity.

[7] Flash – Cast material that has squeezed into the space between mold halves, typically at the parting line.

Mold Preparation and Casting



Spray mold release onto all areas that will be exposed to the casting material and place the mold halves together. Use tape, rubber bands, or clamped boards to hold the mold together, preventing the cast urethane from leaking through the parting line. Do not squeeze a soft mold too tightly as the mold cavity may flex or distort. A cup or sprue is usually placed at the gate of the mold as a receptacle for pouring or injecting the casting material.

Preparation and dispensing of the casting materials varies. Two-part urethanes are typically packaged in cartridges and dispensed through a handheld pneumatic static mixer for smaller scale applications. Automated meter mix dispense equipment is usually used by small production facilities. The use of hand pumping static mix dispensers is not recommended, as they tend to produce off ratio mixtures.

Placing the mold in pressure pot after material has been cast into it to minimize any bubbles present is a common practice. This will reduce the effects trapped air will have on the final part.

Follow the cure cycle of the cast material before attempting to de-mold the cast part.

Conclusion

RTV molding is an extremely efficient method of generating multiple parts with thermoplastic properties. There is no faster method of generating the master pattern than with a Z Corporation 3D Printer, which will reduce the overall time it takes to get your final cast part. Whether a Z Corp. 3D Printer is your complete prototyping solution or just a piece of it, there is no tool more valuable at saving the things most valuable, your time and money.

10 CHANGING AND ALIGNING THE PRINT HEADS

10.1 CHANGING THE PRINT HEADS

WARNING: Do **NOT** touch or contaminate the gold contacts on either the print heads or the carriage with your fingers. Avoid spilling binder on the contacts. If you do get binder or anything else on the gold contacts, clean them with an alcohol swab.

The print head will need to be changed when the print becomes uneven. A print head should be able to print at least 1.2 liters of binder (about 30 Billion pixels, equivalent to about 2500 cubic centimeters of parts). Print head life can depend upon the geometry of the parts printed, so some print heads may last longer. Signs of a worn print head are weak parts, rough surface finish, or visibly uneven printing in the build. The software will display a warning when the print heads will be exceeding the expected print head life during the build.

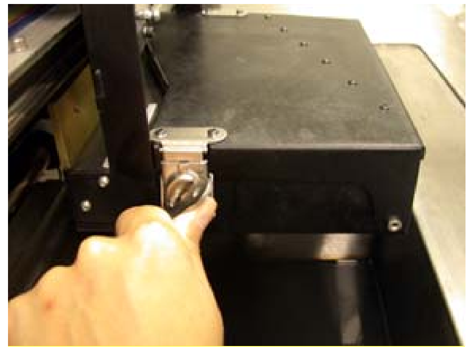
To ensure that the build will be completed and good print quality replace the print heads (Z Corp. part number 13524) as follows:

1. Unpark the carriage by choosing the 'Unpark' option under the 810Service menu. The carriage will move away from the service station.
2. Clean top deck.
3. Repark the carriage by clicking 'OK' on the dialog box.

4. The printer should be online. From the 'Service' menu, select 'Change Print Heads'.
5. Press the 'Start' dialog box button to begin the process. The front panel lights will flash rapidly and the gantry and print heads will move into position.

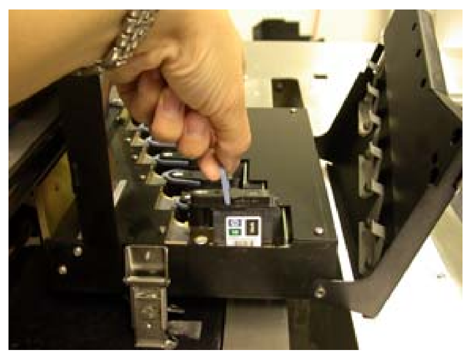
Technical Tip –
If you need to work in another dialogue box, click the close window button (X located on the upper right-hand corner), NOT THE DONE OR CANCEL button. You may continue changing print heads. Complete the procedure by pressing the 'Online' button on the printer when complete.

6. Wait for the printer to finish moving and the front panel lights to begin blinking. This indicates that it is safe to open the top cover and remove the print heads.
7. Twist the carriage cover latch in the front and back of the carriage.



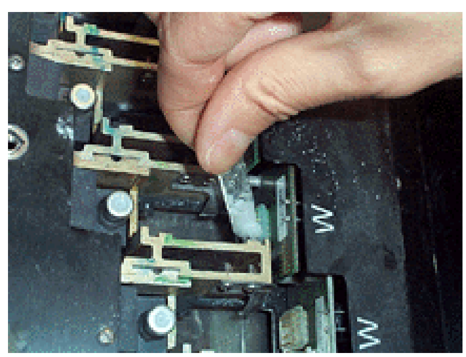
8. Unlock the head clamp latch by pushing the top cover down and unlatch. Open the carriage cover.

9. To remove the print head, lift the blue handle on top of each print head and pull up gently. Repeat for all six print heads.

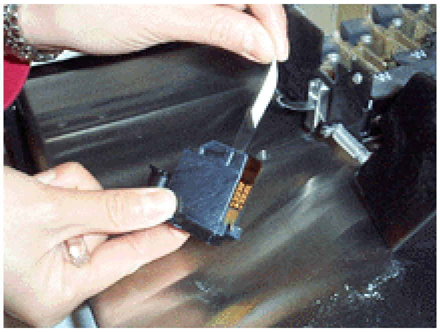


> **PLEASE NOTE:** All print heads are to be changed at the same time to ensure proper print head alignment and logging. For more information about the logging feature, refer to the ZPrint Software Manual.

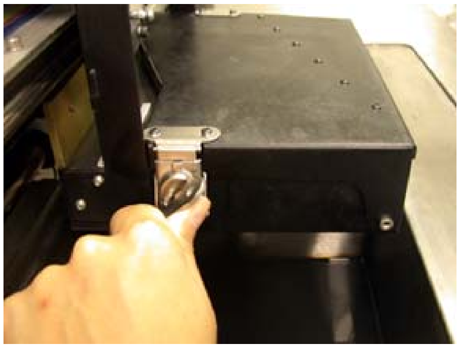
10. Before inserting new print head, clean the contacts in the carriage with an alcohol crush swab (Z Corp. part number 12073.)



11. Remove the print head from the packaging. Remove plastic covering from the print head.
12. Insert the new print head and push down firmly on top to make sure the print head is seated securely in the carriage. Repeat for all print heads.



13. Replace the carriage cover and tighten the clamps in the front and back of the carriage. Press the 'Online' button once to complete the process or click 'Done' in the software. The print heads will now need to be aligned.

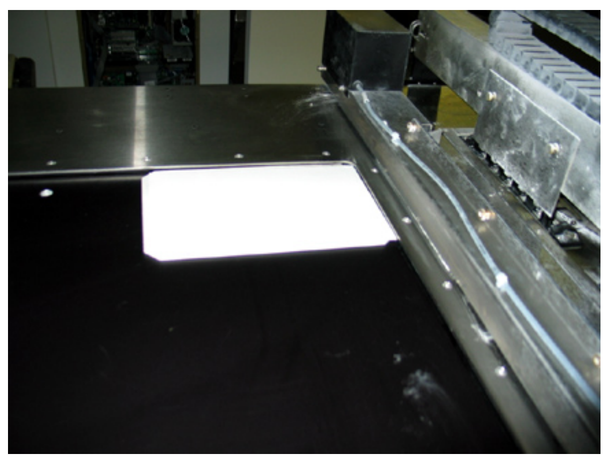


10.2 ALIGNING THE PRINT HEADS

PLEASE NOTE: After every print head change, you must perform the alignment procedure.

1. Place a piece of adhesive paper onto alignment plate by removing one piece of backing, placing the edge of the paper to the edge of the plate. Remove the remainder of the backing slowly while placing it down on the plate. Make sure there are no air pockets between the paper and the plate.

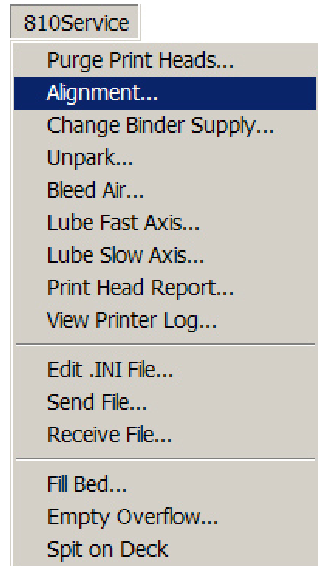
2. Bring the build piston to the top, open the top cover and place the alignment plate in the build area, to the right and rear of the build area.



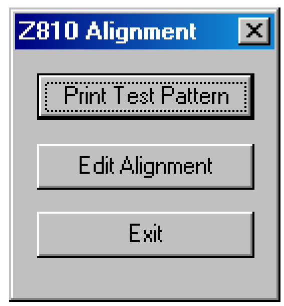
Technical Tips –

- When the alignment plate is too low on the build pallet, the pattern will become blurred. To print a sharp pattern, the pad should be at the height of the top deck.
- **PLEASE NOTE:** If it is too high up, the roller will hit the pad and move it.

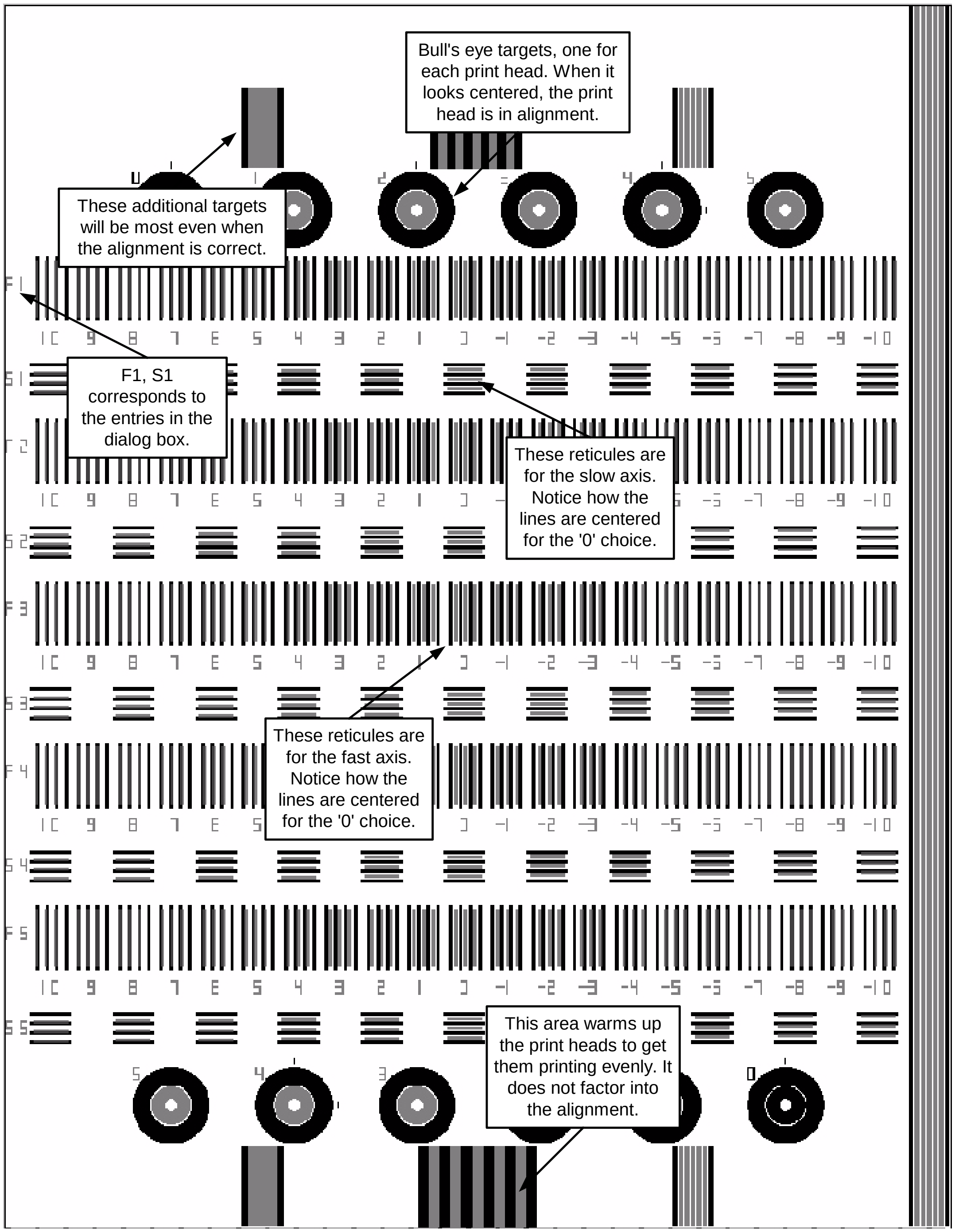
3. Close the top cover and put the printer online.
4. Select the 'Alignment' option under the 810Service menu.



5. Click on 'Print Test Pattern' in the alignment dialog box. It will take a minute to initialize the printer, send the pattern, and print.



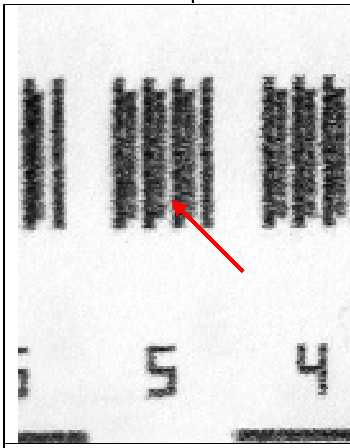
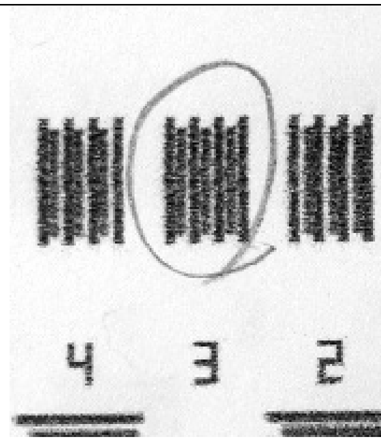
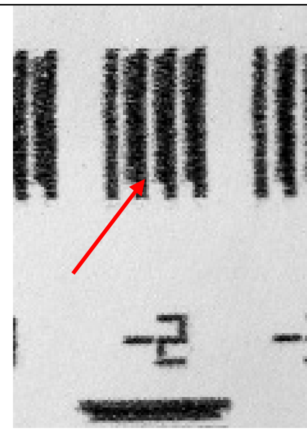
6. For each print head to be aligned, there are two numbers to be chosen. To do this, look at the alignment pattern and decide which pattern looks best.

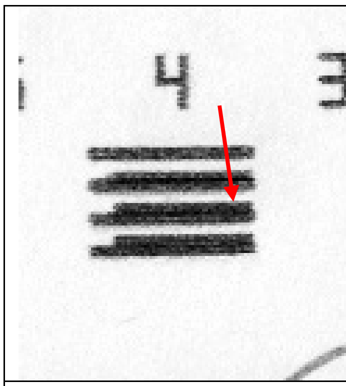
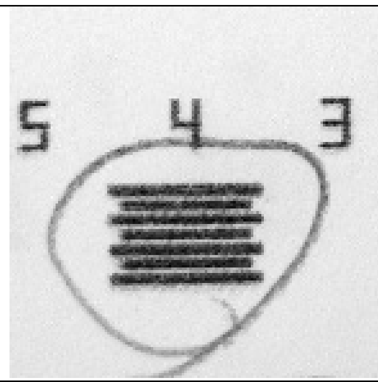
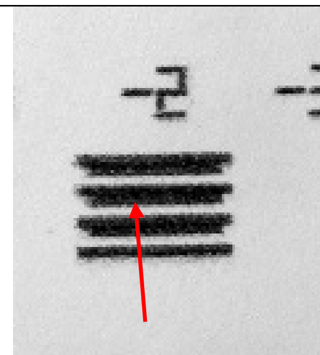


In this pattern, a properly aligned set has four longer lines with three shorter lines centered between them. Print head 0 is the reference, print heads 1 through 5 are aligned to print head 0. Each row is labeled at the left, F1 and S1 correspond to Fast1 and Slow1 on the dialog box and following.

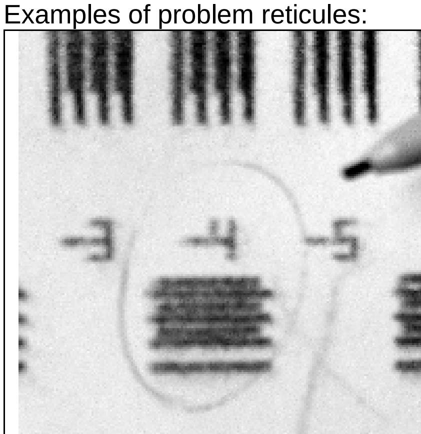
See the examples below for properly and improperly aligned reticules.

Normal reticule patterns:

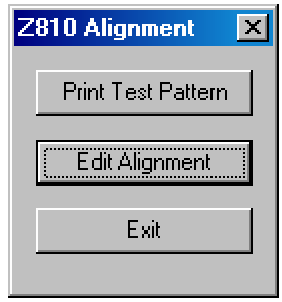
		
Fast axis to the left	Good fast axis reticule The three short lines are interleaved with the long lines.	Fast axis to the right

		
Slow axis too low	Good slow axis reticule. The three short lines are interleaved with the long lines.	Slow axis too high

Examples of problem reticules:

		
The top short line is above the long lines. The three short lines should be between the long lines.	Here the lines are overlapping instead of interleaved.	

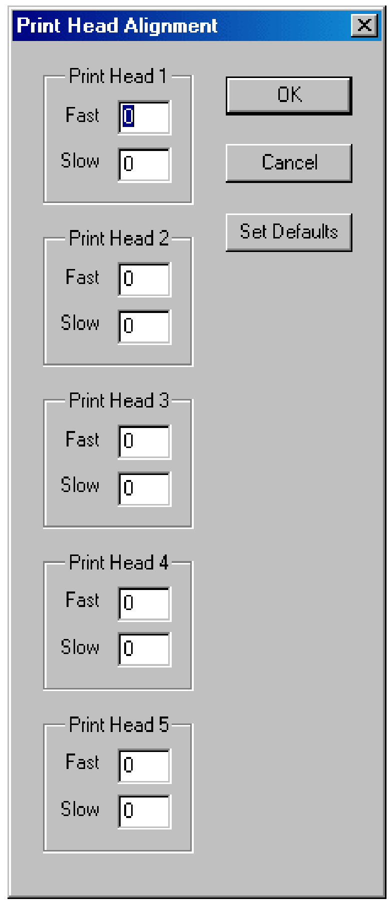
7. Look up the numbers that are next to the best-aligned pattern as described above.
8. Choose 'Edit Alignment' in the alignment dialog box.



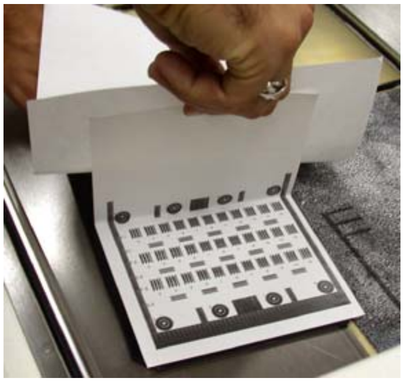
> Technical Tip –
> If you have printed problem reticules, and are not able to choose the best aligned pattern, choose 'Set Defaults' under the Edit Alignment option and continue alignment procedure.

9. Enter numbers for the best aligned pattern in each row into the corresponding boxes (fast and slow axis):

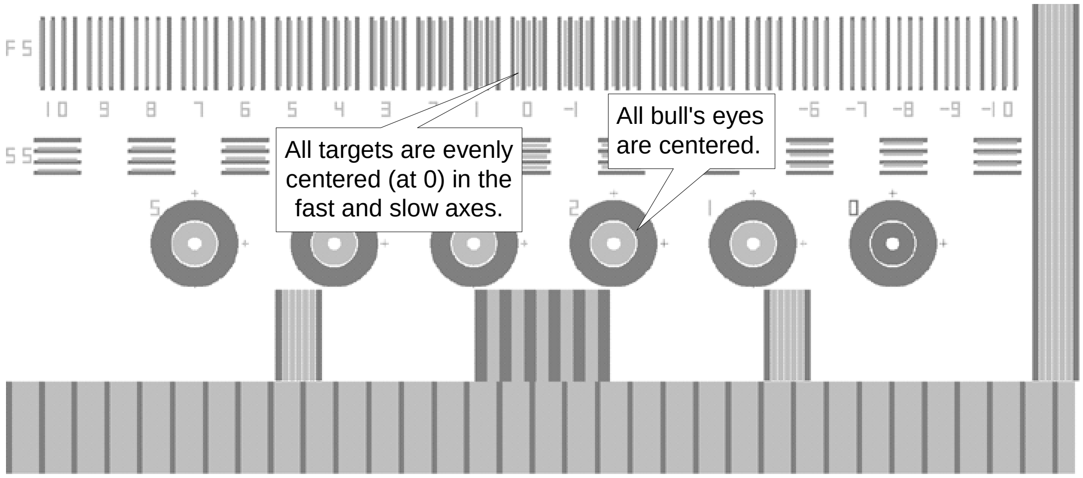
   F1 – Head 1, Fast
   S1 – Head 1, Slow
   F2 – Head 2, Fast
   S2 – Head 2, Slow
   F3 – Head 3, Fast
   S3 – Head 3, Slow
   F4 – Head 4, Fast
   S4 – Head 4, Slow
   F5 – Head 5, Fast
   S5 – Head 5, Slow



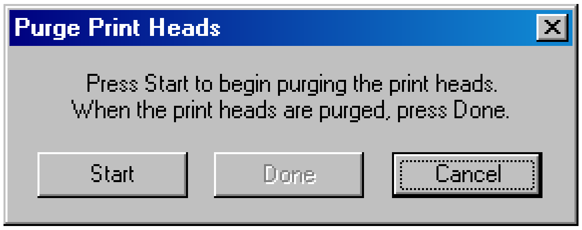
10. Click 'OK'. The software will ask you to update the alignment. Click 'OK' to update the printer's configurations.
11. Remove the paper off the plate carefully. If you would like to save the sheet, remove the top edge of the paper, adhere it to a blank sheet of paper, and pull the blank sheet of paper slowly.
12. Repeat steps 2-12 on a clean sheet of alignment pad until all alignment reticles line up at 0.



13. Look at target drawings to confirm alignment of print heads.



14. Purge print heads after alignment process with binder. This will clear print heads of black ink and fill them will clear binder. The process should take about 10 minutes. The LCD will display 'Online' when the printer has completed the purge process.

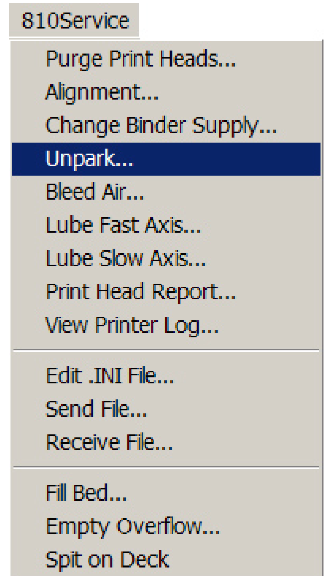


> *Technical Tip –*
> If you need to work in another dialogue box, click the close window button (X located on the upper right-hand corner), NOT THE DONE OR CANCEL button. You may continue purging. Complete the procedure by pressing the 'Online' button on the printer when complete.

15. Unpark the gantry to expose the service station.

16. Clean the service station of any HP ink residue as described in Section 4.2 *Cleaning the Service Station*. Clean the deck and fast axis rails. Oil the fast axis rails.

> *Technical Tip –*
> The first 50 layers of your part will have a tint of black HP ink. You may place a flat brick, such as the purge brick build (810purge.stl), under Sample files, under your part to purge all black ink before printing your part.

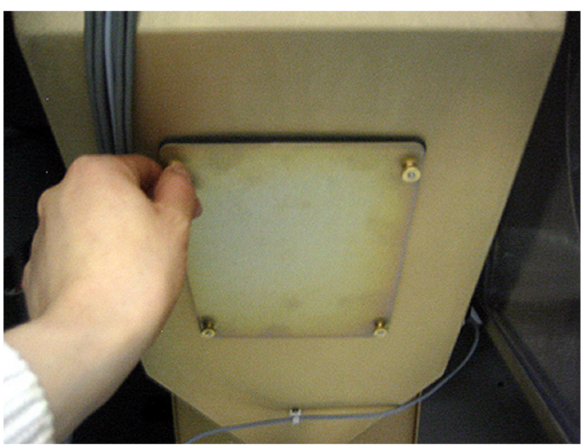


11 CHANGING MATERIAL SYSTEMS

To change material systems on the Z810 3D Printer, use the following procedure:

1. Remove all powder from the top deck and under the build plate.

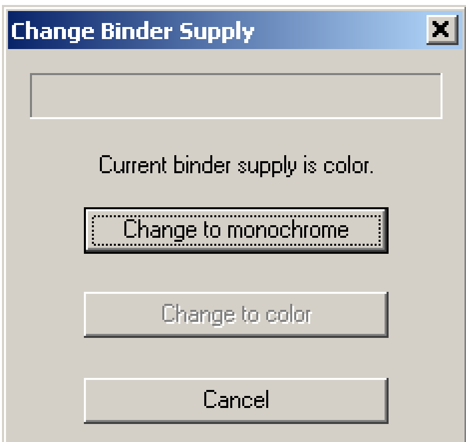
2. Remove the powder from the overflow bin and empty into the ZF8 Feeder.



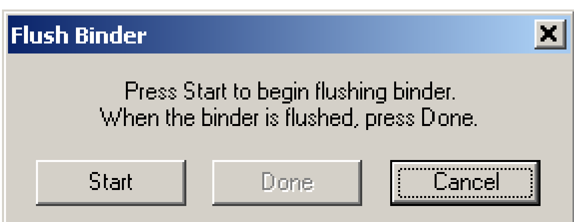
Removing powder through the overflow access panel will allow you to clean out the overflow bin more thoroughly once it has gone through the 'Empty Overflow' function in the ZPrint Software.

Remove the access panel by removing the thumb nuts, turn on the ZF8 Feeder and vaccum all remaining powder from the overflow chute. Then replace overflow access panel.

3. Change binder supply if necessary. If you are using starch powder, use zb®51 binder. If using plaster, zp250 powder, or ZCast powder, use zb56 binder.

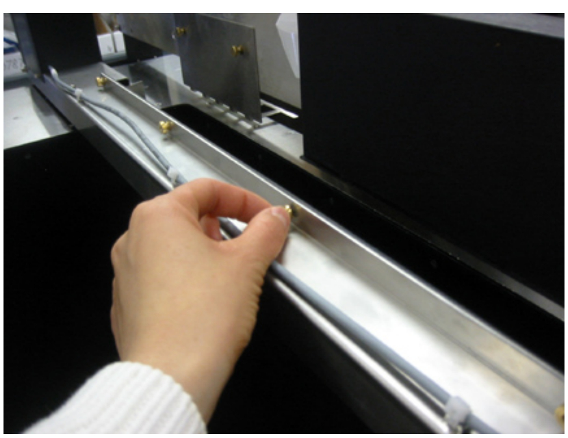


4. Change binder supply mode if necessary using the 'Change Binder Supply' function under the 810Service menu in the ZPrint Software.



5. Flush binder for two minutes if you have changed binder supply by choosing the 'Flush Binder' option under the Service menu.

6. Purge the print heads by selecting the Purge Print heads option under the 810Service menu.

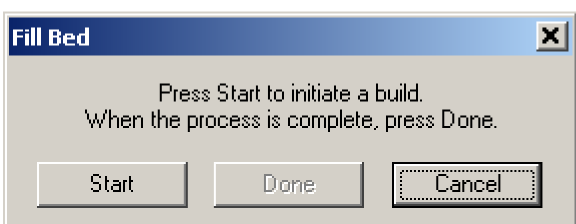


7. **IF USING ZCAST POWDER**, remove scraper blade assembly by unscrewing the thumb nuts. **IF USING STARCH OR PLASTER POWDER**, make sure scraper assembly is attached.

   PLEASE NOTE: Failure to remove scraper assembly when using ZCast powder will result in damage to the scraper blade.

8. Change ZF8 Powder Feeders with the desired powder system.

9. Fill ZF8 Feeder with desired powder if necessary.



10. Use the ‘Fill Bed’ option under the 810Service menu to spread powder.

11. Set up build in ZPrint Software and print.

For information on how to design a ZCast mold, read the ZCast Design Guide which can be found at the appendix of this manual or in the Applications section of the User Group Website at www.zcorp-users.com.

11.1 USING ZCAST® 501 POWDER

11.1.1 GENERAL INFORMATION

ZCast 501 powder is a plaster-ceramic composition that allows you to print sand casting-like molds and/or cores with your Z Corp. printer. Once printed, depowdered and baked, you have the ability to immediately pour molten metal, yielding a cast metal part. Arguably, the ZCast process is the fastest and most direct way to obtain a metal part from digital data. ZCast 501 has been optimized for non-ferrous materials ranging from zinc to brass, including aluminum and magnesium.

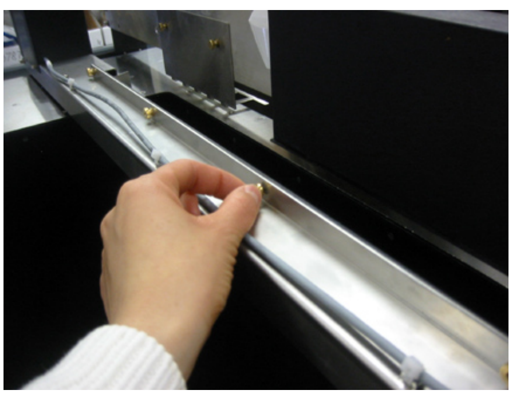
WARNING: Do not pour magnesium without first contacting a Z Corporation technical representative. **NEVER ATTEMPT TO POUR FERROUS METALS IN ZCAST MOLDS.**

You will find a detailed document entitled 'ZCast Direct Metal Casting - Design Guide' located in the appendix of this manual for additional information. Please review the guide along with safety issues before continuing with this product. Upon review, contact Z Corporation Applications Team for information about a **free online training session** by sending an email entitled "ZCAST ONLINE TRAINING SEMINAR" to applications@zcorp.com. Be sure to include preferred meeting times. The session is approximately one hour.

11.1.2 USING ZCAST ON YOUR Z810 3D PRINTER

Before using ZCast powder on your Z810 3D Printer, you will need to remove the scraper blade, and change powder feeders.

Temporary Scraper Blade Removal



When using ZCast powder on the Z810 3D Printer, the scraper blade should be removed. Failure to remove the scraper blade when running ZCast powder will result in excessive wear on the scraper blade and require replacement. Remember to reinstall the scraper blade when printing with ZCast powder is complete.

Loading ZCast Powder into the Z810 3D Printer

1. Remove all powder from the build box and overflow chute. Use the overflow chute window to help you remove all traces of powder.
2. Disconnect the electronic cable, power cable, and air line to the ZF8 Feeder.
3. Pull the release lever on the back side of the printer and simultaneously remove the ZF8 starch or plaster feeder.
4. Slide the ZF8 ZCast Feeder, locking it into place, and reconnect all hoses and cables.

11.1.3 SETTING UP ZCAST BUILDS

Follow normal practices for printing parts in Z Corp. printers. Take into consideration part orientation verses strength tradeoffs and use fixtures when applicable to control the reduced effects of 'squash'. For more information, please refer to the ZCast Direct Metal Casting – Design Guide.

11.1.4 POST PROCESSING ZCAST PARTS

Remove and depowder the part as described in Chapter 6, *Removing the Part*. Unlike other Z Corp. parts, ZCast parts requires no infiltration. However, ZCast molds must be thoroughly baked in a vented oven at sufficient temperatures to burn out the organic materials. Additionally, the user may apply a core wash solution to improve the surface finish of the casting. See the ZCast Direct Metal Casting – Design Guide for bake temperatures, times and additional information.

11.1.5 MATERIAL ORDERING

You can order ZCast consumables either directly from Z Corp. or through your local reseller.

The item list for ZCast is as follows:

Part #	Description	Denomination
06091	ZCast 501 Powder	15 kg pail ~ 500 in^3
06376	ZCast 501 Powder	90 kg pail ~ 3000 in^3
06312	zb56 Clear Binder	1 gallon

11.1.6 RECYCLING

Similar to plaster and starch, ZCast powder can be recycled. Recycle only powder that is unprinted and free of moisture as bonded or printed material will degrade printing performance.

11.1.7 STORAGE

Though ZCast powder has no special storage requirements; however it should be stored in a cool, dry environment. See container labels for additional information.

11.1.8 DISPOSAL

ZCast powder is a non-toxic substance. Please consult the Material Safety Data Sheet for product details. Dispose of ZCast powder according to local and state regulations.

11.1.9 QUESTIONS AND SUPPORT

If you have any questions regarding this product, contact the Z Corporation Applications Team for technical support at (781) 852-5005 or via email at applications@zcorp.com.

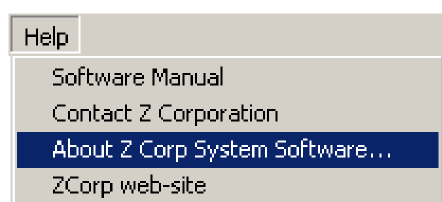
11.2 USING ZP®250 POWDER

zp250 powder is the newest powder system formulated for Z Corporation 3D Printers utilizing the Hewlett Packard print head technology - the ZPrinter 310, Z406, and Z810 3D Printers. Specifically formulated to have an open matrix to absorb infiltration resins, zp250 powder is an extremely versatile, composite-based powder used to fabricate models with plastic flexural properties which are ideal for snap fit applications. It can be used as your sole powder to fulfill a number of application needs. zp250 powder is best suited for monochrome parts. It is also recommended for parts that have a wall thickness that is greater than 0.06” (1.5 mm).

11.2.1 MACHINE SETUP

- Remove all of the powder currently in the Z810 3D Printer (build piston, overflow bin). Consult the Z Corporation Service Department for documented instructions on changing a ZF8 Feeder from zp102 to zp250 powder.
- zb56 binder is the required binder system for zp250 powder. If you are not currently using zb56 binder, replace the current binder with zb56 binder then flush and purge the fluids system.
- Fill the ZF8 Feeder with zp250 powder.

11.2.2 SOFTWARE SETUP

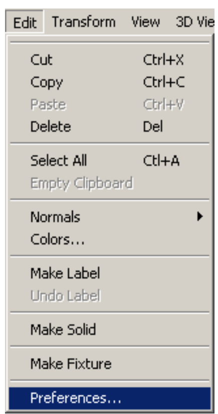


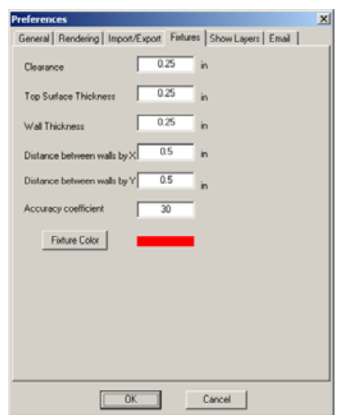
- ZPrint Software version 6.2 or higher should be used when printing with zp250 powder. To check the version of ZPrint Software currently installed select “About Z Corporation Software” from the Help Menu. If ZPrint version 6.2 or higher is not installed contact the Z Corporation Service Department for an upgrade at service@zcorp.com.
- You will also need firmware version 1.027 or higher. To check the firmware version you are currently using, choose the ‘Check Status’ option under the Service menu.

- Due to the nature of the open powder matrix of zp250 powder, and its capacity to absorb Z-Snap or Z-Max epoxy infiltrant, the use of a fixture generated in ZPrint Software is recommended for parts with a wall thickness less than 0.375” (9.5mm) should be built with a fixture as well. For a complete explanation of how to use the “Make Fixture” function in ZPrint Software refer to the ZPrint Software Manual. Fixtures used as cradles for zp250 powder parts should be built with the following parameters:

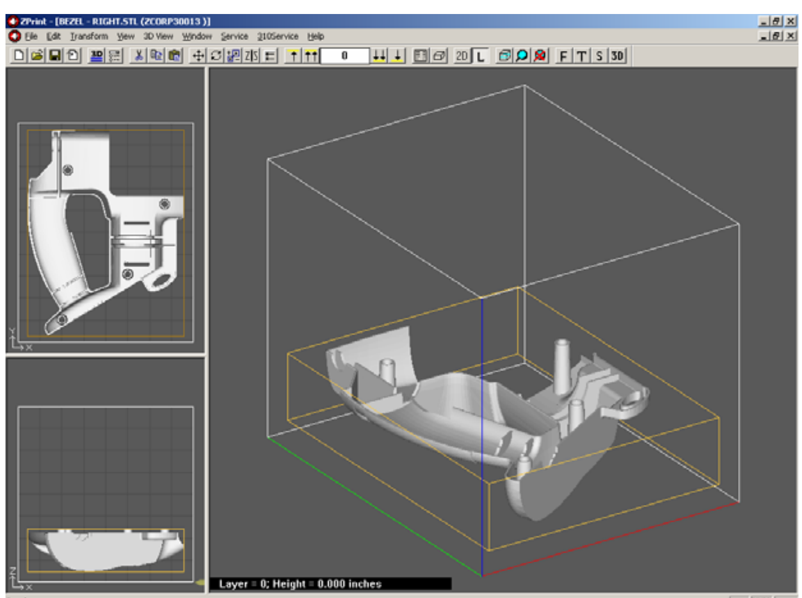
Clearance	0.125” – 0.25” (3.175 – 6.35 mm)
Top Surface Thickness	0.1” – 0.25” (2.54 – 6.35 mm)
Wall Thickness	0.1” – 0.25” (2.54 – 6.35 mm)
Distance Between Wall by X	0.5” – 1.0” (12.7 – 25.4 mm)
Distance Between Wall by Y	0.5” – 1.0” (12.7 – 25.4 mm)
Accuracy Coefficient	High enough to avoid collisions between the part and the fixture

- To change the default values in the “Make Fixture” window, select “Preferences” from the ZPrint Edit Menu and select the “Fixtures” tab. Enter the new values, and click ‘OK’.

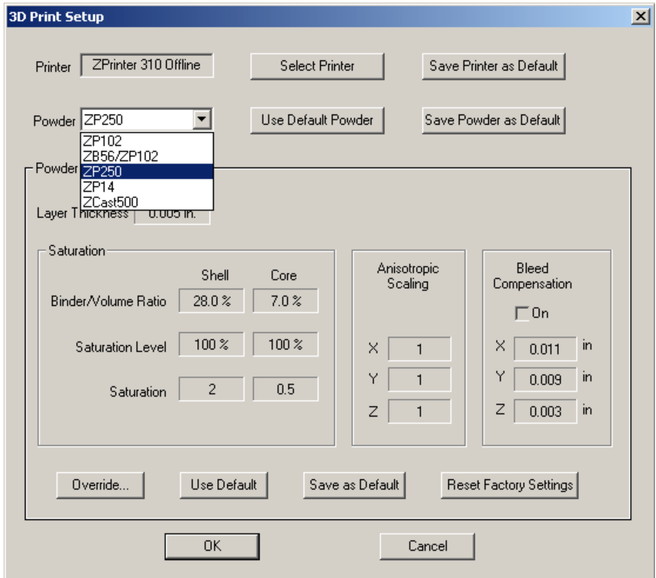




- To create a fixture that completely cradles the entire part, raise the part in the z-axis at least 0.5” (12.7 mm) from the bottom of the build plate in the ZPrint Software. If the part is not raised it will not be fully support by the fixture after depowdering.



- Go to the “3D Print Setup” window under the File Menu and select zp250 powder as the powder type.



11.2.3 PART REMOVAL AND POST PROCESSING

1. Remove the part and depowder. Dry the parts in in an oven at 150°F (66°C) for at least 2 hours or longer depending on the mass/volume of the part.
    a. If a fixture was used during the printing process it should be used as a cradle for the part during the infiltration and curing steps as well.

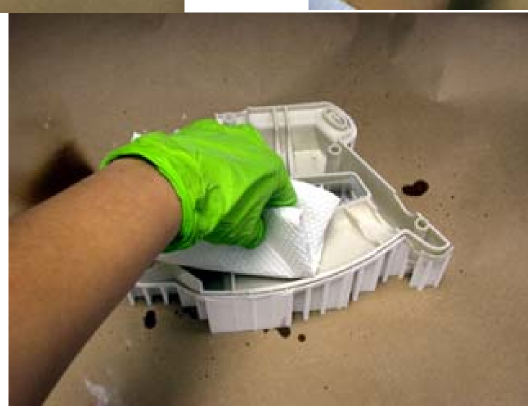
2. Depowder the part and the fixture.

3. Remove part from build plate and place on a clean surface. Then separate the part from the fixture.

4. Apply a silicone mold release (such as IMS Paintable Neutral Oil Mold Release – www.imscompany.com or_Hapco GREASE-IT FDG - www.hapcoweb.com) liberally onto the top surface of the fixture where the part will make contact with the fixture. This is done to prevent the infiltrated part from adhering to the fixture during the infiltration process.

5. Gently apply Z-Snap or Z-Max epoxy to the bottom surface of the part and carefully place the part back onto the fixture.

6. Apply Z-Snap or Z-Max epoxy to the rest of the part. Do not apply excess epoxy as pooling will occur. Several thin coats are better than one thick coat. Use a paper towel or tissue paper to remove excess epoxy that may have pooled on the surface of the part.



7. Let the part sit for 30 minutes at room temperature to allow excess Z-Snap epoxy to drain or wick into the fixture. Z-Max parts should sit at ambient for one hour prior to the oven cure.

8. If using Z-Snap epoxy place the part with fixture into an oven for 30 minutes at 120°F (49°C). This step reduces the occurrence of unsightly bubbling or pooling of the resin. Parts infiltrated with Z-Snap epoxy should then be cured for an additional 2 hours in the oven at 165°F (74°C).

9. If using Z-Max, parts should be oven cured for an additional 2 hours at 160°F (71°C).

10. Let the part sit for 30 minutes at room temperature to cool before handling.

11.2.4 INFILTRATION ADDENDUM

Parts with large unsupported overhangs that are difficult to manually handle without breaking should be left on the fixture. Remove as much powder as possible from the top and side surfaces while the part is on the fixture. Lightly infiltrate the exposed top surfaces of the part with Z-Snap or Z-Max epoxy. **DO NOT** apply too much infiltrant to prevent the infiltrant from wicking through to the bottom side of the part. Cure the part for one hour at 165°F (74°C).

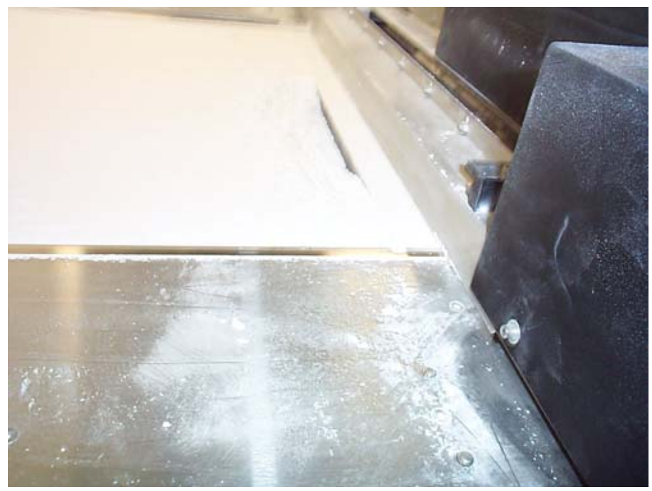
For more information, please contact one of our applications engineers at applications@zcorp.com.

12 CHANGING INI VARIABLES

In certain situations, you may encounter the need to change your INI variables. One situation that may require you to change the INI settings is the need to increase the amount of powder deposited by the ZF8 Powder Feeder. Below you will find instructions on how to change this INI variable. Please contact the Z Corporation Service Department before changing the INI settings.

The ZF8 Powder Feeder metering system does not always deliver enough powder to the spread roller to fill an entire layer. This short spreading will cause a noticeable shortage of powder near the overflow during the course of a large build. It can also increase Z-axis inaccuracy on plaster powder parts and may ruin a part printed near the overflow.

Parts with features near the overflow may have very rough surfaces on those features. There may be a depressed area or cavity near the overflow where powder has not been deposited (see picture).



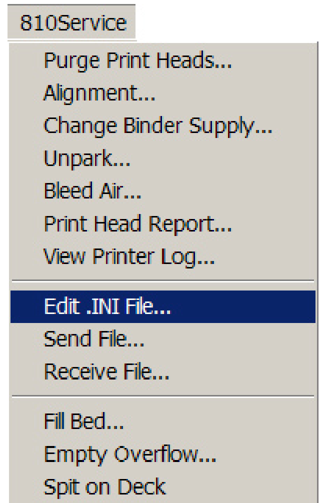
There are two causes of short spreading and it is important to determine the real cause of the problem.

1. The powder feeder may be running out of powder. If there is short spreading at the end of deep builds check to be sure the ZF8 Powder Feeder is really full at the beginning of the build.

2. Short spreading may be the result of an inadequate amount of powder being deposited by the metering system. Generally this occurs under humid conditions. If this is the cause of the problem there is now an .ini variable that will solve the problem by causing the metering system to deposit more powder.

To adjust the INI variable to control the amount of powder fed per layer follow the instructions below:

Select "Edit .INI file" from the "Z810 Service" menu.



WARNING!!!

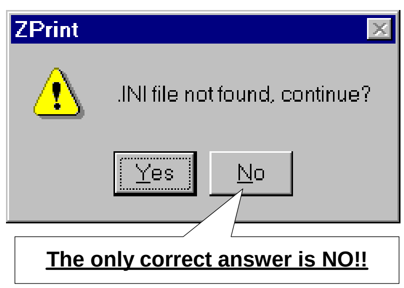
If there is a problem with communication a dialog such as this one will show. Or you may get a similar box with 'Printer busy or not found.'

Press Cancel.

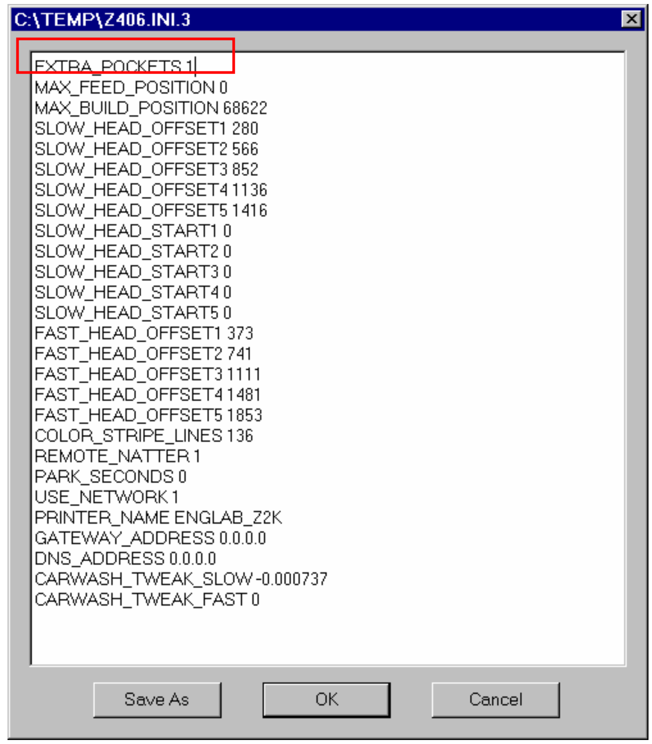
Make sure the printer is online and not busy and try again.

Here is the important part!!!

If this dialog box shows, press **No!**



Assuming there are no errors, an edit box will be shown similar to the one at the right.



Add the line “EXTRA_POCKETS 1” and select “OK”. The printer will restart. Run a test build to see if the short spreading problem has been solved. If not change the line to “EXTRA_POCKETS 2” and test again.

It is important to start at a value of 1 and to increment by 1. Under almost all circumstances a value of 1 will solve the problem. Large values will reduce the depth of build that can be completed successfully because there is only a limited amount of powder in the feeder. A large value may also cause a “50103, POWDER: Overflow Full” error.

Values larger than 5 will be treated by the firmware as a value of 5.

If you later experiences an “Overflow Full” error, you can edit the .INI file and reduce the value of EXTRA_POCKETS.

13 MAINTENANCE

Maintenance Action	Frequency
Z810 3D Printer	
1. Refill zc10 Wash Fluid	As needed
2. Flush Binder with Distilled Water	When not in use for two or more weeks
3. Greasing Fast Axis	As needed
4. Greasing Slow Axis	As needed
5. Clean Under Gantry	Once a month or as needed
6. Clean Fan Filter	Once a month or as needed
7. Clean Spreader Roller	Once a month or as needed
8. Clean Squeegee Scraper	Before every build
9. Clean Wipers	Before every build
10. Bleed Air	If you run out of binder or air enters the fluid system
11. Clean Fast Axis Pulley	After every print head change
ZF8 Powder Feeder	
1. Clean Powder Screen	Once a week or after vacuuming up small parts
2. Clean the Metering System	As needed
ZD8 Depowdering Unit	
1. Empty Powder Drawer	Once a week or as needed

13.1 ADD ZC10 WASH FLUID

The zc10 wash fluid will need to be refilled when the zc10 wash fluid container is empty.

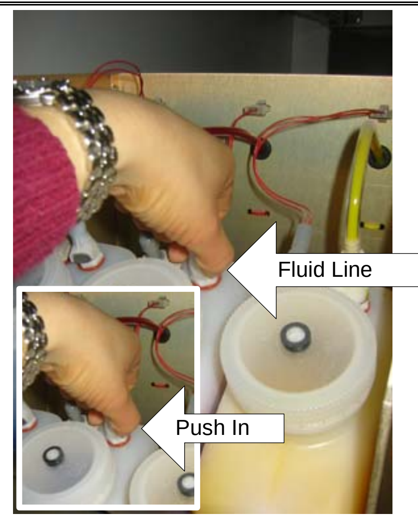
1. Unpark the gantry by selecting the ‘Unpark’ option under the 810Service menu in the ZPrint Software.
2. Open the service station cleaning station.
3. Fill the container with a full bottle of zc10 wash fluid.
4. Replace cover, close top cover, and repark the gantry.

13.2 FLUSH SYSTEM WITH DISTILLED WATER

If the printer will not be in use for more than two weeks, it is strongly recommended that it be flushed with distilled water. This will prevent the binder from coagulating in the fluid lines. Make sure waste bottle is empty prior to flusing your fluid system. This will prevent overfilling the waste bottle.

> **PLEASE NOTE:** If the printer is in color mode and will only be used in monochrome mode for more than two weeks, only place distilled water in the color binder containers and flush in color mode. Then change to monochrome mode.

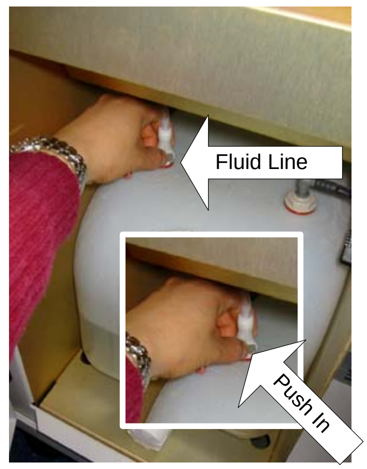
1. Open cabinet door.
2. Remove primary color binder fluid lines using the quick disconnect by pushing in the fitting button and pulling the fluid line away from the bottle.



3. Connect the supplied flush tubing accessory (part number 06452) to the printer binder line fitting.

4. Place other end of tubing in a bottle of distilled water.

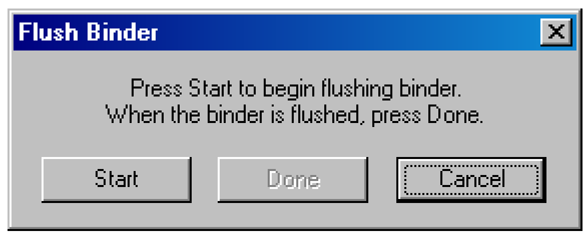
5. Disconnect clear binder fluid line through the quick disconnect.



6. Connect accessory binder flushing tube to the end of the fluid line.

7. Place other end in a bottle of distilled water.

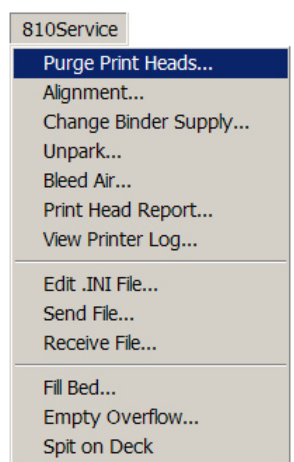
8. Choose the ‘Flush Binder’ option under the Service menu.



9. Click ‘Start’ to begin flush process. Flush distilled water into the fluid lines for three minutes. Press ‘Online’ to complete flush process.

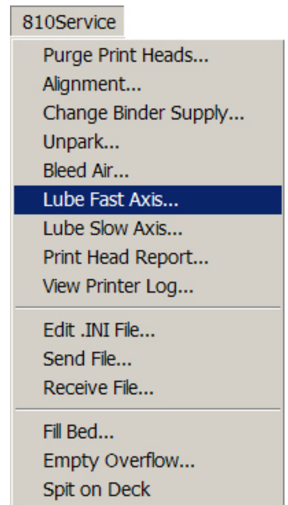
PLEASE NOTE: The printer will continue flushing unless the ‘Online’ button or ‘Cancel’ button is pressed to complete the operation.

10. Then choose the ‘Purge Print Heads…’ option under the Service menu.



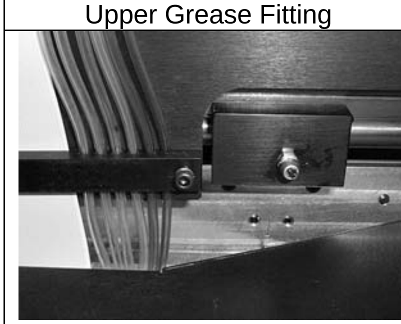
11. Remove the rubber tubing from the bottle of distilled water. Disconnect the end of the fluid line to the rubber tubing and reconnect. Close cabinet door.
12. Turn Printer off.
13. When ready to use the Z810 3D Printer, turn Printer on, replace the distilled water with Z Corp. binder and flush fluid system for three minutes. Then purge the print heads.

13.3 GREASING THE FAST AXIS



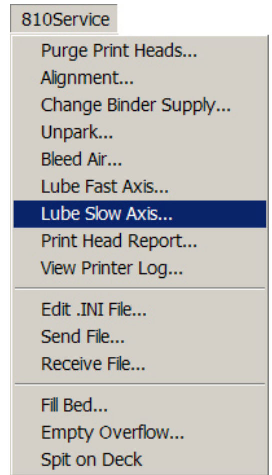
It is necessary to add grease to these fittings approximately every two weeks. The grease lubricates and protects the bearing. The grease also coats the fast axis rails and prevents powder from adhering to them. This further protects the bearings. For instructions on how to assemble the grease gun, please refer to the instructions on the grease gun packaging.

1. Before lubricating the fast axis, empty the build box of both parts and powder.
2. Select the Lube Fast Axis option under the 810Service menu. The build piston will be lowered and the gantry will move to the ideal location for greasing.
3. Push the grease gun onto the Zerk fitting and compress the lever on the grease gun once to inject grease. Then pull the grease gun off the fitting. It may be harder to remove the grease gun than to insert it. It is not possible to damage the bearings by greasing them too often.
4. Select 'Done' in the ZPrint Software. The carriage will move along the fast axis a few times to distribute the grease that was applied to the bearings.
5. Clean up excess grease near each end of the fast axis rails with a paper towel.

Upper Grease Fitting	Lower Grease Fitting	Lower Front Grease Fitting
		

PLEASE NOTE: Greasing too often may result in the excessive grease accumulating on the fast axis that may drop onto the build area during printing. Please be sure to check the fast axis after greasing and to wipe off excess grease.

13.4 GREASING THE SLOW AXIS



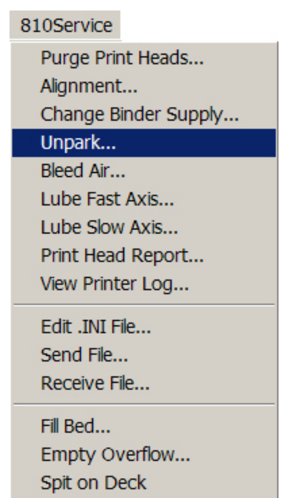
1. Select the Lube Slow Axis option under the 810Service menu.
2. There are two locations for greasing the slow axis. The gantry will move to the first position. Grease both the front and back slow axis rails.
3. **REMOVE grease gun BEFORE pressing 'Done' in ZPrint Software.**
4. The gantry will move to the second position. Grease both the front and back slow axis rails.
5. **REMOVE grease gun BEFORE pressing 'Done' in ZPrint Software.**
6. The gantry will move across the slow axis in order to spread the grease deposited into the bearings.

13.5 CLEAN UNDER GANTRY

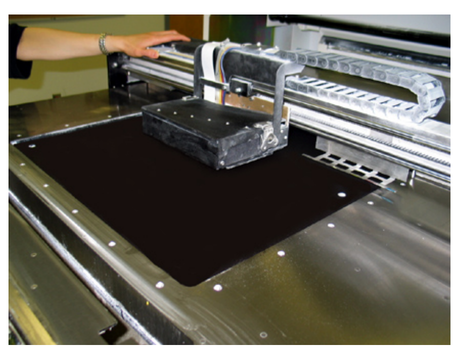
It is necessary to clean under the gantry when powder and binder have adhered to the bottom causing layers to be dragged when printing. It is also good practice to clean under the gantry to prevent powder and binder build-up once a month.

1. Lower build piston 50% down by pressing the 'Build Down' button on the control panel.

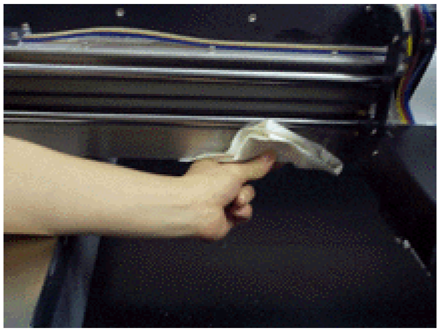
2. Unpark the gantry by choosing the 'Unpark' option in the 810Service menu.



3. Push the gantry over the build piston.



4. Using a moist paper towel wipe underneath the gantry. Dry the bottom of the gantry after cleaning with a dry paper towel.

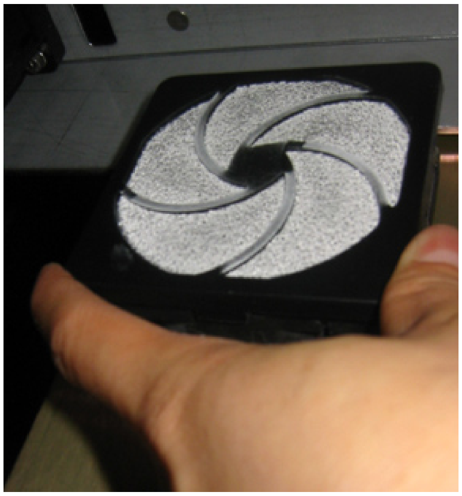


5. Repark the gantry by clicking 'OK' on the dialog box.
6. Raise build piston to original position and vacuum up any powder or debris that has fallen into the build area.

13.6 CLEAN FAN FILTER

The fan filter is located on the left side of the electronics panel. It circulates and filters air into the electronics area. The filter should be cleaned once a month.

1. Turn off the Printer.
2. Open the front, left cabinet door.
3. Locate the filter on the upper, right side of the cabinet, against the electronics panel.
4. Remove the fan filter by removing the plastic cover. It will snap off.
5. Separate filter from plastic cover.
6. Wash and rinse the filter with soap and water.
7. Dry the filter.



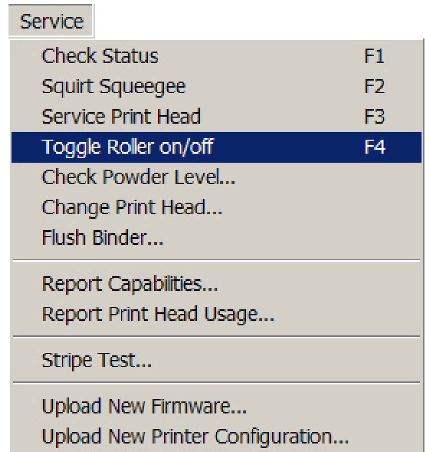
> **PLEASE NOTE:** The filter needs to be completely dry before it is replaced. Powder may adhere to a wet filter and prevent airflow into the electronics area.

8. Replace fan filter into plastic cover and snap plastic cover back into place.
9. Close cabinet door.

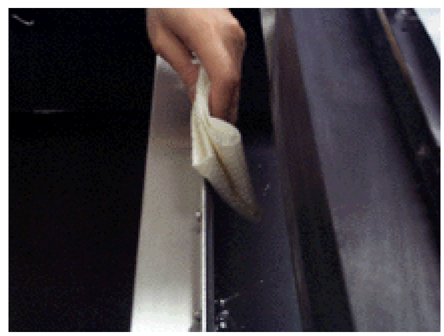
13.7 CLEAN SPREADER ROLLER

The spreader roller may become dirty with powder and binder debris after printing. Cleaning the spreader roller will prevent uneven spreading of powder over the build pallet.

1. Choose the 'Toggle Roller on/off' option under the Service menu or press F4.



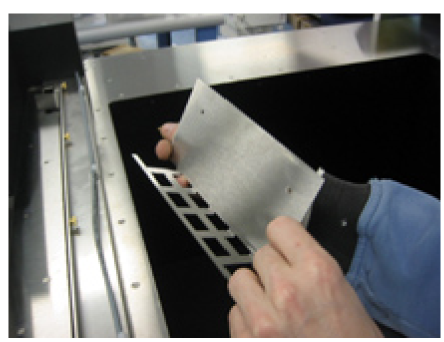
2. Using a moist paper towel, wipe the spreader roller. Dry spreader roller with a dry paper towel.
3. To untoggle roller, choose 'Toggle Roller on/off' option again or press F4.



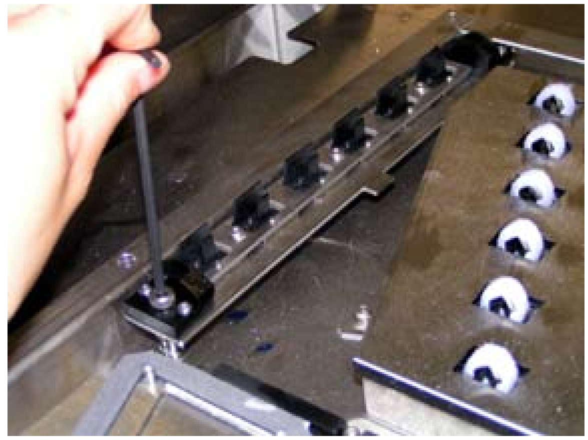
13.8 CLEAN SQUEEGEE SCRAPER

1. Remove squeegee scraper by removing the thumb screws manually.

2. Remove the squeegee scraper and wipe or wash clean.
3. Restore squeegee scraper and tighten thumb screws.



13.9 CLEAN SQUEEGEE WIPERS

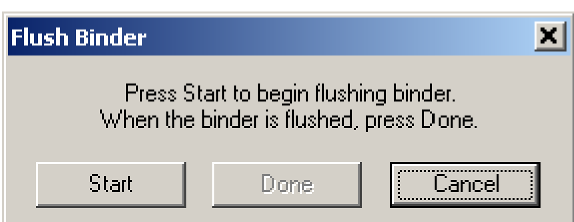


1. Remove squeegee wipers, by loosening and removing the screws located at each end of the wiper assembly with a hex wrench.
2. Wash the wipers.
3. Restore wipers and tighten screws.

13.10 BLEED AIR FROM THE FLUID SYSTEM

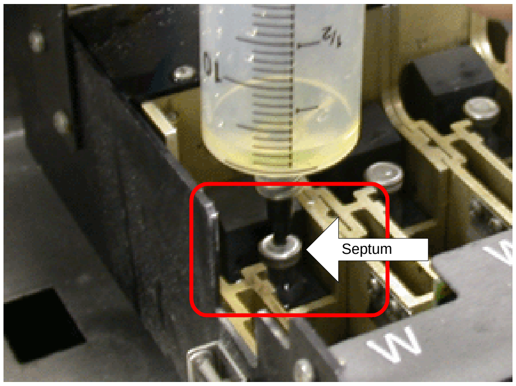
Air will enter the fluid lines anytime the bottle fittings are disconnected. This is normal and is expected. You will need to bleed air to remove air from your system. Follow the procedure below:

1. Fill the binder jug with binder solution.



2. Select the 'Flush Binder' option under the Service menu.
3. Flush binder for three minutes.

4. Unpark carriage and remove print heads.
5. Select the 'Bleed Air' option under the 810Service menu.
6. Assemble the syringe (part number 10674) and needle (part number 13115) if needed from your toolkit by screwing on the needle at the end of the syringe.



7. Remove plunger from syringe.

8. Insert needle into septum and wait until you do not see any air entering into the syringe, characterized by bubbles in the fluid.

9. Continue for every septum.

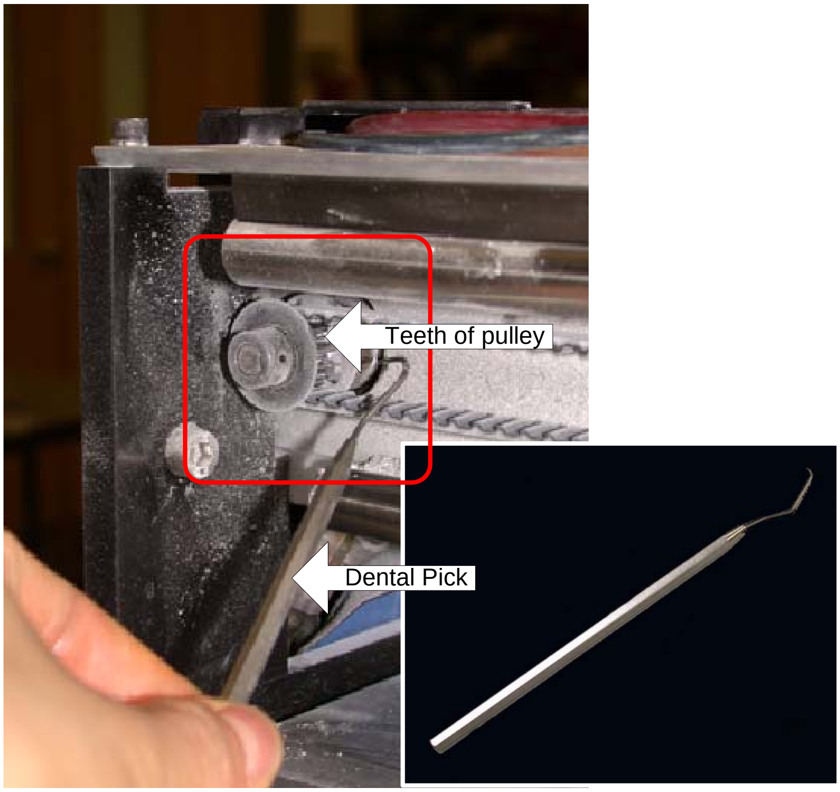
10. Close the carriage cover, repark the carriage using the ZPrint Software, and change print heads as described in Section 10, *Changing and Aligning the Print Heads*.

13.11 CLEAN FAST AXIS PULLEYS

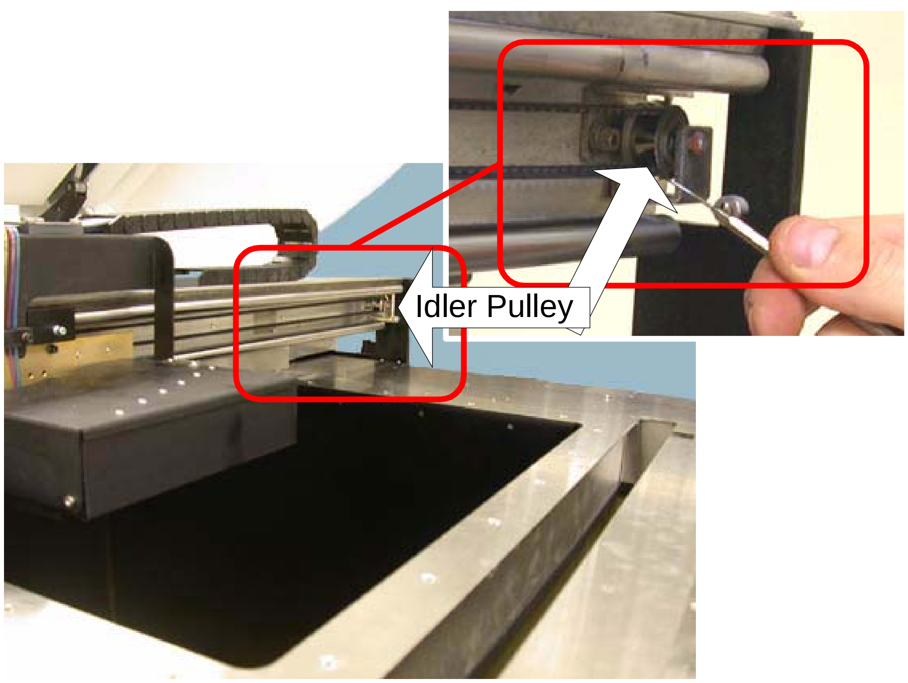
Powder build-up on the fast axis pulley will prevent proper function of the carriage and may result in a 2303 (1) error or similar errors. It is recommended that you clean your fast axis pulley after every print head change. This will prevent build up of powder on the fast axis pulley.

1. Unpark the gantry by selecting the 'Unpark' option under the 810Service menu.

2. Using the dental pick provided in the tool box remove powder from pulley.



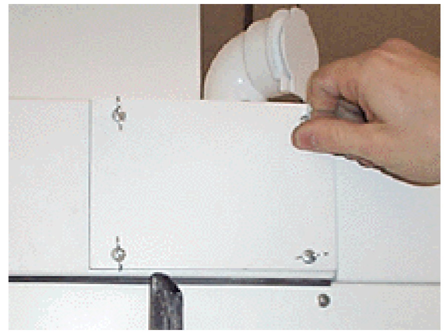
3. Clean idler pulley.



13.12 CLEAN POWDER SCREEN ON THE ZF8 POWDER FEEDER

The powder screen in the ZF8 Powder Feeder prevents any large pieces of debris from entering the Feeder. Periodically, the screen needs to be cleaned in order to allow steady airflow through the Feeder.

1. Remove wing nuts to expose powder screen.



PLEASE NOTE: Be careful when opening the access panel to the powder screen, powder may be piled up behind the access panel.

2. Use the external vacuum to remove any debris.
3. Replace powder screen cover.

13.13 EMPTY POWDER DRAWER ON THE ZD8 DEPOWDERING UNIT

The Powder Drawer in the ZD8 Depowdering Unit collects the excess powder removed during the depowdering process. The powder drawer should be emptied weekly. If you are a heavy user or if your part geometry encapsulates large volumes of powder, the powder drawer may need to be emptied more frequently.

1. Release powder drawer by moving the control switch to the left.

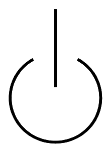
2. Slide the powder drawer out. There are two handles available. One handle option extends out to allow you tow, push, and maneuver the powder drawer to and from an emptying location. The other handle option allows you to pull and push the powder drawer at the base.

3. Remove powder. If you are using two different material systems, use the external vacuum or scoop to remove powder. If you are using one material system and would like to recycle, use the powder feeder vacuum to remove powder for reuse.
4. Slide back powder drawer and replace handle.
5. Return control panel to Stand By mode.

14 Z810 SYSTEM DETAILS

14.1 SYMBOLS USED

The following symbols are used on the Z810 3D Printer:



This is the international symbol for 'standby power'. It is used on the Z810 3D Printer power switch. The Z8103D Printer is partially powered as soon as you plug it in. The power switch is momentary contact and toggles the machine from idle mode to full power on mode.

This is the international symbol for 'warning' or 'caution'. When it appears on the exterior of the equipment, it indicates the need to consult your manual for further information.

14.2 SYSTEM SPECIFICATIONS

Operating Conditions: 68 to 85ºF, 20 to 60% Relative Humidity, non-condensing.

Lithium Battery: Internal to the Z810 3D Printer is a lithium coin cell type battery. This may be any one of the following: Type: CR2032, either Maxell, Panasonic, Renata, Sanyo or Sony.

PLEASE NOTE: This battery is not in a user accessible area and is not user replaceable. The expected lifetime of the battery is in excess of five years. Replacement will be handled by your Z Corporation customer service representative.

FCC Notice: Note: this equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interferance to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CENELEC Class A Warning: Note: this equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to EN 55022. Class A devices are for office and light industrial environments, and are not generally suitable for home use.

WARNING: This is a Class A product. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

14.3 MATERIAL STORAGE PRECAUTIONS

Carefully read the Material Safety Data Sheets (MSDS) before using any Z Corporation materials.

Material	Storage	Usage
Powder	Store powder on pallets in a cool, dry, ventilated area away from sources of heat, moisture, and incompatible materials. Keep containers tightly closed.	Use of powder in environments with more than 30% relative humidity will affect powder performance.
Binder and Wash Fluid	Store in cool, dry place, away from sun. Keep tightly capped.	Binder is NOT recyclable.
Print head	Store in cool, dry place, away from sun. Keep tightly capped.	
Infiltrants	Store in cool, dry place, away from sun. Keep tightly capped.	For more information, visit the User Group Website at www.zcorp-users.com.

14.4 ERROR CODES

PLEASE NOTE: %d and %x are place holders for numbers corresponding either to print head number or a value.

1000 Unknown head error
1001 Can't turn on head 5 + 12 V
1002 ROM read failed for head %d
1003 I2C read failed for head %d
1004 Head %d fire voltage failed
1005 Head %d temperature too low
1006 Head %d temperature too high
1007 Head %d current too high
1008 Head cover is open
1009 Head %d fire voltage stuck
1010 Invalid head temperature
1011 Out of binder
1100 SYSTEM: out of memory in thread %d
1101 SYSTEM: can't log ETS events
1200 THREAD %d: can't create events
1201 THREAD %d: can't initialize window system
1202 THREAD %d: can't make window
1203 THREAD %d: can't begin
1204 THREAD %d: can't set priority
1205 THREAD %d: illegal state
1206 THREAD %d: refuses to stop
1207 THREAD %d: refuses to die
1300 QUEUE: out of memory
1301 QUEUE: can't create event

1302 QUEUE: received null pointer
1400 KEYBOARD: can't add callback
1401 KEYBOARD: can't create pipe
1402 KEYBOARD: error writing pipe
1403 KEYBOARD: error reading pipe
1500 KEYMAP: duplicate key %d
1501 KEYMAP: bad key index %d
1600 COM%d is not a valid port
1601 COM%d: queue is too small
1602 COM%d: ETS monitor is using port
1603 COM%d: port already in use
1604 COM%d: can't create event
1605 COM%d: can't create thread
1606 COM%d: can't set priority
1607 COM%d: bad interrupt number
1608 COM%d: IRQ already in use
1609 COM%d: can't save interrupt vector
1610 COM%d: can't set interrupt vector
1611 COM%d: UART isn't 16550 compatible
1612 COM%d: input queue overrun
1613 COM%d: UART not found
1614 COM%d: bad UART identifier
1615 COM%d: UART already in use
1700 STATUS: spurious read event
1701 STATUS: bad thread index %d
1702 STATUS: unknown system message %d
1703 STATUS: invalid state %d
1704 STATUS: unknown dispatch type %d
1705 STATUS: message queue overrun
1706 STATUS: can't save state
1707 STATUS: can't restore state
1708 STATUS: too many held layers
1800 PACKETS: layer is too big
1801 PACKETS: invalid upgrade file
1802 PACKETS: network init failed
1900 LAYERS: spurious read event
1901 LAYERS: zlib InflateInit error %d
1902 LAYERS: zlib Inflate error %d
1903 LAYERS: zlib InflateEnd error %d
1904 LAYERS: missing layer info packet
1905 LAYERS: layer is too big, %dK bytes
2000 STRIPES: spurious read event
2001 STRIPES: bad saturation
2002 STRIPES: too many lines per stripe
2003 STRIPES: line is too long
2004 STRIPES: bad print mode %d
2005 STRIPES: bad line offset
2100 UNRLE: bad layer number
2101 UNRLE: bad print mode %d

2200 BMOCO: LM629 does not respond
2201 BMOCO: can't reset motor %d
2300 MOVER: bad axis
2301 MOVER: axis %d destination out of range
2302 MOVER: axis %d move intersects no-fly zone
2303 MOVER: axis %d excessive position error
2304 MOVER: axis %d timed out completing move
2305 MOVER: axis %d didn't settle
2306 MOVER: axis %d can't change acceleration
2307 MOVER: axis %d can't set filter
2308 MOVER: axis %d excessive speed
2308 MOVER: axis %d safety handler not installed
2400 REZERO: axis %d can't find end of travel
2401 REZERO: axis %d already over sensor
2402 REZERO: axis %d timed out looking for sensor
2403 REZERO: axis %d couldn't find sensor
2500 SHAKER: can't read layer info
2501 SHAKER: bad layer number
2600 HEAD: bad ROM format
2700 DRAWSPAN: bad bit number
2701 DRAWSPAN: bad print mode
2800 TIGERCOM: serial write timeout
2801 TIGERCOM: serial read timeout
2900 TIGER: bad head index
3000 SEQUENCER: bad FIFO size, %d entries
3001 SEQUENCER: can't create event
3002 SEQUENCER: can't create thread
3003 SEQUENCER: can't set priority
3004 SEQUENCER: bad interrupt number
3005 SEQUENCER: can't save interrupt vector
3006 SEQUENCER: can't set interrupt vector
3007 SEQUENCER: not enough data
3008 SEQUENCER: overrun while waiting for HF
3009 SEQUENCER: stalled while waiting for HF
3010 SEQUENCER: sequence didn't finish, flags = %x
3011 SEQUENCER: error in DPC, flags = %x
3012 SEQUENCER: spurious interrupt, flags = %x
3013 SEQUENCER: timed out finishing swath, flags = %x
3100 PRINTER: spurious read event
3101 PRINTER: bad dispatch type %d
3102 PRINTER: unknown message %d
3103 PRINTER: message queue overrun
3104 PRINTER: need service call, error %d
3105 PRINTER: can't create event
3106 PRINTER: SendMessage deadlock
3200 MONITOR: can't create waitable timer
3201 MONITOR: can't set waitable timer
3202 MONITOR: thread took too long
3300 TIMER: unknown time unit

3400 SWITCHES: switch %d is undefined
3500 KEYPAD: object already exists
3501 KEYPAD: can't create event
3502 KEYPAD: object not initialized
3503 KEYPAD: object has too many users
3600 BLINK: object already exists
3601 BLINK: object not initialized
3602 BLINK: object has too many users
3603 BLINK: undefined sequence
3700 LCD: object already exists
3701 LCD: object not initialized
3702 LCD: object has too many users
3800 LOWLEVEL: can't find PCI card
3801 LOWLEVEL: error opening FPGA file
3802 LOWLEVEL: invalid FPGA load
3803 LOWLEVEL: bad IRQ number
3900 SOCKETS: can't initialize WinSock interface
3901 SOCKETS: WinSock 1.1 not supported
4000 TCP: can't create event
4001 TCP: can't launch thread
4002 TCP: thread refuses to die
4003 TCP: error %d creating socket
4004 TCP: error %d setting socket option
4005 TCP: error %d binding socket
4006 TCP: error %d listening on socket
4007 TCP: error %d accepting socket
4008 TCP: error %d selecting socket
4009 TCP: error %d getting received byte count
4010 TCP: error %d receiving from socket
4011 TCP: error %d looking up host by name
4012 TCP: error %d connecting to host
4013 TCP: error %d sending to socket
4014 TCP: error %d setting non-blocking mode
4100 UDP: error %d creating socket
4101 UDP: error %d setting socket mode
4102 UDP: error %d setting socket option
4103 UDP: error %d binding socket
4104 UDP: error %d looking up host by name
4200 ZDNS: can't launch thread
4201 ZDNS: thread refuses to die
4300 NETWORK: can't find ethernet device
4301 NETWORK: can't get device configuration
4302 NETWORK: can't set device configuration
4400 BITBUS: object already exists
4401 BITBUS: object not initialized
4402 BITBUS: readback error
4500 FLUIDS: object already exists
4501 FLUIDS: object not initialized
4502 FLUIDS: unsupported pump rate

4503	FLUIDS: waste bottle full
4504	FLUIDS: lost pressure on pump %d
4600	CARWASH: object already exists
4601	CARWASH: object not initialized
4602	CARWASH: carwash is stuck
4603	CARWASH: can't finish squirt
4700	BINDER: weak pressure from pump %d
4701	BINDER: can't write plumbing state
4702	BINDER: invalid plumbing type %d
4800	MATERIALS: unknown combination
4900	STICKY: object already exists
4901	STICKY: object not initialized
4902	STICKY: too many keys
4903	STICKY: duplicate variable
5000	POWDER: no more build
5001	POWDER: no more feed
5002	POWDER: tray full
5100	ROLLER: speed calibration failed
5200	ALIGNMENT: can't update god variable
30000	SPIBUS: object already exists
30001	SPIBUS: object not initialized
30002	SPIBUS: invalid ADC channel specified
30003	SPIBUS: timeout waiting for Read()
30004	SPIBUS: write verify failed
30005	SPIBUS: unknown device
30100	TIGER: object already exists
30101	TIGER: object not initialized
30102	TIGER: temp calibration exceeds range: %dmA
30103	TIGER: head TSR exceeds range: %dohms
30200	HEADCARD: object not initialized
30201	HEADCARD: object already exists
30300	SMARTCHIP: unknown block type
50000	CUSTOM: can't find CBDIO PCI card
50100	POWDER: feeder timeout
50101	POWDER: feeder not present
50102	POWDER: can't find feeder
50103	POWDER: overflow full
50200	SERVICE: failed head check
50300	PISTONS: build piston is tilted
50301	PISTONS: illegal move
50400	TIDIO: invalid command
50401	TIDIO: invalid port
50402	TIDIO: invalid adc channel
50403	TIDIO: pockets # out of range
50404	TIDIO: vomiter timeout
50405	TIDIO: invalid toggle argument
50406	TIDIO: unknown error

15 INDEX

ZCast® 501 Direct Metal Casting

DESIGN GUIDE

September 2004

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1 Introduction

The ZCast® process was created to allow for the rapid fabrication of metal parts. It allows cast metal parts to be verified without the time and expense that is typically associated with production tooling. While the range of uses is broad, the ZCast process most closely resembles sand casting in both the finished part and the functionality of the mold. It is suggested that anyone making parts with ZCast powder should:

- Become familiar with the design of sand casting molds
- Locate a foundry experienced with the sand casting process

ZCast users range from individuals with little or no mold design to knowledgeable, experienced pattern makers or foundrymen. Since ZCast users possess a wide range of experience, this guide has been written with all users in mind. It is meant to be a guide to provide a framework for designing molds for use with ZCast. But it also covers some of the basics of sand casting to help familiarize those with less casting experience.

Z Corporation is dedicated to your successful application and usage of this product. Please contact Z Corporation directly to schedule a **free online training** session at (781)852-5005. Ask for the ZCast applications engineer or email the applications team at applications@zcorp.com.

2 General Safety

This manual has safety information and instructions to help users reduce or eliminate the risk of accidents and personal injuries. This section briefly explains hazards associated with fabrication of metal parts using the ZCast process.

2.1 Safety Precautions

The making of molds and casting of metal parts using the ZCast process involves steps, such as mold baking and handling molten metal, that have particular safety hazards. Designers, fabricators, and foundry operators should be experienced or under supervision to perform these process steps using safe operating procedures.

The mold-baking step emits smoke and gases that are toxic and irritating. Refer to the ZCast 501 Powder MSDS for more information on these health hazards. Ovens must have exhaust fans and be vented to the outside.

Operators must wear heat-resistant Personal Protective Equipment (PPE) while handling molten metal. Molten metal can cause serious injury to unprotected eyes and skin. Operators must wear at least heat-resistant gloves, face shields and aprons suitable for foundry operations. Other protective clothing may be necessary depending on the casting operation.

2.2 Safety Symbols

An exclamation mark inside a triangle is a safety alert symbol. The safety alert symbol is used to draw attention to safety information in this manual. It is followed by a signal word, WARNING or CAUTION, which tells the level of risk to the user.

WARNING	Means if the safety information is not followed someone **could or can** be seriously injured or killed.
CAUTION	Means if the safety information is not followed someone **may** be injured.

The following symbol is used for information purposes only, for example:

NOTICE	Ensure that the any loose material on the mold is removed before proceeding to the next step.

2.3 Safety Instructions

Read and follow this safety information to reduce or eliminate the risk of accidents and personal injuries.

GENERAL SAFETY

WARNING	**Do not allow untrained individuals to design or handle ZCast molds during manufacturing. Only trained individuals with sand casting design and foundry experience should design and handle the ZCast molds.**
WARNING	**Do not bake ZCast molds in unvented ovens. Irritating and toxic fumes are formed at elevated temperatures during oven baking. Ovens must be vented to the outside. Refer to the ZCast 501 powder MSDS for more information on the irritating and toxic fumes.**
WARNING	**Bake ZCast molds until all moisture is removed before metal casting. Residual moisture in the mold can cause the mold to unexpectedly fail, releasing entrapped gases and molten metal and causing serious personal injury.**
WARNING	**Do not use ZCast 501 molds with molten ferrous metals or other metals with pouring temperatures above 1100^{o}C (2000^{o}F). The molds can suddenly fail unexpectedly releasing entrapped gases and molten metal causing serious personal injury.**
WARNING	**Do not handle molten metal without heat-resistant faceshield, gloves and apron and tools suitable for handling molten metal in foundry operations.**
CAUTION	**Depowdering with compressed air will generate airborne particles. Only trained or supervised individuals should depowder a mold. Use hood ventilation and safety goggles or faceshield to protect the eyes and face. Refer to the ZCast 501 powder MSDS for more information.**

DESIGNING MOLDS

WARNING	**Improper design of molds can result in the release of molten metal and personal injury during the metal casting steps. Only trained or supervised individuals should design molds.**
WARNING	**Use only ZCast 501 material for the mold sections and cores for the Combination Method casting technique. Other mold materials can unexpectedly release molten metal and cause personal injury during metal casting.**

WARNING	**Inadequate venting in the mold or core can lead to the unexpected release of entrapped gases and molten metal causing personal injury during metal casting. Venting paths in the mold must be arranged and directed away from the metal path to avoid entrapment of gases.**
WARNING	**Do not cast molten metal in molds with multiple sections without using core paste or adhesive. Molten metal can leak from the mold and cause personal injury.**
WARNING	**Unshelled molds may not bake thoroughly to remove all residual moisture. Residual mold moisture after baking when contacted with molten metal can cause the unexpected release of molten metal from the mold and personal injury.**
WARNING	**Insufficient venting of thick mold sections can result in the unexpected release of molten metal and personal injury during metal casting. Design molds with adequate venting capacity and proper location.**
CAUTION	**Vents not located in the core, vents too close to parting lines, or vents that break through to the casting surface may leak molten metal and cause personal injury. Locate vents in the core, away from the casting surface, and as far as possible from parting lines.**
CAUTION	**Mold wall thicknesses of less than 0.5 inches (13 mm) may allow molten metal to leak from the mold unexpectedly and cause personal injury. Design molds to ensure at least 0.5 inches (13 mm) mold wall thickness.**
CAUTION	**Vents not located in the cope may unexpectedly release molten metal and cause personal injury.**
CAUTION	**Parting lines near core vents may leak molten metal into the vents. The vents may not function properly and cause the unexpected release of molten metal and personal injury.**
CAUTION	**Loose powder left in molds may create pockets, voids or block vents during metal casting resulting in the unexpected release of molten metal. Ensure that all loose powder is removed before casting.**

PREPARING AND BAKING MOLDS

WARNING	**Bake ZCast molds until all moisture is removed before metal casting. Residual moisture in the mold can cause the mold to unexpectedly fail, releasing entrapped gases and molten metal and causing serious personal injury.**
WARNING	**Do not bake ZCast molds in unvented ovens. Irritating and toxic fumes are formed at elevated temperatures during oven baking. Ovens must be vented to the outside. Refer to the ZCast 501 powder MSDS for more information on the irritating and toxic fumes.**
CAUTION	**Depowdering with compressed air will generate airborne particles. Only trained or supervised individuals should depowder a mold. Use hood ventilation and safety goggles or faceshield to protect the eyes and face. Refer to the ZCast 501 powder MSDS for more information.**
CAUTION	**Pouring sleeves attached to the ZCast mold with core paste may shift while pouring molten metal into the mold. Leaking of molten metal may cause personal injury. Attach sleeves with clamps and securing wires as needed.**

POURING MOLTEN METAL

WARNING	**Do not use ZCast 501 molds with molten ferrous metals or other metals with pouring temperatures above 1100^{o}C (2000^{o}F). The molds can suddenly fail unexpectedly releasing entrapped gases and molten metal causing serious personal injury.**
WARNING	**Do not handle molten metal without heat-resistant faceshield, gloves and apron and tools suitable for handling molten metal in foundry operations.**
WARNING	**Do not handle molten metal without adequate local exhaust ventilation. Hot gases emitted during the casting process can burn skin and are irritating and toxic. Refer to the ZCast 501 powder MSDS for more information.**
WARNING	**Inadequate venting in the mold or core can lead to the unexpected release of entrapped gases and molten metal causing personal injury during metal casting. Venting paths in the mold must be arranged and directed away from the metal path to avoid entrapment of gases.**
CAUTION	**Do not cast metal parts in molds with multiple sections without core paste or adhesive. Molten metal may leak from the mold seams and cause personal injury. Avoid blocking vents with paste or adhesive.**
CAUTION	**Attachment of risers and cups without core paste may result in the unexpected release of molten metal and personal injury. Always use core paste or adhesive for attachments. Additional clamps or securing wires may also be needed.**

FINISHING

CAUTION **Breaking molds with a hammer or high-pressure water jet releases airborne objects and may cause personal injury. Wear eye, face and hand protection while breaking molds.**

CAUTION **Drill, cutting or grinding cast parts releases airborne objects and dusts and may cause personal injury. Wear eye and face protection while performing these tasks.**

3 ZCast Advantages

Today, metal casting molds are commonly created by first producing a machined pattern (or pattern set) that is then used to create the molds. Instead of utilizing this costly and often time consuming process, the ZCast process utilizes 3D printing to create the molds and mold inserts directly from CAD data. With the ZCast process, Z Corp. provides the option to skip the pattern or tooling step, significantly reducing the time required to obtain metal castings, while also reducing the cost.

The production of prototype castings using conventional methods can often take several weeks and be prohibitively expensive. These constraints limit the number or preclude the production of metal prototypes during the development process. Specific time and cost savings will depend on the size and complexity of the desired part, but can also be substantial for most customer needs. Castings can be produced in as few as one or two days for a fraction of the cost of traditional tooling.

3.1 The Material

ZCast 501 powder is a plaster-ceramic composite suitable for casting low temperature metals (aluminum, magnesium, and zinc). Tests conducted by Z Corp. and it's foundry partner (Griffin Industries) have shown results that mimic traditional sand casting finishes and tolerances. Many successful castings have been made in 356, 390 and 319 aluminum as well as zinc, bronze, and magnesium.

The ZCast material set can be used on the Z810 Large Format 3D Printer, the Z406 3D Printer and the ZPrinter® 3D Printer.

WARNING **Do not use ZCast 501 molds with molten ferrous metals or other metals with pouring temperatures above 1100^{o}C (2000^{o}F). The molds can suddenly fail unexpectedly releasing entrapped gases and molten metal causing serious personal injury.**

3.2 Design Freedom

In addition to reducing the time and cost to create a prototype casting, the ZCast process also provides the freedom to produce complex castings that previously were difficult or impossible to produce using conventional tooling methods. One of the powerful features of the ZCast process is the freedom to incorporate undercuts and channels in the molds. Runners and vents can be formed inside the mold that are otherwise impossible to machine; cores can be integrated into the mold, minimizing the number of parts and simplifying setup. For prototype parts, this greatly simplifies the mold design process.

Design alternatives include:

- **The Direct Pour Method** involves printing an entire mold, cores and all, in the ZCast material. This usually uses the most material, but allows for virtually no set-up time and very quick production of your prototype casting.

- **The Shell Method** involves printing only a thin (½ inch thick) mold to surround the entire part. This shell is then backed with traditional foundry sand in a flask to create a mold suitable for pouring. This helps to minimize the amount of ZCast material used and is

particularly useful for assembling large molds that are too large to fit in the build volume of the Z Corporation Printer.

- **The Combination Method** involves printing cores with ZCast material and using them in conjunction with a conventional sand mold. Either the sand mold can be created with machined patterns, or to keep the time of casting to a minimum, the patterns can be printed on a Z Corporation 3D Printer using zp®100 series materials.

4 Locating a Foundry

Whether you are an experienced mold designer with a foundry in-house, or a design engineer who has never designed a mold, the first step in the ZCast process is to run a trial with your foundry. Typically, any foundry will find their end of the process (the set-up and pouring) to be very much the same as traditional sand casting; therefore, the first choice would be to find a foundry with experience in sand casting.

The foundry should be set up for running prototype quantities, or be able to comfortably adapt to pouring parts in low volume. Depending on the design style (direct pour, shell method, etc.), the foundry should be an active participant in the design. The more experience you and your foundry have in pouring ZCast molds, the more efficient your digital to prototyping process becomes.

Though not a requirement, your chosen foundry should be near the location where the molds are printed. Close proximity minimizes the amount of travel the molds must endure. Molds and cores may be shipped (even around the world), but they must be packaged carefully. Shipping molds long distances can add days to the development cycle and increase risk of damage due to shipping.

We recommended that you **provide a copy of this design guide** to your chosen foundry partner.

4.1 Foundry Trial Parts

Once you have a foundry, you'll want to introduce them to the ZCast process with a trial mold. Z Corporation can supply you with files for two such parts. One is a cover plate and the other is a manifold:

Figure 1: Cover Plate mold and casting

Figure 2: Manifold mold and casting

The molds can be printed, baked and brought to your foundry. All of the instructions necessary to pour these parts are in the "ZCast Direct Metal Casting: Quick Guide" (contact your Z Corp. sales representative for a copy). These documents, as well as other instructions, will accompany the mold. The goal of this exercise is to make your foundry comfortable with the ZCast process. You would like them to be as well informed about the materials and the process as you are.

If you have trouble finding a foundry in your area, contact your Z Corp. sales representative to help you locate an experienced foundry.

5 Designing with ZCast – Mold Design

ZCast powder offers flexibility and simplicity in mold design. Because of its simplicity, the engineer or designer can spend more time focusing on the design of the part rather than on the design of the mold. This simplicity does away with undercuts and draft which are critical when using other methods. ZCast's unprecedented flexibility allows the designer to choose the technique that is the most proper for the application at hand.

CAUTION **Improper design of molds can result in the release of molten metal and personal injury during the metal casting steps. Only trained or supervised individuals should design molds.**

5.1 Sources of Mold Design Information

The subtleties of casting design are beyond the scope of this document. The designer may wish to gain as much information as possible on designing sand molds before attempting to use the ZCast process. The more knowledge one possesses about good mold design, the more successful you will be at designing complex and challenging parts. By contrast, simple parts require simple gating and are more straight forward. If you do not have the experience, but have complex parts, consult a local experienced foundryman. They should be capable of helping you design your mold properly.

Several references are available on the topic of designing castings. There are numerous publications be the American Foundry Society, as well as textbooks. Among the best of these are: Campbell, J., Castings, Butterworth Heinemann, 2000: Heine, R.W.; and Rosenthal, P.C., Principles of Metal Casting, McGraw-Hill, 1955: Ammen, C.W., The Complete Handbook of Sand Casting, Tab Books (McGraw-Hill), 1979.

Important aspects in good mold design are:

- Even filling of the mold
- Accurate cooling of the casting
- Proper mold ventilation

The conventional features of designing molds for sand casting apply equally well to ZCast patterns. Some of the special properties of ZCast powder affect some of the design considerations. To make high-quality castings, a strong emphasis should be placed in the design of risers. These will be discussed below.

Properties of light metals such as aluminum and magnesium cause them to be especially sensitive to exposure to air, water vapor, and mold gases. Gating design for these metals should focus on minimizing turbulence during filling. These metals also tend to shrink a great deal during solidification.

Figure 3: Direct pour molds in aluminum after pouring (note significant number of risers).

5.2 Selecting a Design Method

This first step in designing a mold is to decide which design method best suits the desired casting. These are the three basic methods.

5.2.1 Direct Pour

A mold designed by this method incorporates the cavity of the casting and the entire gating system, including risers and vents. This keeps the mold setup simple by minimizing parts. It is most handy for small molds: up to 5 lbs in aluminum or 15 lbs in bronze. Larger castings can be feasible if the gating system is kept simple. For example, a short sprue leading to a single gate. These molds are least complicated, usually only two or three parts.

Using the Direct Pour method, the parting surface need not be a flat plane, as usually is the case in conventional sand casting. Nor does the gating system need be constrained to the parting surface. The requirement for “draft” with respect to the parting surface is absent as well.

This method is ideal for molds for which the components (entire cope, entire drag, and cores) can each be printed out in their own build without modification.

5.2.2 Shell Method

In this method, the mold cavity is formed by a 0.5 in (13 mm) thick shell of ZCast material and is held in place by backing it with conventional sand. The gating system: sprue, wells, runners, and risers are constructed in the foundry sand, merging with ingates and riser holes that penetrate the ZCast shells. This method is conceived for larger molds than those used in the Direct Pour method and when the gating system would require very large ZCast components. If the size of the mold exceeds the working volume of the printer, the Shell Method is recommended.

These molds are more complicated to design than Direct Pour molds, and require the designer to be familiar with tool design for conventional sand casting. The designer must allow for the ZCast pieces to mount to a pattern board, which aligns them with respect to the rest of the mold. The ZCast shells must provide connections to the gating system, vents, and risers, and they must have features that anchor them to the backing of foundry sand. Finally, the ZCast shells must be structurally sound by themselves so they can be handled and baked individually.

CAUTION **Improper design of molds can result in the release of molten metal and personal injury during the metal casting steps. Only trained or supervised individuals should design molds.**

The printed mold pieces consist of cores and a uniform shell (at least 0.5 in or 13 mm) that surrounds the mold cavity. A flange of similar thickness extends out on the parting line. The flange contains vent holes, core prints, and alignment pins. The mold pieces can be built in sections and aligned together on a blocking board (usually a plywood construction). The blocking board assembly is placed in a mold box. Standard gating forms can be positioned and foundry sand is packed around the printed parts.

Figure 4: Shell Method – ZCast components of a shell mold (left). Assembled mold with ZCast components packed in foundry sand. Note that the risers, runners and sprue have been formed in the foundry sand (right).

5.2.3 Combination Method

Combining ZCast with the traditional sand casting techniques can keep the cost per prototype down to a minimum. Mold sections (cores in particular) are made in ZCast while the rest of the mold is made conventionally. In the combination method, foundry sand is packed around a pattern. The pattern can be machined from a variety of materials or the pattern can be printed on a Z Corp. 3D Printer. If printed, the patterns would be made with one of the Z Corp. plaster based materials (zp100 series), infiltrated with an epoxy and mounted to a board. A zp100 series pattern can be used multiple times.

This method requires an intimate understanding of the design of conventional sand molds. ZCast mold components used in the Combination method are subject to most of the same restrictions that apply to conventional mold components. The advantage to using ZCast in this case is that cores and inserts can be made without any special tooling (e.g. core boxes) that would lengthen the time to produce the first casting.

A further enhancement of the sand casting process applies to both the Shell Cast and Combination methods. One can fabricate conventional patterns using Z Corp. materials; most preferably with zp100-series plaster-based materials as shown below[1].

CAUTION **Use only ZCast 501 material for the mold sections and cores for the Combination Method casting technique. Other mold materials can unexpectedly release molten metal and cause personal injury during metal casting.**

[1] For step-by-step guide on this topic, contact your Z Corp. account representative.

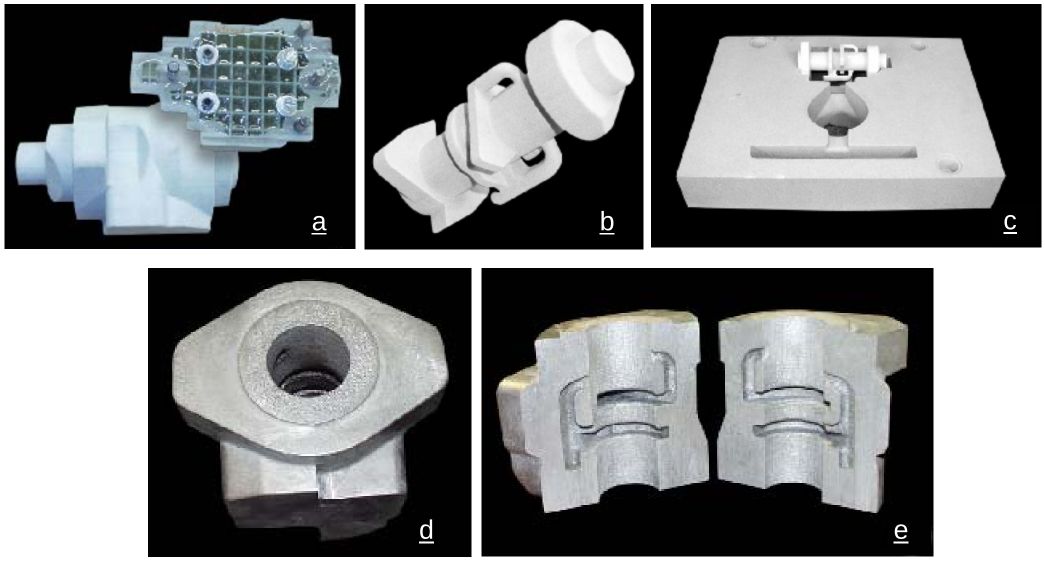


Figure 5: Combination Method – a) zp102 patterns infiltrated and backed with epoxy; b) ZCast 501 core; c) traditional foundry sand mold half with ZCast core; d) and e) finished casting.

5.3 Designing Molds in your CAD System

Regardless of the method you select, it is likely that some CAD work will be required. It is necessary to create the most accurate representation of your design digitally, as it will be represented by a 3D print.

5.3.1 Direct Pour Method

Before addressing the mold design specifics, we will consider the basic steps of designing a mold using a standard CAD package.

Most middle to high-end CAD packages such as Pro/E, SolidWorks, Catia, Unigraphics, and Autodesk Inventor, etc. as well as some tooling packages such as Magics Tooling will contain the tools you need to create a mold. These are the steps required to design a mold:

1. Import part data. It is advantageous to use native files. If it is not possible, next best would be an IGES or STEP file. If neither choice is available an .STL (sterolithography slice file) would be suitable with a package like Magics RP. Processing tends to be much slower when working with .STL files.
2. Add finish stock to machined surfaces, typically 0.080 in (2mm).
3. Apply shrinkage factors based on material to be cast and part geometry.
4. Define and divide out cores, using surfaces generated within the model.
5. Add core prints to the cores.
6. Design the gating system as a positive component around the part to be cast.
7. Encapsulate the part and gating within a larger form (typically a rectangular block). Subtract the casting and gating and core prints away from the larger block, leaving the mold cavity.
8. Generate a parting surface and split the mold block.

9. Add mating features to help align the mold components. These can be simple holes pegged with dowel pins, or mating positive and negative features built into the model.
10. Add venting to the mold cavity and to the cores.
11. Add flanges or seats for prefabricated pouring cups (if utilized – direct pour only).
12. (optional) Lighten mold pieces by cutting out material from heavy mold sections (direct pour only), or shell the entire mold to approximately 0.5 to 0.75 in (13 to 19mm) (Shell method only).
13. Add mating surface offsets to facilitate assembly of components.
14. Divide the mold components into sections suitable enough to print in your Z Corp. 3D Printer (Typically Shell method only).

WARNING **Inadequate venting in the mold or core can lead to the unexpected release of entrapped gases and molten metal causing personal injury during metal casting. Venting paths in the mold must be arranged and directed away from the metal path to avoid entrapment of gases.**

5.3.2 Shell Method

If you plan to use the Shell method you will need to:

1. Begin with steps one through five from the Direct Pour method.
2. Divide out the core geometry (if a core or cores exist in your design) and add core prints
3. Isolate the casting surfaces of your part to be cast and divide it into desired number of sections.
4. Shell each of the resulting open surface sections.
5. Design gating system on a separate conventional pattern.
6. Incorporate alignment features into shell and patterns.
7. Incorporate locking features so that shells are firmly held into place by foundry sand.

5.3.3 Combination Method

The combination method is slightly more process oriented and is not represented in the context of this document. Users familiar with the conventional sand casting process that incorporates the use of a pattern will find this technique to be desirable using ZCast. The primary advantage of the Combination method is that a significant number of components can be manufactured using this technique. A tutorial can be provided upon request to your Z Corp. account representative.

5.4 Printing Your Model

Setting up your build using ZCast is the same as using other Z Corp. powders. Use the ZPrint™ software to optimize placement of your parts to be printed. Be mindful that round objects are stronger printed in the X-Y plane. Use the '**Make Fixture'** option (under the Edit menu) to support overhanging features. ZCast powder is denser than the zp10, zp100 and zp200 series products and therefore requires **no tamping**.

5.5 Conclusion

In summary, whichever method you choose to implement, the basic steps remain the same when using ZCast powder as shown in Figure 5a.

Figure 5: Steps involved in using ZCast powder

6 Design Techniques with ZCast Patterns

6.1 Direct Gating

Conventional methods of runner design are based on having a flat pattern that must be drawn out of a sand mold. This forces the runners and gates out sideways resulting in a mold that covers a larger area. Such a design can exceed the size of the build volume of the 3D Printer. Consider bypassing the runner system entirely by gating the sprue and risers. This allows for a simple, compact design which can easily be printed.

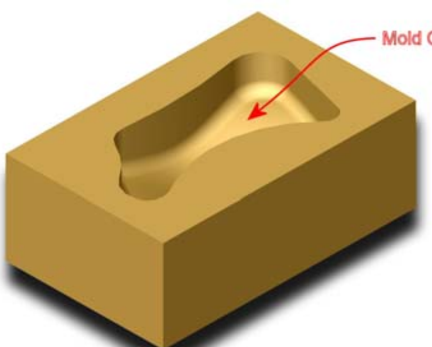
6.2 Mold Parts Larger Than Build Volume

It is quite possible that your mold will exceed the size of the build volume of your Z Corp. Printer. Multiple sections of the mold can be printed and assembled separately. Use core paste between the shell seams to ‘bridge’ the shell section together. Clamp the mold halves together with dowel pins for alignment.

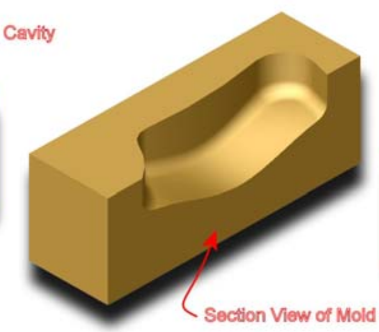
WARNING **Do not cast molten metal in molds with multiple sections without using core paste or adhesive. Molten metal can leak from the mold and cause personal injury.**

6.3 Shelling your Mold

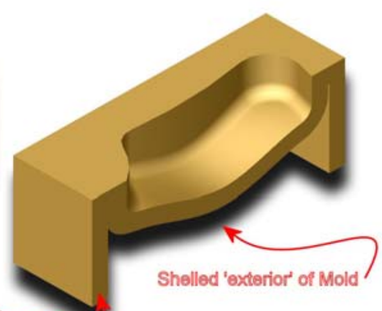
As will be discussed in the ‘Mold Preparation’ section, baking is a requirement for all ZCast molds. To ensure thorough baking throughout the entire mold, hollow out the backside of your mold for better performance. Take the following example: Figure 6a illustrates a mold cavity surrounded by a solid mass of ZCast material. Figure 6b shows the same mold with a section passing through it for clarity. With a thick section of ZCast powder, it becomes difficult for the heat to penetrate the depths at uniform levels. Figure 6c illustrates the same mold with a section view. This is the optimal situation. With uniformity to the walls throughout, it is easier for the heat to thoroughly disperse throughout the mold.



Figures 6a: Unshelled solid



Figures 6b: Unshelled section view



Figures 6c: Shelled section view

WARNING **Unshelled molds may not bake thoroughly to remove all residual moisture. Residual mold moisture after baking when contacted with molten metal can cause the unexpected release of molten metal from the mold and personal injury.**

6.4 Stiffening Ribs

Increase the strength of your mold with the addition of stiffening ribs. You can use the **Make Fixture**[2] functionality in the ZPrint software, or you can create a rib lattice in your CAD system of choice. In either case, rib thickness should be roughly one half inch (0.5 in or 13 mm) in thickness. Rib spacing is subjective. However, as a guideline, distances greater than four (4) inches (102 mm) should not be spanned without placing a rib in between walls or adjacent ribs.

NOTICE **Spacing ribs more than four inches is not recommended because of possible part deformation during the molten metal process.**

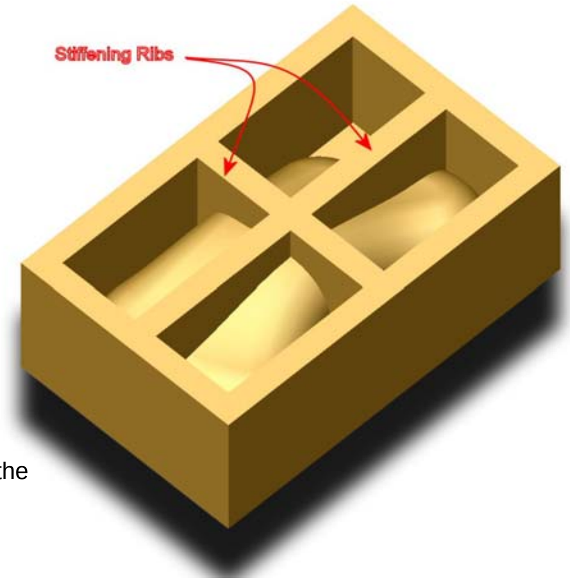
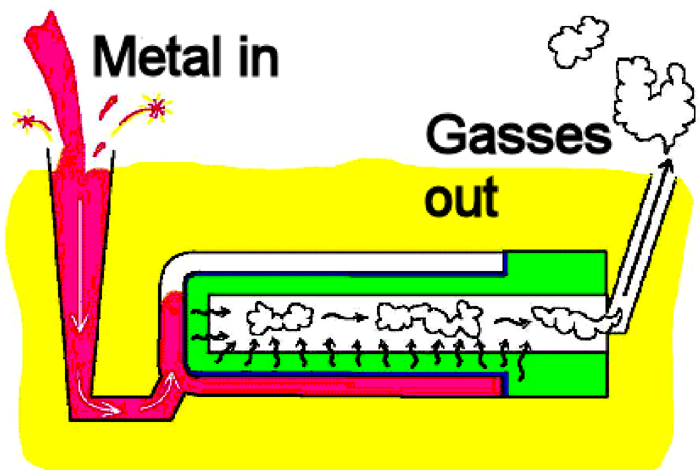


Figure 7: Addition of stiffening ribs printed in the shelled mold

6.5 Venting



Perhaps the most important concept in ZCast mold design is venting. The mold must be properly vented to avoid entrapping gases in the cast part, and more importantly, to avoid violent release of gases through the molten metal. For those familiar with traditional sand casting, it will be observed that a ZCast mold (even when properly vented) may smoke more than conventional foundry sands.

Vents can be small holes (usually at high points in the casting) extending through the cope to the atmosphere. These are often small enough (0.125 in or 3 mm is recommended) to freeze off before the metal reaches the exterior of the mold.

Vents also must be used in cores (Figure 9). When molten metal comes in contact with ZCast compounds, out-gassing occurs. If the cores are solid, the gas would have nowhere to go but

[2] For more detail, attend online ZCast Design Guide seminar or refer to the ZPrint software help section

into the metal. When gas passes through the metal as it cools, it can be trapped, forming pockets called porosity. To avoid this, the cores can be hollowed with the hollow sections vented through the core print to the outside of the mold. It is important to keep the venting path away from the metal path.

WARNING **Inadequate venting in the mold or core can lead to the unexpected release of entrapped gases and molten metal causing personal injury during metal casting. Venting paths in the mold must be arranged and directed away from the metal path to avoid entrapment of gases.**

WARNING **Do not handle molten metal without adequate local exhaust ventilation. Hot gases emitted by during the casting process can burn skin and are irritating and toxic. Refer to the ZCast 501 powder MSDS for more information.**

6.5.1 Venting Cores

Follow these guidelines to obtain best results when designing vents for your cores:

- The cores should be shelled in by approximately 0.25 in (6.35 mm) wall thickness where possible.
- Any single wall of the core should be no thicker than 0.5 in (13 mm), or thinner than 0.14 in (3.5 mm). Very slender cores with thinner walls are possible over short lengths, distortion will limit how long they can be.
- The core vents should continue through the mold walls and out to the atmosphere. This should typically be done through the core print, as far away from the parting lines as possible (to limit the possibility of metal leakage).

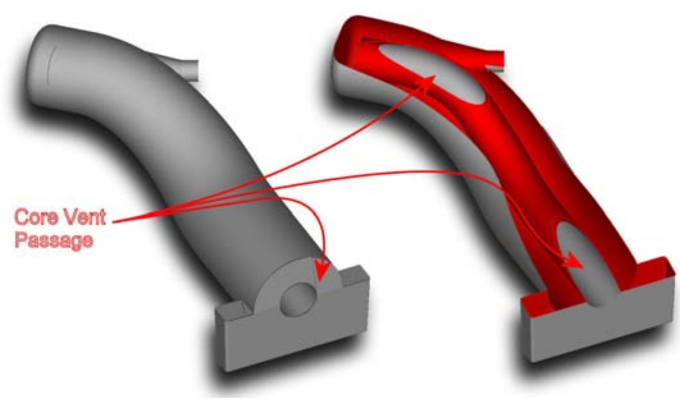


Figure 9: Venting the core

CAUTION **Vents not located in the core, vents too close to parting lines, or vents that break through to the casting surface may leak molten metal and cause personal injury. Locate vents in the core, away from the casting surface, and as far as possible from parting lines.**

- Depowdering heavily contoured core vents can be a challenge if 0.12 in (3 mm) diameter vents curve into a tight radius.

6.5.2 Venting the Mold

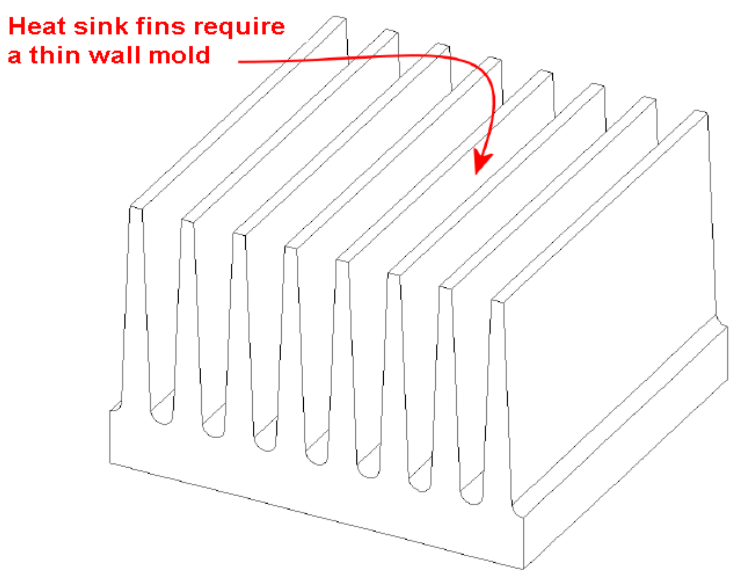
Vented molds facilitate the safe passage of gas generated as a result of molten metal coming into direct contact with the ZCast material. The design and adequacy of the mold vents is a contributing factor that strongly influences whether quality castings are made or the mold possibly fails releasing molten metal. Therefore, when designing mold vents, careful consideration is placed on their overall design, capacity, placement, and number. Here are the more common vent design issues a mold designer must consider:

- Large Surface-Area-To-Volume Ratios - As depicted in the example below, closely spaced, thin walled mold geometries can lead to gas entrapment, because there is a large area of interaction between the molten metal and the resins in the ZCast powder. In some situations, such geometric conditions can impede proper ventilation. Mold geometries with thin walls, such as those used to cast heat sinks, illustrate this issue well. They require careful design and placement of vents to prevent unexpected mold failure and yield quality castings.

- Excessive mold wall thickness can prevent adequate curing of the binder resins during the mold baking process. Inadequately baked molds, when in contact with molten metal, will create excessive quantities of gas and an increased possibility of unexpected mold failure during casting.

- Poor ventilation can cause the entrapment of gas during the pouring process resulting in the unexpected release of molten metal through the gating system.

- Gas entrapment within the mold cavity walls will result in an infiltration of gas in the molten metal. This entrapment will show up in the solidified casting resulting in porosity – a quality control issue.



Suggested Solutions:

- For the majority of the molds, there should be least a 0.5 in (13 mm) wall thickness between the metal and the outside of the mold.

CAUTION **Mold wall thicknesses of less than 0.5 inches (13 mm) may allow molten metal to leak from the mold unexpectedly and cause personal injury. Design molds to ensure at least 0.5 inches (13 mm) mold wall thickness.**

- Around areas of the casting where low porosity is important, or near thick sections in the casting, there should be vents for gases to escape.

WARNING **Insufficient venting of thick mold sections can result in the unexpected release of molten metal and personal injury during metal casting. Design molds with adequate venting capacity and proper location.**

- Vents should be approximately 0.125 in (3.2 mm) in diameter and open to the atmosphere. The lower limit of vent diameter is 2-3 mm, determined by depowderability.

- Vents **DO NOT** need to break through to the casting surface. If they pass to within 0.1 in to 0.2 in (2.5 to 5 mm) from the casting surface, the gas generated inside should permeate through except in extreme cases.

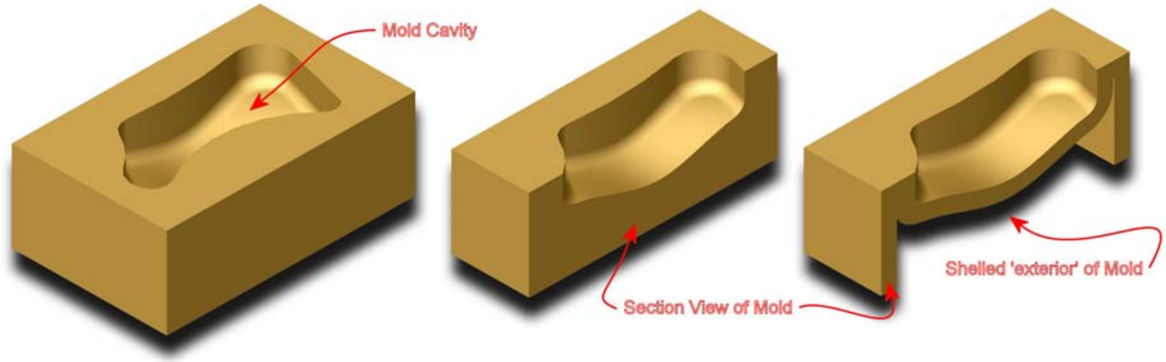
CAUTION **Vents not located in the core, vents too close to parting lines, or vents that break through to the casting surface may leak molten metal and cause personal injury. Locate vents in the core, away from the casting surface, and as far as possible from parting lines.**

- Insert vents vertically where possible, opening in the cope. Bringing the vents close to the casting surface runs the risk that the metal will break through, so limiting their openings to the upper surface of the cope limits the risk of leaking metal.

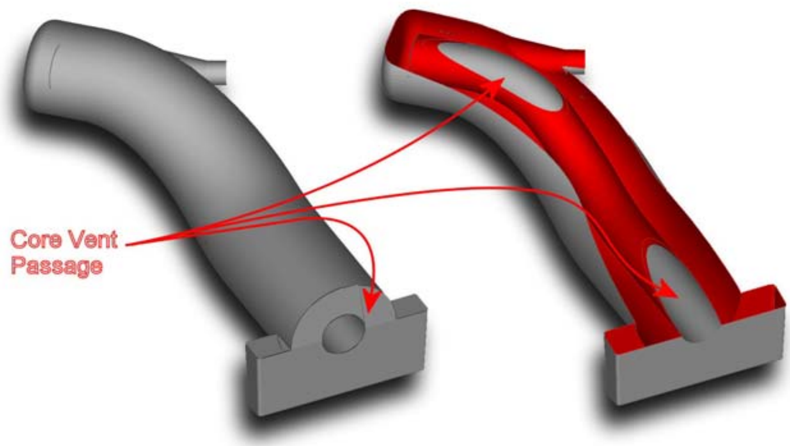
CAUTION **Vents not located in the cope may unexpectedly leak molten metal and cause personal injury.**

- Mold vents may be designed into the mold and printed or they may be drilled in after printing. Modifications like these, and the tooling to perform them, are commonplace in traditional sand casting foundries. It may be the choice of an experienced foundryman to vent a mold in this manner.

- Make sure that geometries are properly shelled. Almost all molds are capable of having ‘sacrificial’ outer surfaces that can be removed to allow for even baking and proper gas dispersion during the pouring process (see below).



- Make certain that if the mold has a core that the core is properly vented to the atmosphere to allow unimpeded release of gas.

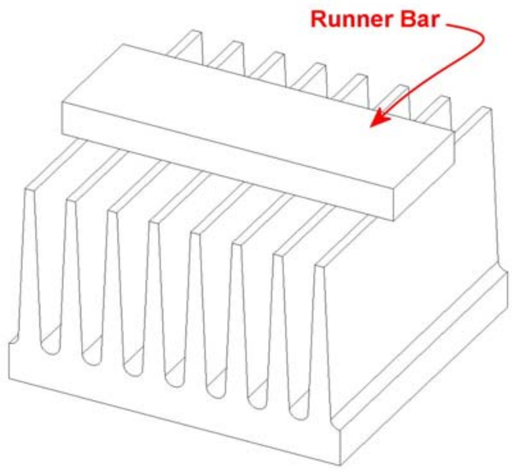


- For situations where large surface area to volume ratio geometries are present (i.e., thin wall mold geometries), skillfully design vents so that gas can readily escape from the large surface area. It is worth noting that these molds are the most challenging geometries for ZCast because the user must ensure adequate mold ventilation while also ensuring mold strength with thin wall geometry.

WARNING

Thin mold geometries can prevent proper mold ventilation during molten metal casting leading to the unexpected release of entrapped gases and molten metal causing personal injury. Design vents to avoid gas entrapment in thin mold geometries. Ensure venting paths in the mold are arranged and directed away from the metal path to avoid entrapment of gases.

- Creating a runner bar, for example, across the heat sink fins would help to facilitate proper filling; however mold vents must still be provided for adequate exhausting of any gas.



6.6 Parting Lines

The process for creating a mold in CAD software typically involves taking an object (the casting) and subtracting it from a larger, encompassing object (the mold). The mold must then be split along a generated surface or a plane. Traditionally, the parting line is very carefully chosen to create a pair of patterns to form the cope and drag without undercuts, and minimize the number of cores necessary.

Since ZCast molds are printed using the 3D printing process, the choice of a parting line becomes a much less demanding chore. The parting line can theoretically cut through any portion of the mold cavity without regard for undercuts. Below is a list of the few things to consider when choosing a parting line:

- *Avoid thin edges* – thin edges can break easily: during either handling or pouring.

- *Keep cores intact* – splitting cores will leave flash where the parting line passes through resulting in metal fouling the core vent.

- *Cores can sometimes be incorporated directly into either mold half* - these 'internal cores' possess the benefit that they are always aligned and that no requirement exists that venting pass through a parting surface.

- *Position parting line where flash can be tolerated and/or ground off* – putting the parting line across a complex region without room to grind will limit the possibilities of finishing the part.

- *Keep parting line as far away as possible from core vents* – since some metal can leak along the parting line, be careful that it does not reach the openings for core vents. Metal will potentially leak out of the mold and into the core, preventing the vent from performing its function.

- *Minimize the number of jogs* – keep the design as simple as possible. The more angles and steps in the parting line, the more difficult it will be to assemble the mold accurately.

CAUTION **Parting lines near core vents may leak molten metal into the vents. The vents may not function properly and cause the unexpected release of molten metal and personal injury.**

6.7 Depowderability – Fixed vs. Removable Cores

Part depowdering refers to the removal of loose, unprinted powder from the mold cavities following the printing process. While the possibility to print complex geometries exists, such as undercuts and runners that tunnel under the mold cavity, the risk remains that all of the powder may not be removable during depowdering. Loose powder left in the mold when metal is poured has the possibility of affecting the outcome of the finished casting by creating pockets or voids.

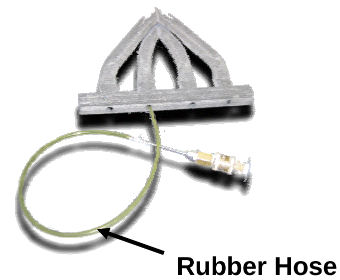


Figure 10: Attach a **flexible plastic** hose like the one shown above to reach 'blind spots'

In order to avoid the aforementioned, ensure that your mold has undergone a thorough removal of powder. In difficult to reach areas such as blind channels and areas not visible, use a small flexible hose like the one shown in Figure 10 to extract loose powder.

A 1/8 in (3.2 mm) O.D. and 1/16 in (1.6 mm) I.D. urethane tube is ideal because it slides firmly over the nozzle on the ZD4 or ZD8 depowdering units.

CAUTION **Loose powder left in molds may create pockets, voids or block vents during metal casting resulting in the unexpected release of molten metal. Ensure that all loose powder is removed before casting.**

CAUTION **Depowdering with compressed air will generate airborne particles. Only trained or supervised individuals should depowder a mold. Use hood ventilation and safety goggles or faceshield to protect the eyes and face. Refer to the ZCast 501 powder MSDS for more information.**

6.8 Mating Surfaces

The mating surfaces of the mold should be offset to accommodate for surface imperfections. *A total gap of 0.02 in (0.51 mm) should be created, in the model, at all mating surfaces.* The offset can be created on either side of the parting surface or split between them.

Even with an intentional gap, there will likely be some portion of the mold or core that rubs against another part when the mold is assembled. When one ZCast object rubs against another ZCast object, they essentially sand each other down, leaving a little bit of loose sand. Since this is bound to happen, you should prepare for this by leaving room between cores and core prints, and, where possible, at junctions on the parting line, taking care not to extend this gap into the path of metal. Add a small

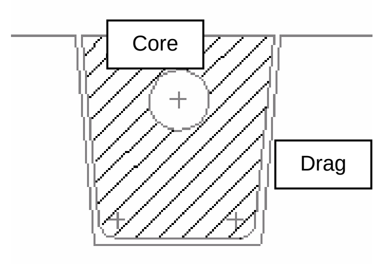


Figure 11: Tapered core and core print. Core has radiused bottom edge. Add offset between mating surfaces.

radius to the bottom edges of core prints where they sit in the cope or drag; this provides space for loose powder to collect safely away from metal flow.

A foundry will typically seal parting surfaces with core paste. A bead of this material is placed around the outer edges of the mating surfaces of the mold and across the core prints to prevent leakage.

6.9 Geometry Guidelines

For the majority of metals that can be poured in ZCast 501 molds, the following are the geometric limitations:

- Minimum core size – 0.14 to 0.16 in (3.5 to 4.0 mm); some distortion will occur if small cores project across large distances.
- Minimum cast feature size (positive feature) – 0.12 in (3.0 mm); thinner ribs have been cast but there are limits on how far the feature can extend.
- Volume – no tested limit. Size limitations are related to build size. However, molds can also be built in sections and assembled to make much larger molds.
- Closed/nearly closed volumes – if the core does not have enough body at the core print to support itself (for example, the core of a two liter soda bottle – very narrow neck with respect to the size of the core), then the core may break in the mold. If the core narrows down at the core print so that the bulk of the core cannot be vented, then there is risk of high porosity in the casting.

6.10 Wall Thickness Guidelines

As indicated in the section 6.3 'Shelling Your Mold', thinner sections bake quicker and more efficiently. Maintain the following guidelines for modeling your mold with thin walls:

- Any mold wall that is in contact with metal should be no less then 0.5 in (13 mm) thick, and no more than 1 in (25.4 mm) thick (with exceptions below).
- The mold should be able to sit square on a base for pouring.
- Ribs should be added where necessary to provide rigidity (typically in the drag, where a supporting surface is being built up). Ribs should be about 0.5 in (13 mm) thick.
- Maintain large enough areas for clamping.
- Use "off the shelf" pouring cups and risers

CAUTION **Mold wall thicknesses of less than 0.5 inches (13 mm) may allow molten metal to leak from the mold unexpectedly and cause personal injury. Design molds to ensure at least 0.5 inches (13 mm) mold wall thickness.**

6.11 Pouring Sleeves & Risers

A pouring sleeve is a tapered cylinder made of a refractory material with a ceramic filter at the base. The filter is removable, so the pouring cup can be used as a riser as well. There is no requirement to use sleeves, but the convenience is an advantage.

Pouring sleeves are inexpensive, come in several sizes, have a variety of filters available, and work well with ZCast molds. A conical seat should be printed in the mold to accommodate and position the sleeve. The sleeves should be attached to the ZCast mold with a foundry adhesive or core paste. For safe measure, they can be clamped or wired in place to prevent shifting during pouring.

Additionally, you can design a pouring sleeve to be integrated as part of your ZCast mold. Be sure to make allowances for filter insertion to help alleviate impurities when pouring.

CAUTION **Pouring sleeves attached to the ZCast mold with core paste may shift while pouring molten metal into the mold. Leaking of molten metal may cause personal injury. Attach sleeves with clamps and securing wires as needed.**

6.12 Chills

Chills will be familiar to experienced foundrymen. The purpose of a chill is to help rapidly solidify the molten metal in a portion of a casting. Controlling the solidification rate in this manner helps to control the grain structure; keeping a tight, fine structure. The result is a sound casting with a uniform distribution of the alloying elements.

Chills can be used in ZCast molds in much the same way they are used in traditional sand casting. While they can be complicated, externally cooled components, they are often as simple as steel or iron blocks which can be inserted into cavities designed (or cut) into a ZCast mold.

6.13 Printing

For general printing techniques, you should refer to the User Manual for your 3D Printer and the ZPrint System Software Manual.

- When choosing your powder type (in “3D Print Setup”), simply select ZCast 501 from the powder list (it will show up on the list for any printer that is capable to use the powder system with the proper upgrade). The proper settings for saturation, layer thickness and scaling factors are already set for you.

- Using “Bleed Compensation” is recommended. This will improve the accuracy so parts will fit together better[3].

- Orient parts so that the most critical faces are facing up in the build. For example, when possible, put the outside of the mold components (non-molding surfaces) facing down in the build. Under certain conditions, a slight arching[4] effect can occur on the bottom surfaces in the build.

- When cores are being printed, you may choose to build a fixture underneath it. This will improve the accuracy for critical fit items. Refer to the ZPrint Manual for instructions on using fixtures.

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[3] See Table 1

[4] Arching is a concavity phenomenon that occurs as moisture evaporates from the first few layers of a part that has been printed.

- For mating parts (such as a cope and drag of the same mold), try to always print them in the same orientation in the build.

6.13.1 Machine Settings

Use the following optimized print settings for printing ZCast 501 powder with zb®56 binder:

Saturation Settings

Shell	1.2
Core	0.3
Layer Thickness	0.005”

Bleed Compensation Settings

	ZPrinter® 310	Z®406	Z®810
X	0.016	0.019	0.014
Y	0.015	0.019	0.014
Z	0.010	0.016	0.012

Table 1

6.14 Degassing and Filtering Metal

Figure 12: Refractory sleeves and filters

To help achieve improved part quality, steps should be taken to properly prepare the metal for pouring. Two typical foundry practices are degassing and filtering. When properly taken, these steps help to yield quality parts in any foundry.

Filters can be added directly to the mold. This can be accomplished by strategically locating filters within the drag assembly as shown in Figure 13. Design slots or shelves in the drag for filter placement. Other options include using foundry consumables with ceramic inserts as shown in Figure 12.

Accumulated slag on the top of the crucible should be removed prior to pouring.

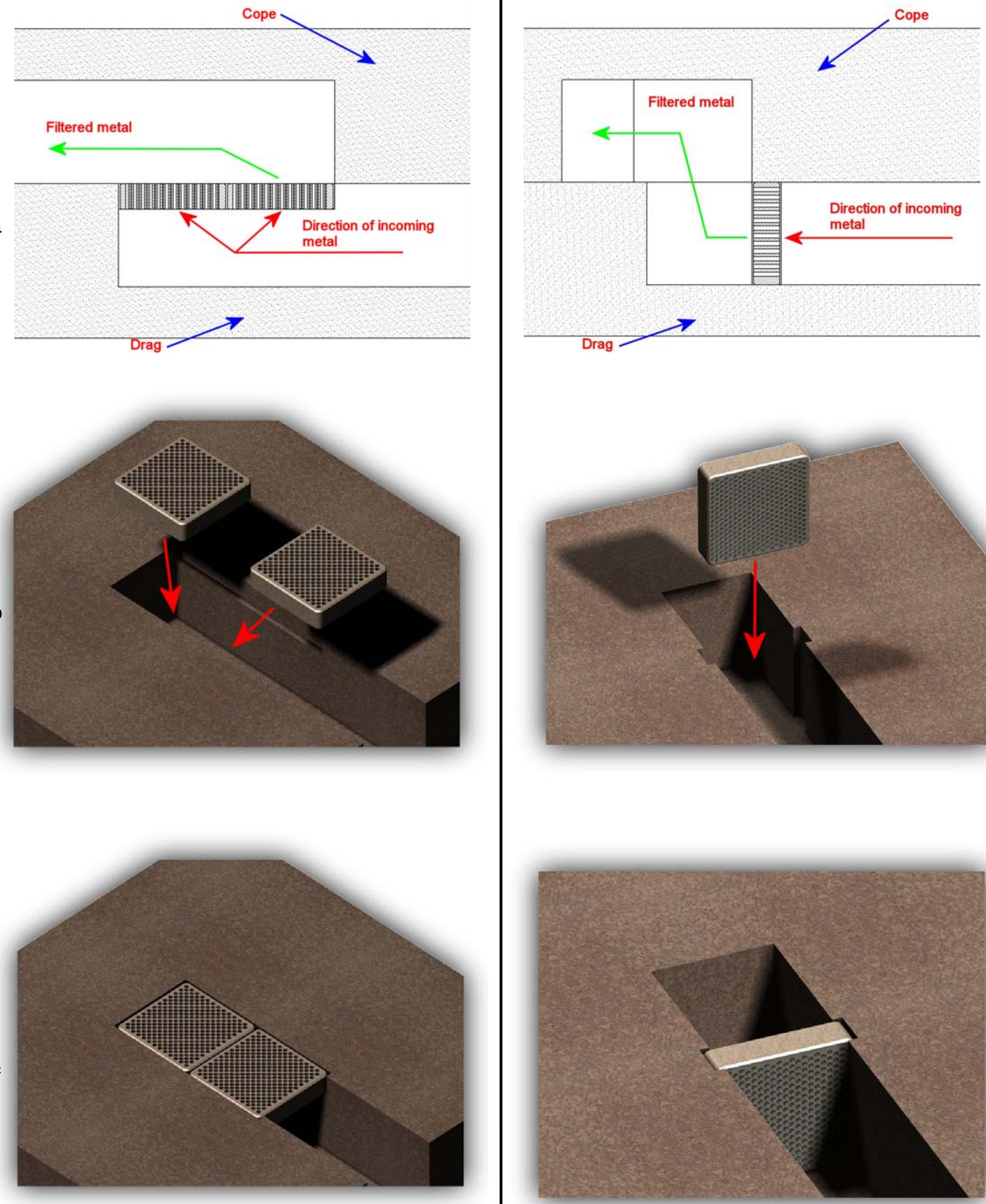

Figure 13: a,b,c: Horizontal filter orientation – Metal rises up through filters (maximum are achieved with horizontal placement.
d,e,f: Vertical filter orientation

7 Mold Preparation

After the mold is designed and printed in a Z Corp. 3D Printer, there are only a few necessary steps before you are ready to pour metal:

Mold Wash – Mold wash is used in traditional sand casting to improve the surface finish of the castings. It is typically a suspension of silica or other refractory materials, which can be sprayed, brushed or used as a dip to coat the surface of the mold and cores. It can improve the surface finish of a part to between 60 and 120 RMS. It should be used with caution. The surface can be built up too much causing unevenness and flaking. Follow the mold wash manufacturer's instructions regarding the drying requirements for such products.

Bake – **MOLDS MUST BE BAKED PRIOR TO POURING.** A ZCast mold in its untreated (raw) state contains about 10% moisture per unit weight. Casting molten metal against untreated material releases large amounts of steam and smoke. To use the ZCast mold properly, it **MUST** be baked in an oven from 350°F (180°C) to 400°F (230°C) for between 4 and 8 hours (depending on volume), until it is "bone" dry, and preferably medium-brown in color on all cavity surfaces that contact molten metal. **THERE WILL BE SMOKE GENERATED WHEN BAKING ZCAST MOLDS; THEREFORE, THE OVEN MUST BE PROPERLY VENTED.**

CAUTION **Bake ZCast molds until all moisture is removed before metal casting. Residual moisture in the mold can cause the mold to unexpectedly fail, releasing entrapped gases and molten metal and causing serious personal injury.**

CAUTION **Do not bake ZCast molds in unvented ovens. Irritating and toxic fumes are formed at elevated temperatures during oven baking. Ovens must be vented to the outside. Refer to the ZCast 501 powder MSDS for more information on the irritating and toxic fumes.**

Final Depowder – Immediately prior to pouring, gently rub the mold surface to knock off any loose material and blow dust away with compressed air.

CAUTION **Depowdering with compressed air will generate airborne particles. Only trained or supervised individuals should depowder a mold. Use hood ventilation and safety goggles or faceshield to protect the eyes and face. Refer to the ZCast 501 powder MSDS for more information.**

Seal – Run a bead of core paste around the parting surfaces to prevent metal from leaking out of the mold during pouring. Use caution not to block vents.

CAUTION **Do not cast metal parts in molds with multiple sections without core paste or adhesive. Molten metal may leak from the mold seams and cause personal injury. Avoid blocking vents with paste or adhesive.**

Clamp – Carefully close the mold with the cores in place. Clamp with C – clamps or similar and orient in the proper direction for pouring. Attach pouring cups and risers if necessary (use core paste to glue in place).

CAUTION **Attachment of risers and cups without core paste may result in the unexpected release of molten metal and personal injury. Always use core paste or adhesive for attachments. Additional clamps or securing wires may also be needed.**

Pour – The mold is now ready for metal.

8 Pouring Metal

8.1 Metal Types

The current product offering is ZCast 501 powder and is designed for low temperature, non-ferrous metals ***[MAX TEMP 1100°C (2000°F)]***. The higher temperature metals will cause more gassing on contact with the mold. Use of molten metals with pouring temperatures above the maximum temperature recommended for the ZCast molds can cause the mold to fail, possibly explode, and release entrapped gases and molten metal. Do not attempt to pour molten ferrous metals into ZCast 501 molds.

WARNING	**Do not use ZCast 501 molds with molten ferrous metals or other metals with pouring temperatures above 1100°C (2000°F). The molds can suddenly fail unexpectedly releasing entrapped gases and molten metal causing serious personal injury.**
WARNING	**Do not handle molten metal without heat-resistant faceshield, gloves and apron and tools suitable for handling molten metal in foundry operations.**
WARNING	**Do not handle molten metal without adequate local exhaust ventilation. Hot gases emitted during the casting process can burn skin and are irritating and toxic. Refer to the ZCast 501 powder MSDS for more information.**

Z Corp. tested and approved materials:

Alloy	Pouring Temperature(s)	Melting Temperature(s)
Aluminum 319	1250°F – 1450°F[5]	1120°F
Aluminum 356	1250°F – 1450°F[5]	1135°F
Aluminum 390	1250°F – 1450°F[5]	1156°F
Bronze Silicon	1900°F – 2150°F[6]	1880°F – 1940°F
Bronze Phosphor	1900°F – 2150°F[6]	1830°F – 1970°F
Bronze Aluminum	1900°F – 2250°F[6]	1915°F – 1930°F
Brass[5]	1900°F[6]	1850°F
Zinc	750°F – 800°F[7]	1090°F
Magnesium[8]	1400°F – 1500°F[7]	**Flammable**

WARNING: NO ATTEMPT SHOULD BE MADE TO POUR FERROUS METALS IN ZCAST 501 MOLDS

[5] ASM metals handbook, 4rth edition
[6] Heine & Rosenthal
[7] Foseco foundryman's handbook
[8] Consult Z Corporation prior to pouring

9 Material Handling

9.1 Storage

Though ZCast powder has no special storage requirements; it should be stored in a cool, dry environment. See container labels for additional information.

9.2 Disposal

ZCast powder is a non-toxic substance. Please consult the Material Data Safety Sheet for product details. Dispose of ZCast powder according to local and state regulations.

9.3 Powder Recycling

Unprinted ZCast material can be recycled. Z Corp. recommends that you add new powder with recycled powder to maintain powder consistency.

10 Finishing

10.1 De-molding

Removing a casting from a ZCast mold is virtually identical in process to the removal of a casting from a traditional chemically set sand mold. After cooling and solidifying, the mold can be unclamped and broken apart. Breaking a mold can usually be done with a hammer or other blunt object. Once the majority of the mold material has been broken off, the cores and detailed sections can be cleaned out with a high-pressure water jet or by simply breaking them apart with a tool (a simple screwdriver will work well). All sand casting foundries will be set up with the means to remove ZCast material from a finished casting.

Figure 14: Despatch baking ovens offered through Z Corporation

	CAUTION	**Breaking molds with a hammer or high-pressure water jet releases airborne objects and may cause personal injury. Wear eye, face and hand protection while breaking molds.**

10.2 Secondary Operations

Castings will often need secondary operations, all of which are *identical* in process to traditionally cast parts. At the very least, the material formed in the gating system will need to cut off. The flashing will probably need to be ground off. Machining may need to be done on critical surfaces (remember to add machining stock (typically around 0.080 in (2 mm)). Holes may need to be drilled out and tapped. The surface may be bead blasted or sand blasted. Castings may be heat-treated.

	CAUTION	**Drill, cutting or grinding cast parts releases airborne objects and dusts and may cause personal injury. Wear eye and face protection while performing these tasks.**

10.3 Ovens

You can bake your parts in one of the ovens offered through Z Corporation, or any other oven that will reach temperatures up to 400°F. Since ZCast molds will tend to smoke when baking, it is a **requirement** to ensure that your oven is properly vented to the atmosphere. For more information about the ovens offered through Z Corp. contact your local representative or go to http://despatch.com/ on the web.

	WARNING	**Do not bake ZCast molds in unvented ovens. Irritating and toxic fumes are formed at elevated temperatures during oven baking. Ovens must be vented to the outside. Refer to the ZCast 501 powder MSDS for more information on the irritating and toxic fumes.**

11 Foundry Consumables

You can purchase foundry consumables through a wide offering of vendors. This includes items such as core wash, pouring sleeves, filters, core paste, etc.

Prominent foundry consumables that are commonly used are:

Ceramic filters – These disposable items are inserted into either the pouring sleeve, or they are often placed in the drag in a cavity in line with the runner channel.

Core paste – This liquid material is a refractory that is used to seal the mold halves together. The net result keeps liquid metal from reaching the outside of the mold, minimizing flash. Core paste can also be used to 'glue' pieces together, such as a sleeve to the mold or mold halves together.

Core wash – Use core wash to improve surface finish and reduce gassing into the mold cavity.

Graphite paint – Graphite paint is used as a non-stick coating (release) that is applied to patterns when forming a mold from a pattern.

Green sand or Pepset™ - Common foundry sand mixed with bonding agent.

Pouring sleeve – The pouring sleeves are essential to any mold design whether they are printed as part of the mold or inserted as a separate consumable. Sleeves can also double as risers and provide a reservoir to continuously feed molten metal into the mold cavity.

Companies that market these consumables into the metal casting industry include:

- **www.ashland.com**
- **www.foseco.com**
- **HA International LLC**

FOSECO ASHLAND. HA International LLC

11.1 Sand Casting Glossary

11.1.1 Cope and Drag

Molds are typically made up of two halves encapsulating the outer surfaces of the casting. The two parts are called the cope and drag; the cope being the "top" section and the drag being the "bottom." These components are traditionally formed by packing sand (typically with a chemical binder) around a machined pattern. There is often a separate machined pattern for each the cope and the drag.

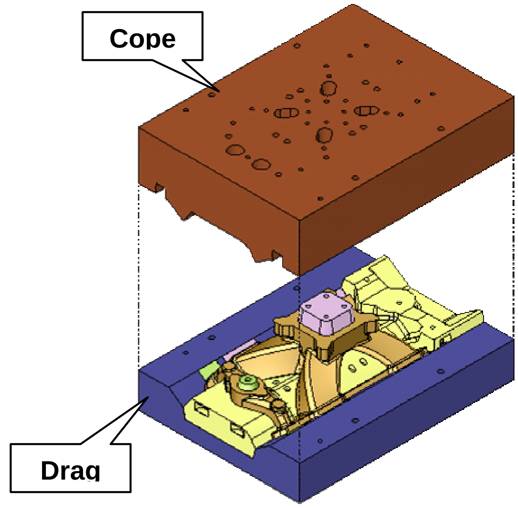

Figure 15: Cope and drag – manifold

11.1.2 Cores

Cores form the internal surfaces of a casting. In traditional sand casting, cores are also used to form features that are undercuts with respect to the parting line. The limitation in traditional casting is the pattern must be pulled out of the packed sand, and therefore must not contain undercuts in the pull direction. Some castings will not have any cores; others will need several as shown in Figure 16. The mold in Figure 15 has three separate cores.

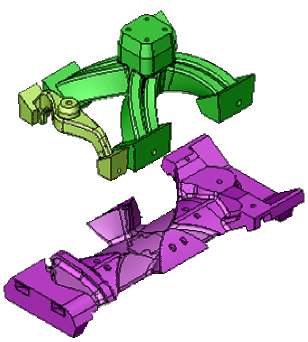

Figure 16: Cores for manifold casting

In traditional casting, for every core a tool called a core box must be made. A core box is essentially a machined mold used to form sand cores on a large scale basis. Complexity varies from simple to complex with separate cores and multiple components (Figure 17).

11.1.3 Core Prints

Core prints are simply the locations at which the core lock into the cope or drag (typically the drag). These are designed to minimize the amount of flash (metal leaking between mating surfaces) between the cores and the cope and drag. They also key into the drag, typically utilizing drafted walls to help maintain accuracy and positioning of the core in the proper location.

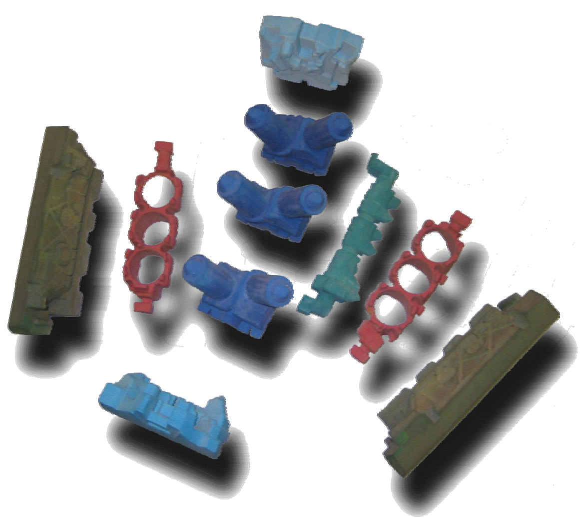

Figure 17: Multi-piece core

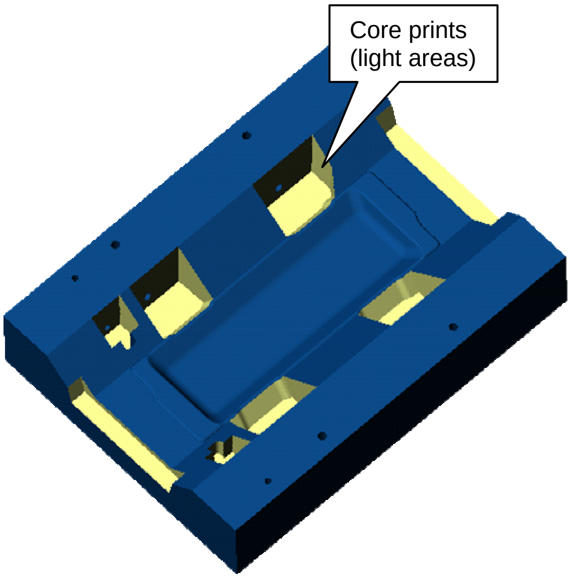

Figure 18: Core prints – pockets where cores lock in place (drag of manifold from Figure 15)

11.1.4 Pouring Cup

The pouring cup, as the name implies, is where the molten metal is poured into the mold. The pouring cup can take many different forms, each to optimize the feeding of metal into the mold and minimize the amount of turbulence produced in the metal stream.

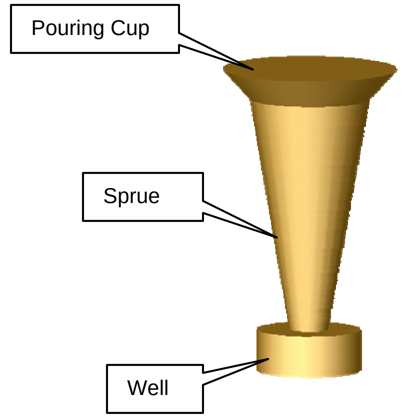

Figure 19: Pouring cup, sprue and well. The well is typically where the filter would be placed

11.1.5 Sprue

The sprue connects the pouring cup to the gating system. It is typically a conical shape tapering in as it extends through the cope and into the drag. The sprue (with the pouring cup at its top) should be the tallest component of the mold. The height is what produces the pressure needed to fill the mold with metal. The sprue should be at least 4 in (102 mm) higher than the casting.

The base of the sprue is often used as a choke to control the flow rate of metal into the mold. The diameter of this point can be derived from the geometry of the casting and the subsequent gating design.

11.1.6 Well

Just beyond the choke at the bottom of the sprue, the metal path opens up to the well. The well is typically a cylindrical opening with a diameter about 2.5 times bigger then the choke. It directs the metal to the runner system. The well often serves the dual purpose of housing a filter. Filters are usually ceramic webs or open cell sponges used to help remove some of the dross (metal oxides) and dirt from the molten metal.

11.1.7 Runners

Runners are the paths that feed metal around the mold to regions farthest from the pouring cup. Runners are usually designed to minimize the turbulence of the metal as it travels through them. Typically, they are rectangular in cross section, and again, like many other components of the gating system, the runner dimensions can be determined from the cast part's geometry. Runners also serve as additional filters. They will often run out to a dead end beyond the last ingate. It is in this dead end that dirt, debris and dross collect, while good, clean metal enters the mold.

11.1.8 Ingates

The metal enters the mold cavity through the ingates. Ingates typically feed thicker sections of the casting, which subsequently, feed thinner sections. Thick sections, where the metal will be slowest to cool, should be allowed to feed thin sections that cool more quickly and may freeze off before the entire casting is filled. Sometimes it is difficult to design a mold this way, and for this reason (among others) risers are sometimes placed between the runner and the ingate.

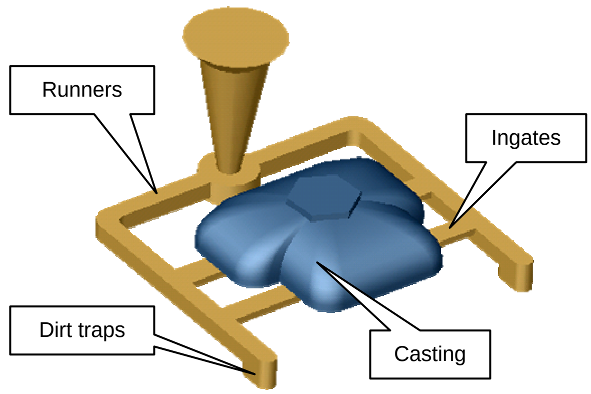

Figure 20: Runners lead out from the well. Ingates connect the runners to the casting. Runners dead end at dirt traps.

11.1.9 Risers

A riser helps to feed the casting before the whole thing solidifies, but it also helps to minimize the shrinkage in the casting by serving as a reservoir of molten metal which can continue to feed the casting as it begins to shrink. The riser is typically cylindrical and **MUST** stand as tall as the pouring cup. Failure to do so will result in a significant loss of material as the level in the pouring cup reaches equilibrium with the level at the risers.

Aluminum alloys require extensive use of risers. Often more than one half of the casting mass is in the risers!

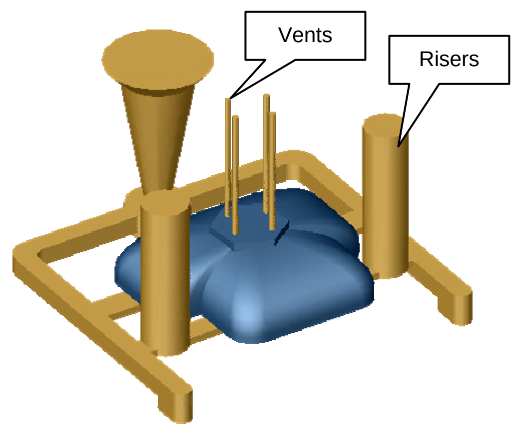

Figure 21: Risers are often placed at the ingates, but could be put anywhere. Vents are shown coming off the high points. Their diameters are small, so they will likely freeze off before they reach the upper surface of the cope.

For more on riser design see:

- Basic Principles of Gating and Risering: AFS Cast Metals Institute
- Principles of Mutual Casting: Heine & Rosenthal
- Castings: John Campbell
- ASM Mutuals Handbook, Volume 13

12 Conclusion

If you have questions about any of the information contained herein, or need additional information, please contact us at applications@zcorp.com.