ZPrinter™ 310 User Manual

Part Number 09508

Rev C, September 2003

TABLE OF CONTENTS

CHAPTER 1

OVERVIEW

THIS CHAPTER WILL GIVE YOU AN OVERVIEW OF THE PRINCIPLES BEHIND THE ZPRINTER 310 SYSTEM, FAMILIARIZE YOU WITH THE TERMINOLOGY WE WILL USE TO DESCRIBE THE SYSTEM, AND INTRODUCE YOU TO SOME OF THE FEATURES OF THIS MANUAL.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM. YOU MAY ALSO VISIT THE USER GROUP WEBSITE AT WWW.ZCORP-USERS.COM.

Manual Overview

This ZPrinter™ 310 User Manual will speed you along the path towards quickly and inexpensively building parts. We recommend that you use this manual together with service training for best results. The manual contains the following sections:

1. Introduction. This section provides an overview of the principles behind the ZPrinter 310 System, familiarizes you with the terminology we will use to describe the System, and reviews the components of the System.

2. Quick Start Guide. This section provides an overview of the steps needed to print a part.

3. Material Systems. This section instructs you on how to use ZCast™ Powder and zp®250 powder with instructions on how to prepare your printer, print and post-process the part.

4. Preparing the ZPrinter 310 to Print. This section guides you through putting powder and binder solution in the Printer, and cleaning the Service Station.

5. Printing a Part. This section takes you through preparing the build and checking parameters in the ZPrint Software before printing.

6. Post Processing. This section leads you through removing the printed parts from the build envelope, removing excess powder from the part, and infiltrating the parts to improve strength and surface finish.

7. Applications. In this section you will learn some advanced post-processing steps that will enable you to enhance the way you use the 3D Printer.

8. Maintenance. Here we review a few preventative maintenance steps, offer some tips for troubleshooting and inform you about where to go if you experience any problems with the system.

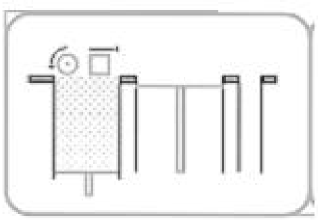
How it Works

Z Corporation 3D Printer processes are based on the Massachusetts Institute of Technology's patented 3DP™ (Three-Dimensional Printing) technology.

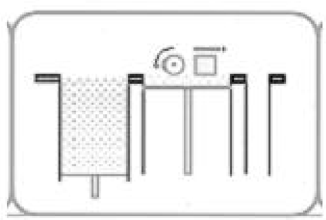
The Our proprietary ZPrint Software first converts a three-dimensional design built using 3D CAD into cross-sections or slices that can be between 0.003" – 009" (0.0762 - 0.2286 mm) thick.

The ZPrinter 310 then prints these cross-sections one after another from the bottom of the design to the top. Inside the printer there are two pistons. The *feed piston* is represented in the diagrams below on the left and is shown in the 'down' position filled with powder. The *build piston* is the piston on the right, shown below in the 'up' position. Also represented in the diagrams is the *roller* (drawn as a circle) and the *print assembly* (drawn as a square.) On the printer, the roller and the print assembly are mounted together on the *gantry* which moves horizontally across the build area.

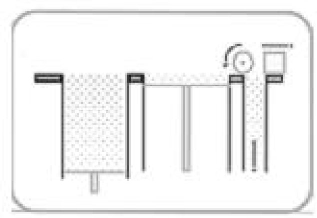
To begin the 3D printing process, the ZPrinter 310 first spreads a layer of zp® series powder in the same thickness as the cross section to be printed. The HP print head then applies a binder solution to the powder, causing the powder particles to bind to one another and to the printed cross-section one level below. The feed piston comes up and the build piston drops one layer of the thickness. The printer then spreads a new layer of powder and repeats the process, and in a short time the entire part is printed.



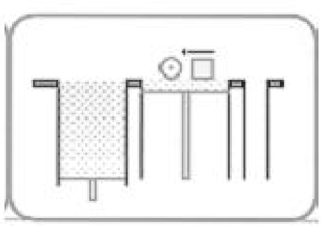
Step 1: As the gantry traverses left to right, the roller collects powder.



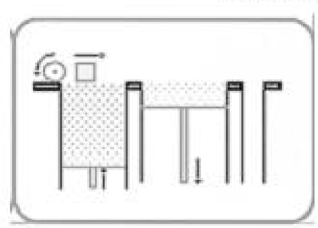
Step 2: The roller spreads a thin layer of powder over the build piston.



Step 3: The roller discharges excess powder down the powder overflow chute.

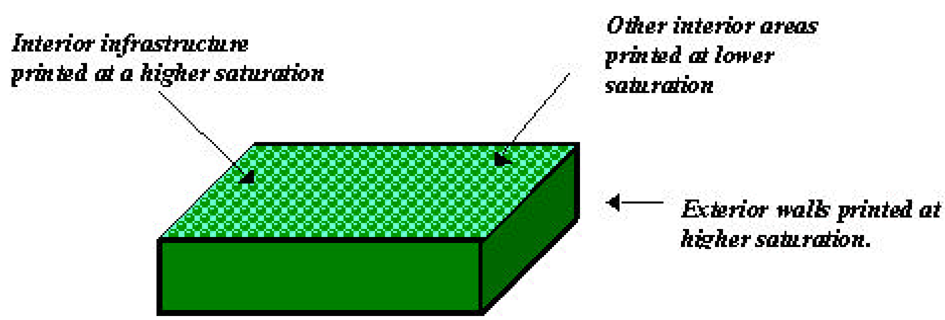


Step 4: As the gantry traverses right to left, the print assembly prints the part cross-section.



Step 5: The feed piston moves up one layer, the build piston moves down one layer, and the process is repeated.

The ZPrinter 310 employs several techniques to quickly build great 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 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 part distortion.



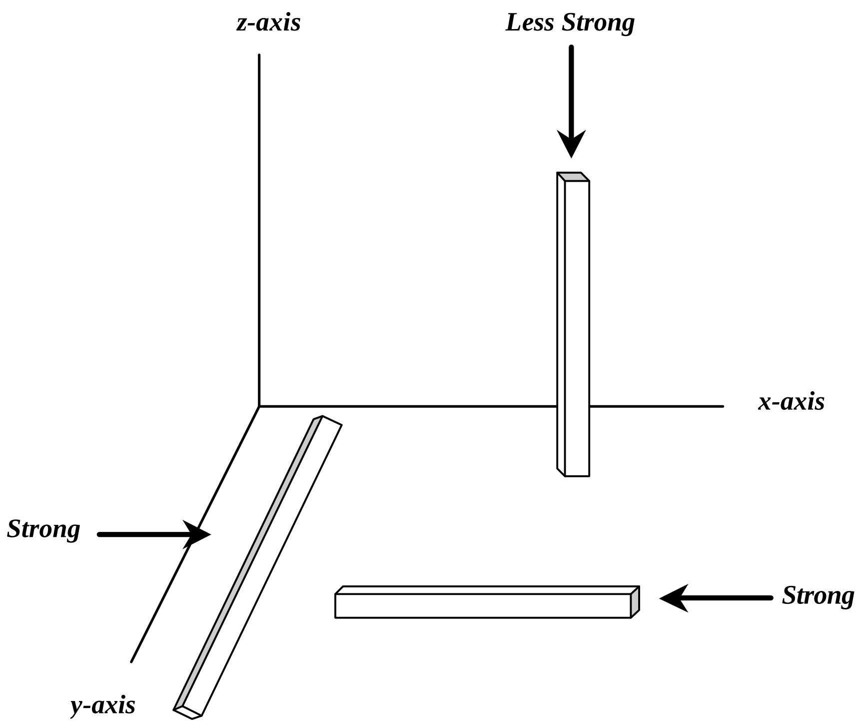
After printing, the part is removed from the powder bed, depowdered and dried. The part can then be infiltrated with wax, or other performance resins to increase strength and durability. For more information regarding infiltrants, see Chapter 6, *Post-Processing*.

Because the powder layers support the structures being printed above, the ZPrinter 310 prints parts without support structures of any kind and can print parts with complex geometries that are impossible for other systems.

There are several important characteristics of the ZPrinter 310 that will help you print the best parts for your intended purpose.

Part Placement. ZPrint Software will place the parts within the build box to maximize build speed, the most important criteria for the majority of our users. ZPrint Software positions the parts with the smallest dimension in the z (vertical) axis. In addition to part placement, however, the following other characteristics should be considered.

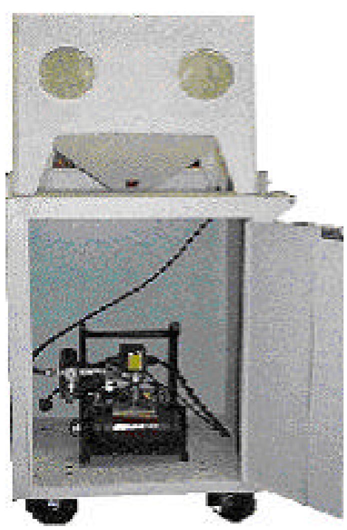
Strength. The ultimate strength of the part will be affected by its orientation within the print box. The part will be strongest along the y-axis and the x-axis and less strong along the z-axis. This is because the cross sections are printed in continuous strips along the y-axis (the binder cartridge direction of travel), bands across the x-axis (the gantry direction of travel) and laminated layers along the z-axis. This discussion only applies to untreated parts; once parts are infiltrated, they uniformly take on the strength characteristics of the infiltrating material.



Accuracy. The accuracy of the system depends on the materials you choose. You can employ the anisotropic scaling feature in the ZPrint Software to adjust for expected shrinkage and bring your parts into true scale. More information on anisotropic scaling factors is found in Chapter 4, *Preparing the 3D Printer*.

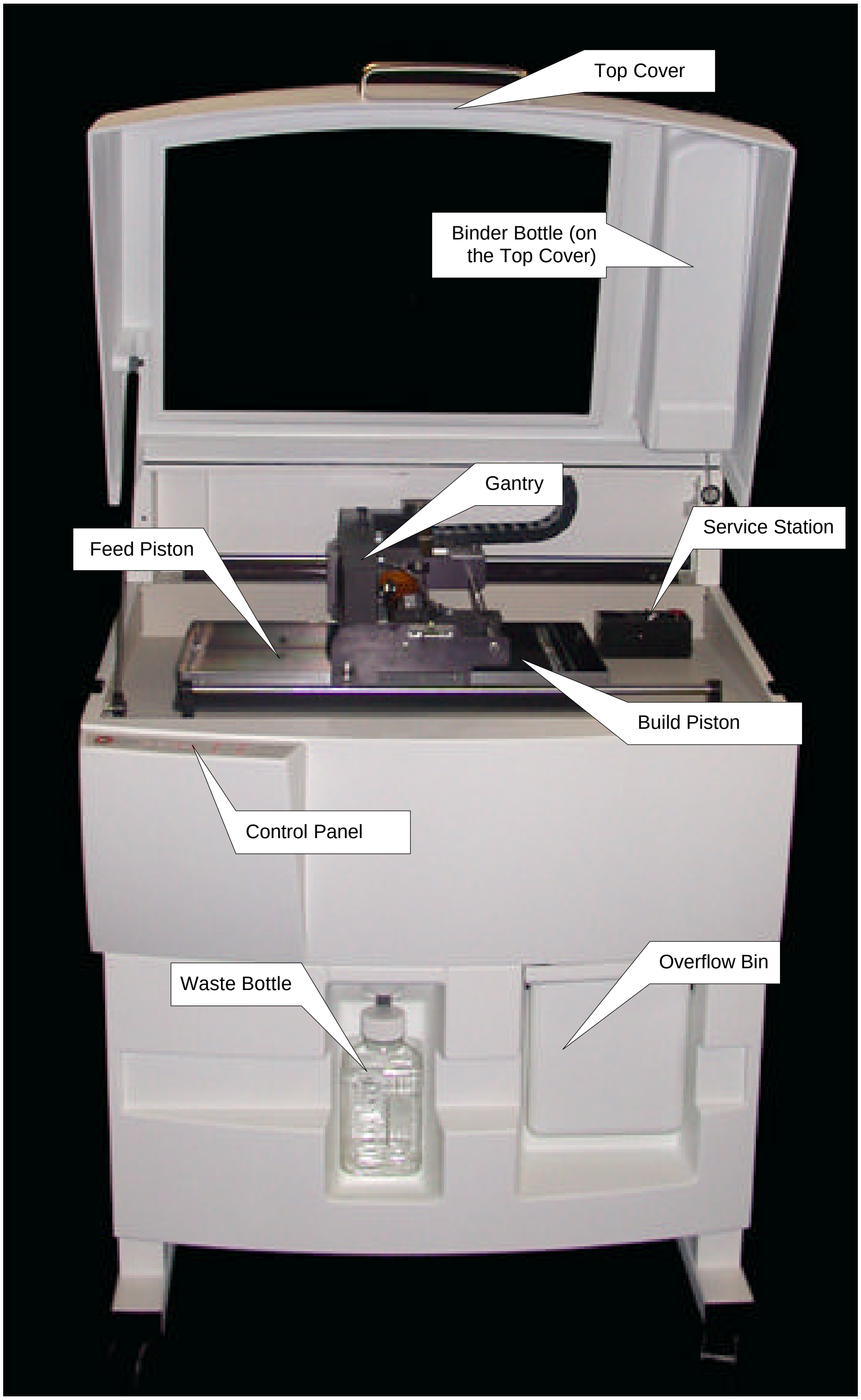
System Components

ZPrinter 310 System

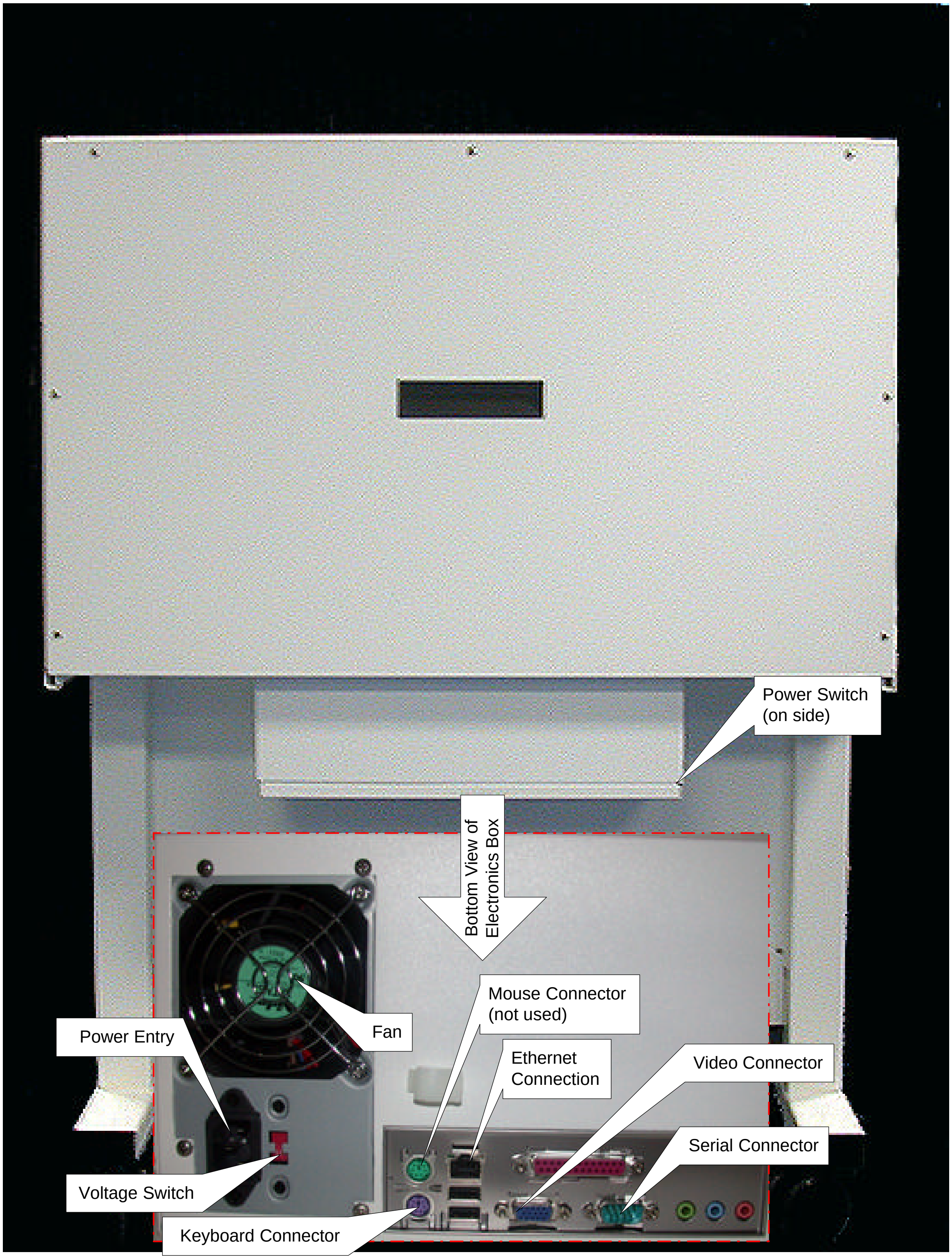


ZD4i Depowdering Station

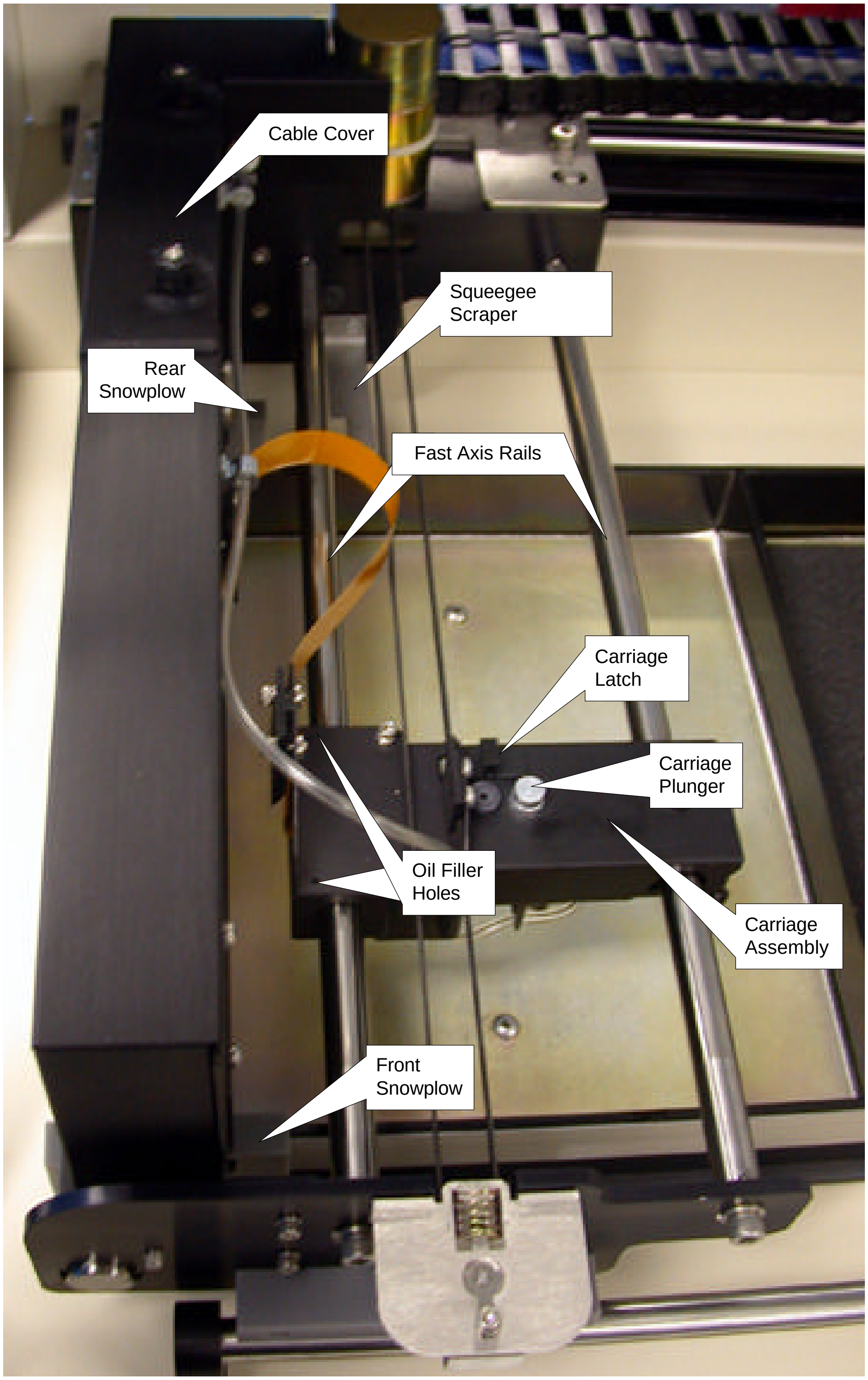
ZPrinter 310 Subcomponents



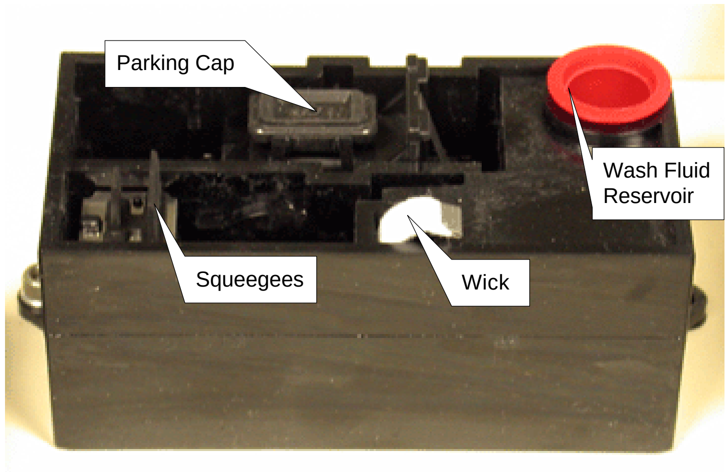
ZPrinter 310 System



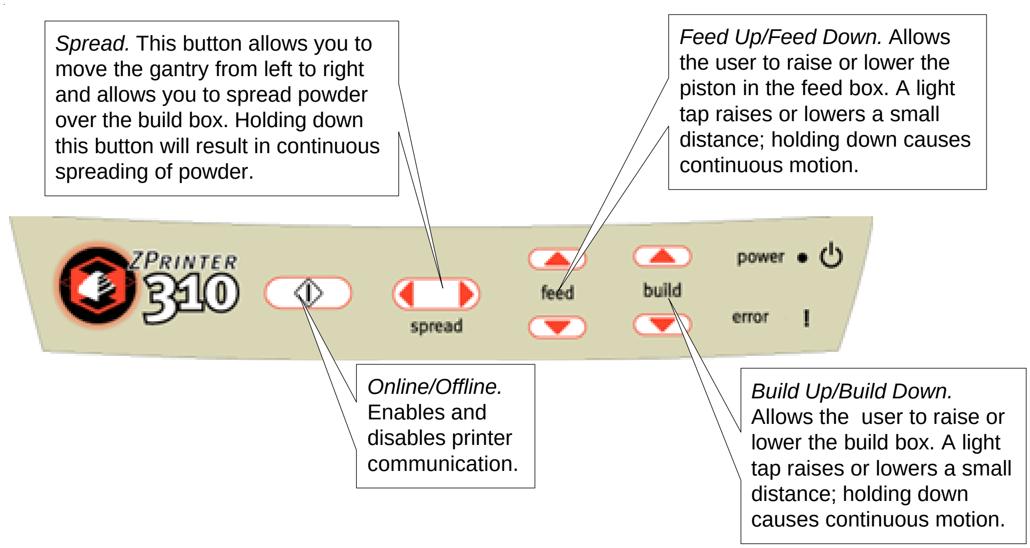
Back Panel View



Gantry (Top View)



Service Station (Top View)



Control Panel

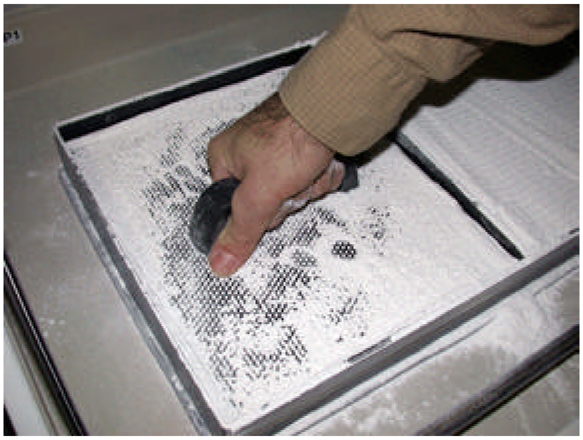
CHAPTER 2

QUICK START GUIDE

THIS CHAPTER PROVIDES AN OVERVIEW OF THE SET-UP, PART REMOVAL, AND PART POST-PROCESSING STEPS REQUIRED TO PRINT A PART. FOR A DETAILED STEP-BY-STEP GUIDE TO PRINTER SET-UP, PLEASE REFER TO CHAPTER 4; USING ZPRINT SOFTWARE IN CHAPTER 5; PART REMOVAL AND POST PROCESSING IS COVERED IN CHAPTER 6.

FOR ADDITIONAL INFORMATION ON POST-PROCESSING TECHNIQUES, REVIEW CHAPTER 7, *APPLICATIONS* OR VISIT THE Z CORP. USER WEBSITE AT WWW.ZCORP-USERS.COM.

Printer Preparation

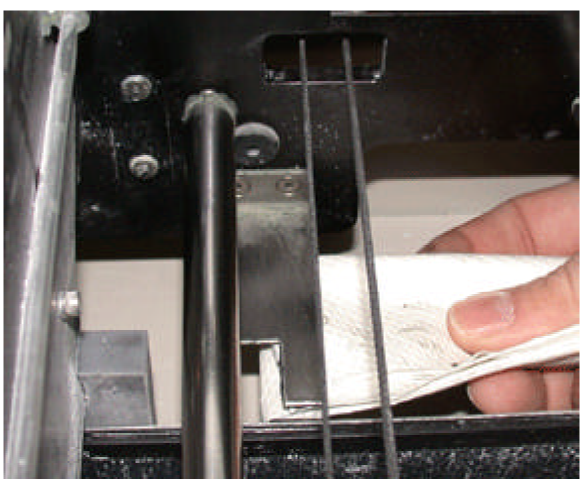


1. Fill the feed box with powder. Remember to use any powder in the overflow bin. Add fresh powder as needed.

2. Spread powder over build area.

3. Vacuum any remaining powder on the top deck.

4. Clean and wipe the squeegees and parking cap on the service station with distilled water.



5. Clean the squeegee scraper with a damp paper towel.

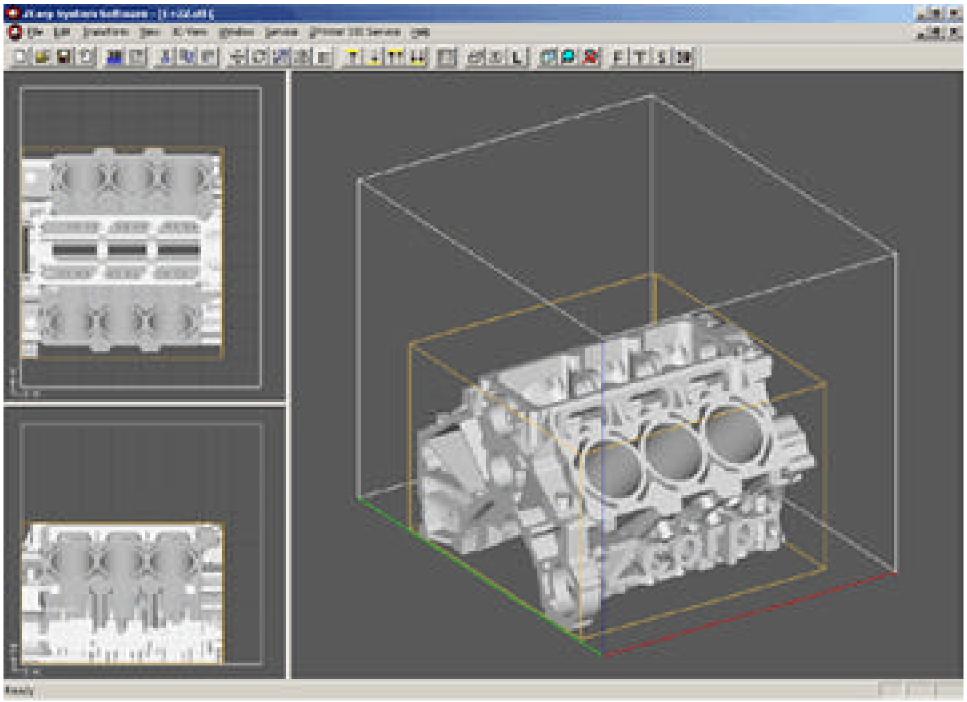
6. Check binder level and fill if necessary. Fill the binder fluid to the neck of the tank.

7. Check the waste bottle. Remove and dispose of liquid in accordance with local disposal regulations.

8. Put printer online.

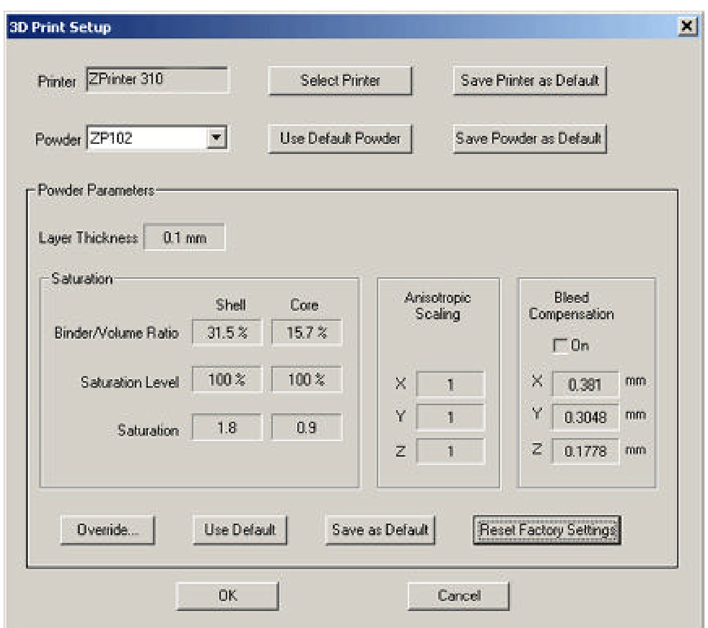
Part Printing

1. Launch the ZPrint Software application. Open or import the file for the build.

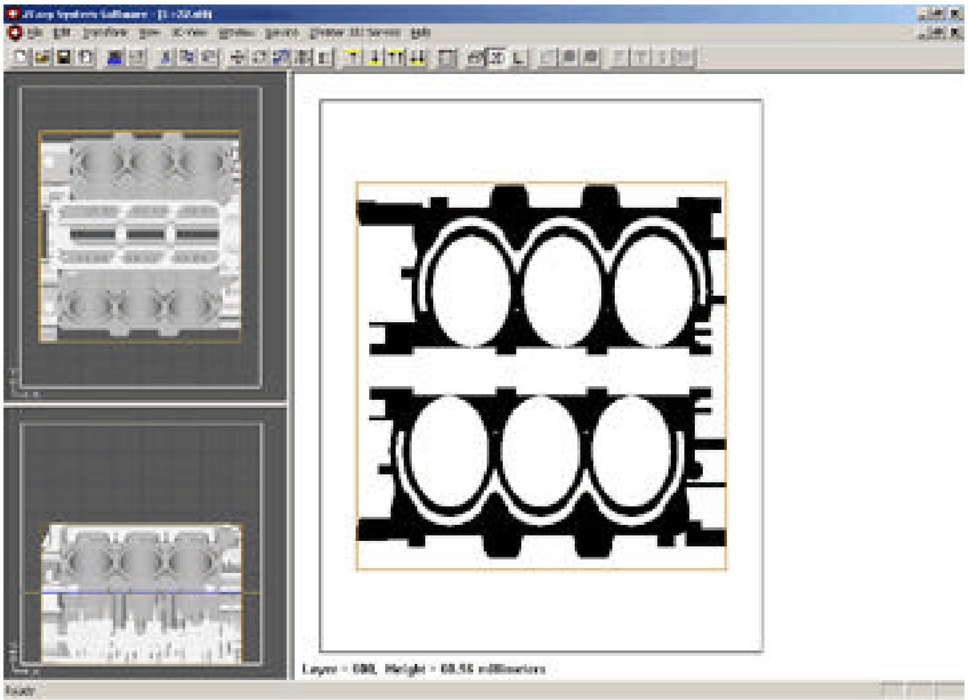


2. Check 3D Print Setup. Make sure the software is communicating with the printer by selecting ‘Select Printer’. Then choose either serial or network depending on how the printer is connected to the computer. The printer should show up as an option if the software is properly communicating with the printer.

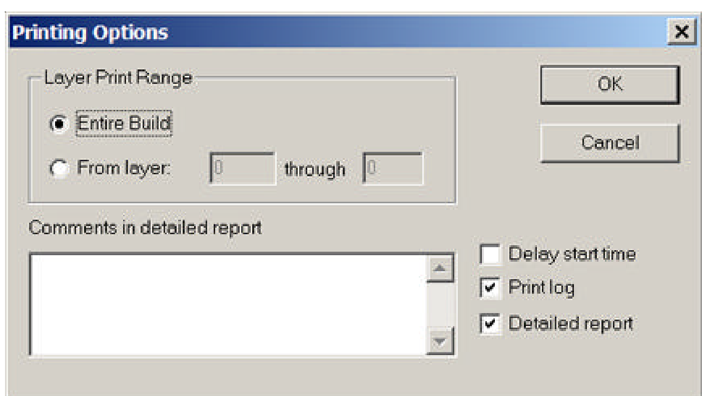
3. Change any powder parameters if necessary.



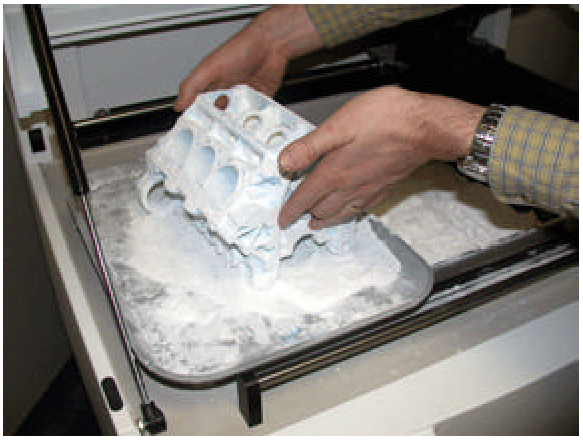
3. View build in 2D View and examine the cross-sections of the build. It is also recommended that collision detection be processed, found under the View menu in the ZPrint System Software (if the build contains multiple parts) before beginning your build.



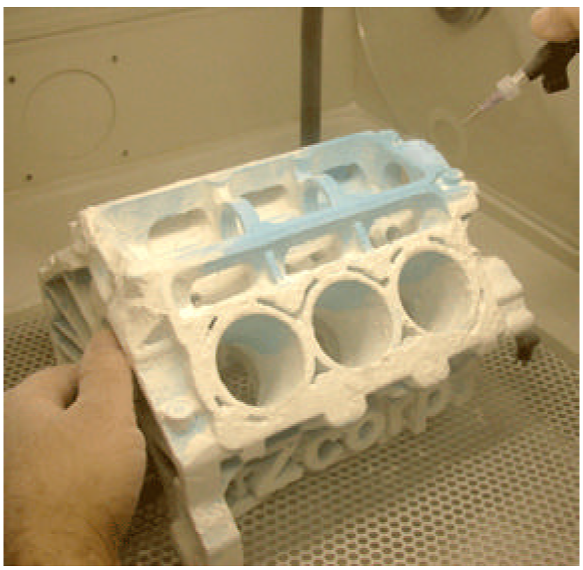
4. Press 3D Print and begin the build.



Post Processing



1. Remove excess powder from the part and remove it from the build box.



2. Depowder the part in the depowdering station.

3. Strengthen the part with the infiltration of your choice. See Chapter 6, *Post-Processing*.

Useful Tips

Part Setup and Post-Processing

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. Allow a little room around the part so you can vacuum the powder away and get your fingers around or under it.

- 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" (1.27 mm). Enabling bleed compensation may reduce the feature size.

- 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.

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 .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.

Use of the Removable Build Plate

- The removable build plate is an excellent tool for the new user. It allows you to quickly remove the part from the build bed and begin printing again. The build plate also allows the user to easily transport the part to the oven (at temperatures below 150°F or 66°C) or the depowdering station without ever having to handle the part.

- If you choose to use the removable build plate keep in mind that you want to orient the parts so that the part does not collapse when powder flows out from the sides of the part after the removable build plate is lifted from the build bed.

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 dramatically increase the strength of the part. This is only recommended for plaster-based powders. If using the removable build plate, remove the part from the removable build plate before placing in the oven.

Part Infiltration

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 the 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.

When Using a Z-Max™ and Z-Snap™ 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-Max and Z-Snap 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.

CHAPTER 3

MATERIAL SYSTEMS

THIS CHAPTER COVERS DETAILED INSTRUCTIONS ON HOW TO USE ZCAST™ 500 AND ZP®250 POWDER SYSTEMS. IT DESCRIBES HARDWARE AND SOFTWARE CHANGES NEEDED TO BUILD PARTS SUCCESSFULLY WITH THESE MATERIAL SYSTEMS. IF YOU ARE NOT USING ZCAST OR ZP250 POWDER, PLEASE PROCEED TO CHAPTER 4, *PREPARING THE 3D PRINTER*.

FOR INFORMATION AND GUIDANCE OR ADDITIONAL QUESTIONS, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM.

Using ZCast Powder

General Information

ZCast 500 powder is a plaster-ceramic composition that allows you to print sand casting-like molds and/or cores with your Z Corporation 3D Printer. Once printed, depowdered, and baked, you have the ability to immediately pour molten metal into the mold, yielding a cast metal part. Arguably, the ZCast process is the fastest and most direct way to obtain a metal part from CAD data. ZCast 500 powder has been optimized for non-ferrous materials ranging from zinc to brass, including aluminum and magnesium.

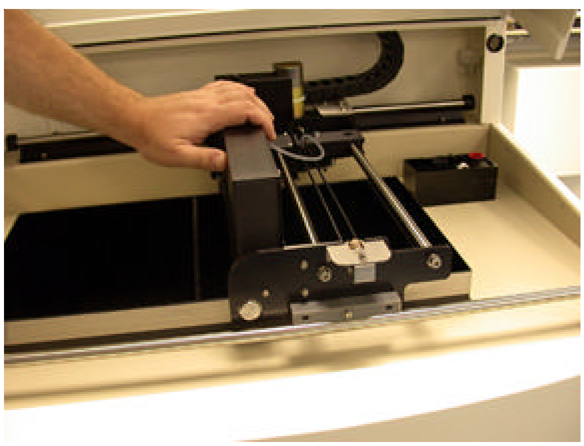
WARNING: NEVER pour magnesium without first contacting a Z Corporation technical representative. **NEVER ATTEMPT TO POUR FERROUS METALS IN ZCAST 500 MOLDS**.

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 the Z Corporation Applications Team for information about a free online training session at (781) 852-5005 or via email at applications@zcorp.com.**

Using ZCast On Your ZPrinter™ 310 Printer

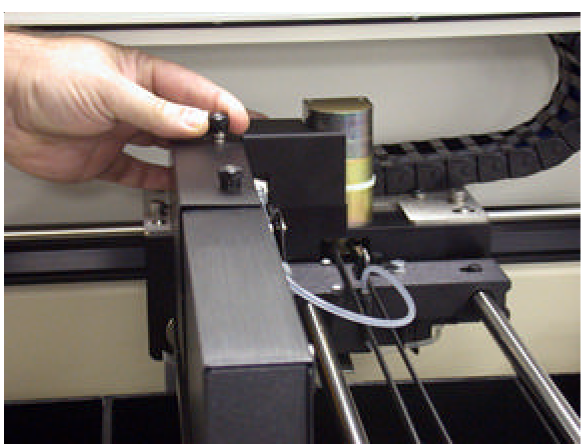
Temporary Scraper Blade Removal

When using ZCast powder on the ZPrinter 310 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. The entire activity should take less than ten minutes and requires two hex wrenches. Remember to reinstall the scraper blade when printing with ZCast is complete. Follow the instructions below to remove the scraper blade.

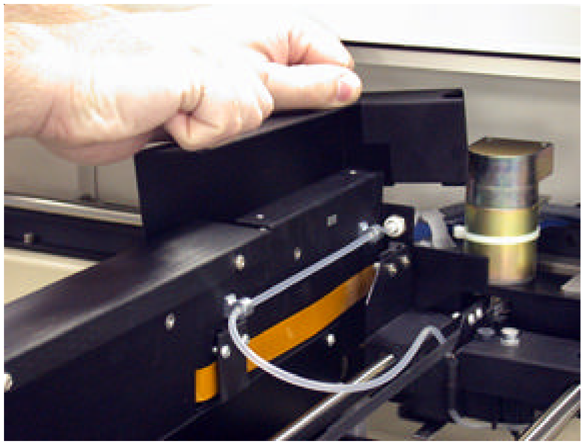


1. Turn off power and unplug the printer.

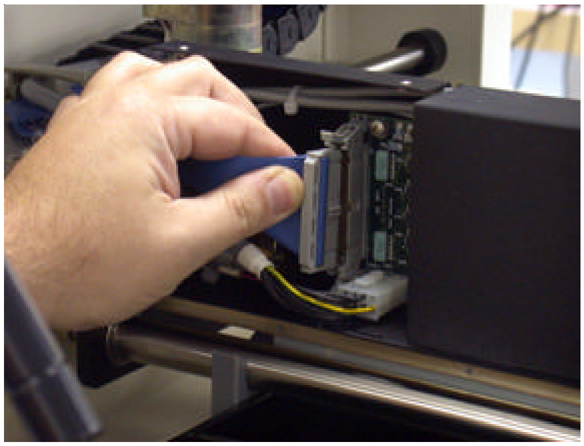
2. Slide gantry to the middle of the print area.



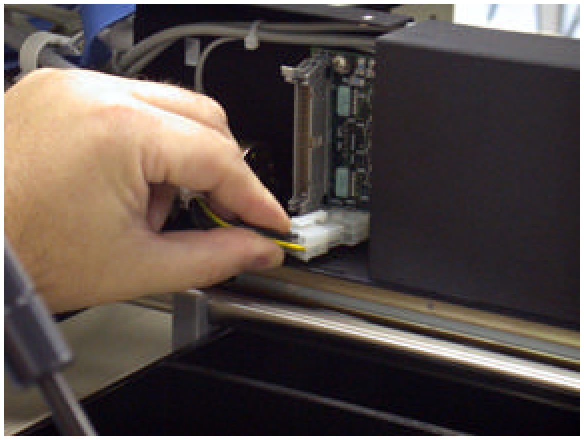
3. Remove the cable enclosure cover by unscrewing the two screws on the top of the enclosure.



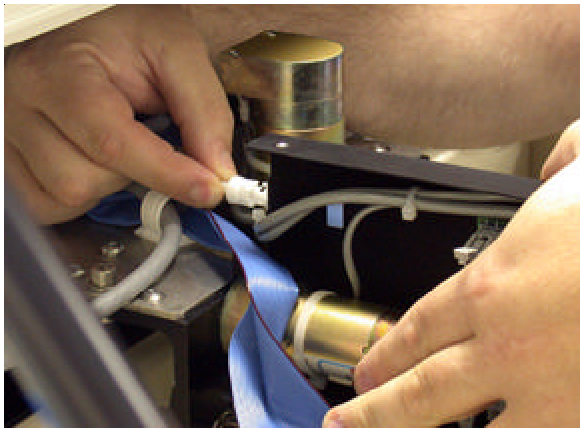
4. Remove the cable enclosure.



5. Disconnect the ribbon cable.

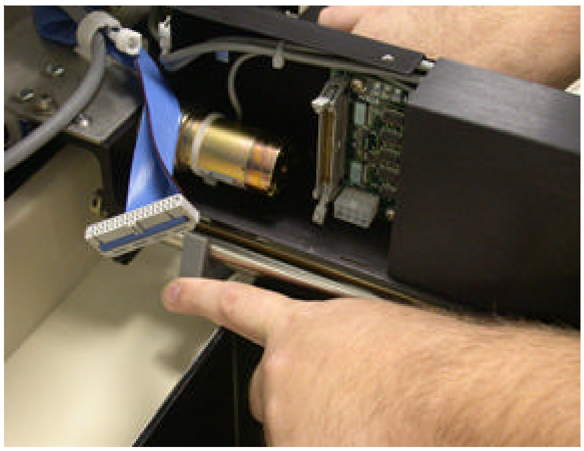


6. Disconnect the head power card.

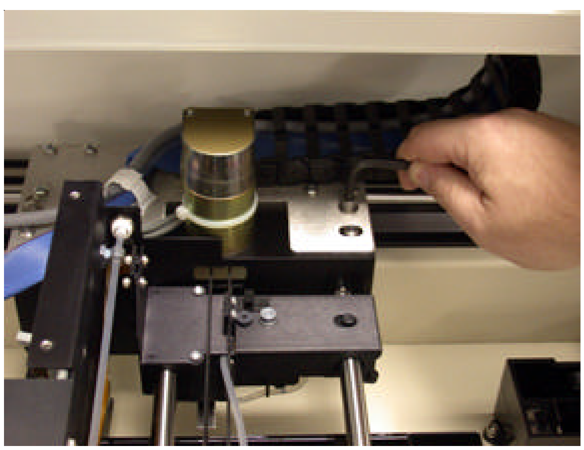


7. Twist and disconnect fluid supply fluid tubing.

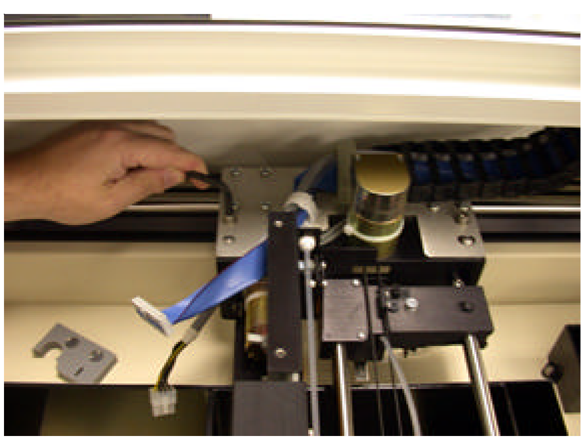
8. Remove the snowplow from the front of the printer module. Slide the snowplow away from the edge of the build box until it disengages from the retaining tab. Press on the top edge of the snowplow until it pops off the spreader roller.



9. Repeat step 8 for the snowplow in the back of the printer module.

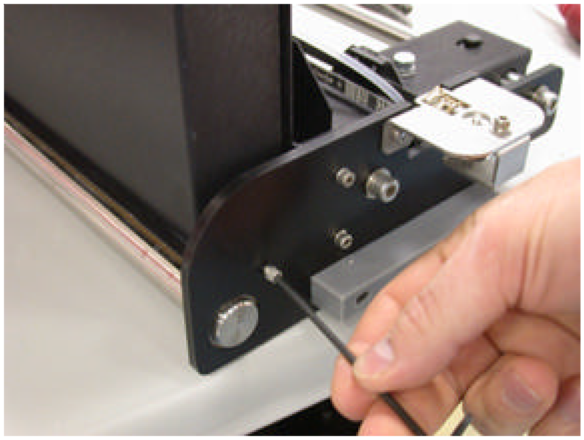


10. Using the 3/16 hex wrench, remove the mounting screw located on the right side of the motor assembly.



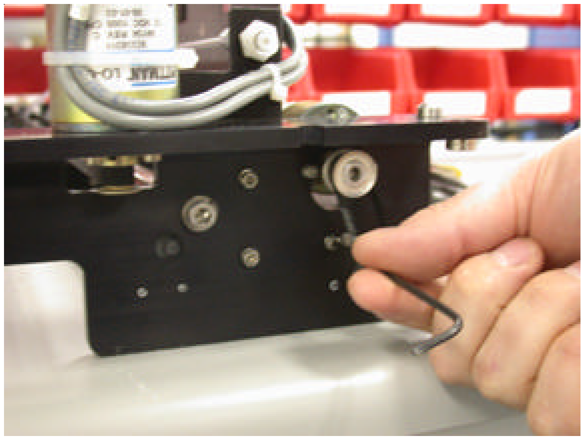
11. Using the same hex wrench remove the mounting screw located on the left side of the motor assembly. Support the printer module by hand while removing the mounting screw.

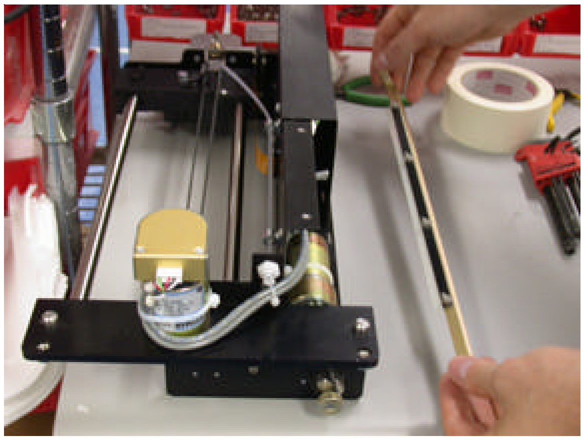
12. Pivot the front of the printer module up while lifting from the rear and remove. Place the printer module on a flat area.



13. Using the 3/32 hex wrench, remove the three hex screws holding the scraper blade retainer and scraper blade onto the printer module.

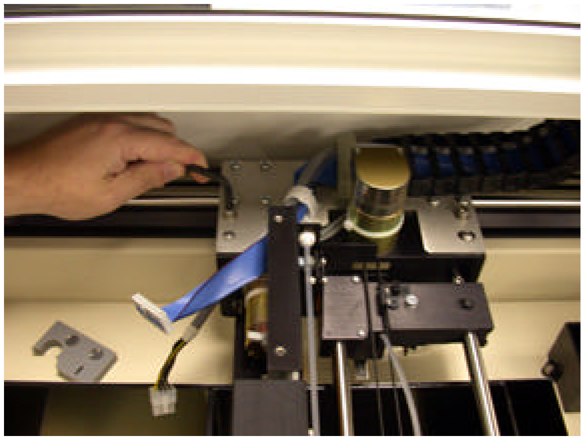
One screw located in the front and two in the back (underneath the roller bearing).





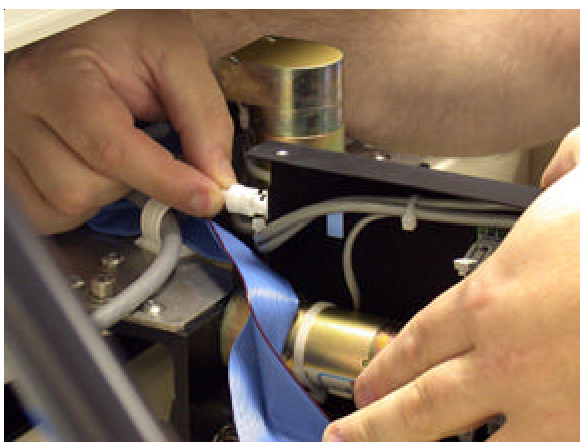
14. Lift the printer assembly. The roller scraper should drop from the printer assembly.

15. Replace the printer module onto the printer.

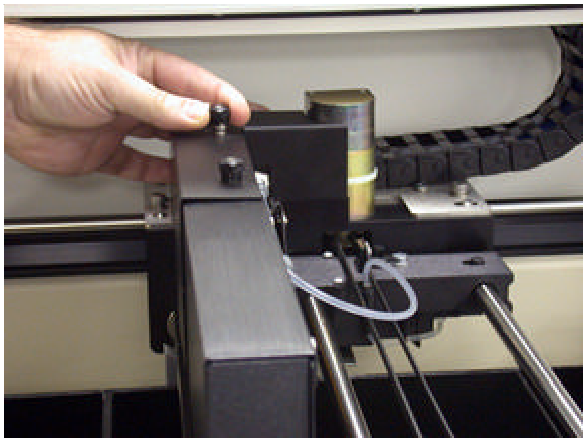


16. Tighten the mounting screws on both sides of the motor assembly.

17. Replace the snowplows in the front and back of the printer module.



18. Reconnect the fluid line, ribbon cable, and head card power cable.



19. Replace the cable enclosure and tighten up the both screws on top of the enclosure.

20. Using the syringe provided in the user toolkit, place the needle into the septum and slowly draw binder through the fluid system until no bubbles are present in the binder tube.

Loading ZCast Powder

1. Remove any non-ZCast powder from the feed piston, build piston, and overflow bucket.

2. Fill the piston completely with ZCast 500 powder being sure to keep the casting powder “fluffy”. Use the tamper to level off the top of the feed piston but **do not compress** the powder.

3. Spread over the build bed and print.

Packing the casting powder into the feed piston increases the density of the powder at the feed piston plate and increases the gripping force that ZCast 500 powder has on the sidewalls of the feed piston. **DO NOT** pack the casting powder.

Setting Up ZCast Builds

Follow best practices for setting up a build in Z Corporation 3D Printers found in the ZPrint Software User Manual. For more information, please refer to the ZCast Direct Metal Casting – Design Guide.

Post Processing

Unlike other Z Corp. parts, ZCast parts require no infiltration. However, ZCast molds must be thoroughly baked in a vented oven at sufficient temperatures to burn out 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.

WARNING: If using a build plate, remove the part from the build plate before placing in the oven. Failure to do so will damage the build plate.

Material Ordering

You can order ZCast consumables either directly from Z Corporation or through your local reseller. The item list for ZCast powder is as follows:

Part #	Description	Denominations
06091	ZCast 500 powder	15 kg pail ~ 500 in^3
06312	zb56 clear binder	1 gallon

Recycling

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

Storage

ZCast powder should be stored in a cool, dry environment. See container labels for additional information.

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.

Questions and Support

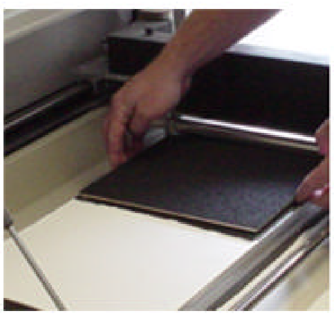
If you have any questions regarding this product, contact the Z Corporation Applications Team for technical support at (781) 852-5050 or via email at applications@zcorp.com.

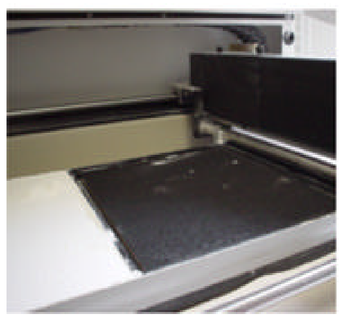
Using zp250 Powder

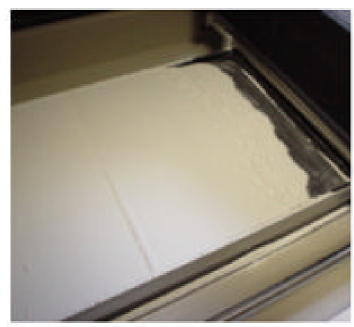
zp250 powder is formulated for Z Corporation 3D Printers utilizing the Hewlett Packard print head technology - the ZPrinter 310, Z®406, and Z810 3D Printers. Specifically formulated to have an open matrix to absorb infiltration resins, zp250 powder is an extremely versatile, composite-based powder used 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).

Machine Setup

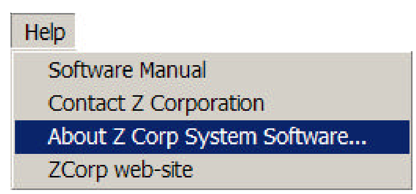
- Remove all of the powder currently in the ZPrinter 310 (feed piston, build piston, overflow bin).
- Remove all powder in the depowdering unit and install a new vacuum bag in the vacuum unit.
- Check to see if the binder solution currently being used is compatible with zp250 powder. If you are not currently using zb56 binder, replace the current binder with zb56 binder then flush and purge the fluids system in accordance with your respective printer's user manual. zb56 binder is the required binder system for zp250 powder.
- Fill the feed piston with zp250 powder. ZPrinter 310 users may use the removable build plate (Z Corp. part number 06302) to aid in the removal of the 3D printed part after the build is completed. Place the build plate onto the build piston and lower the build piston until the top surface of the removable build plate is slightly below the surface of the top deck of the 3D printer to make certain that the spread roller does not hit the build plate.







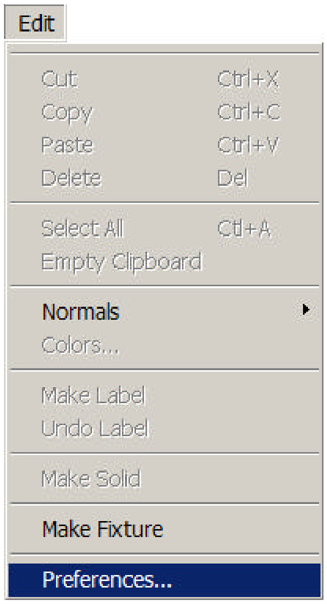
Software Setup

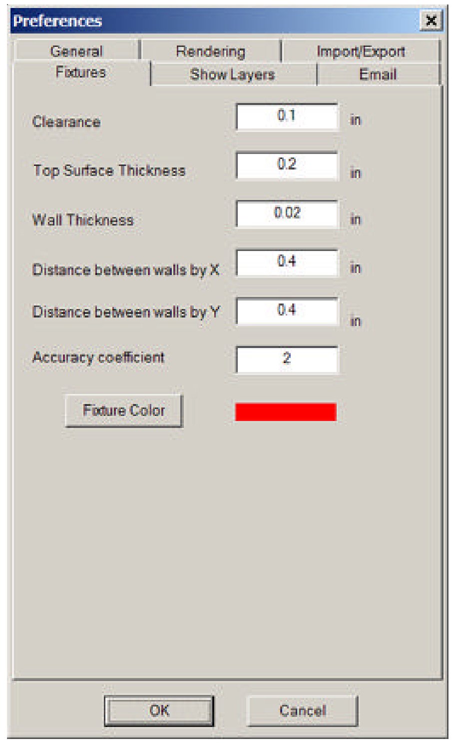


- ZPrint Software version 6.2 or higher should be used when printing with zp250 powder. To check the version of ZPrint Software currently installed select "About Z Corporation Software" from the Help Menu. If ZPrint version 6.2 or higher is not installed contact the Z Corporation Service Department for an upgrade at service@zcorp.com.
- 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 0.25" (6.35mm) on the ZPrinter 310. 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:

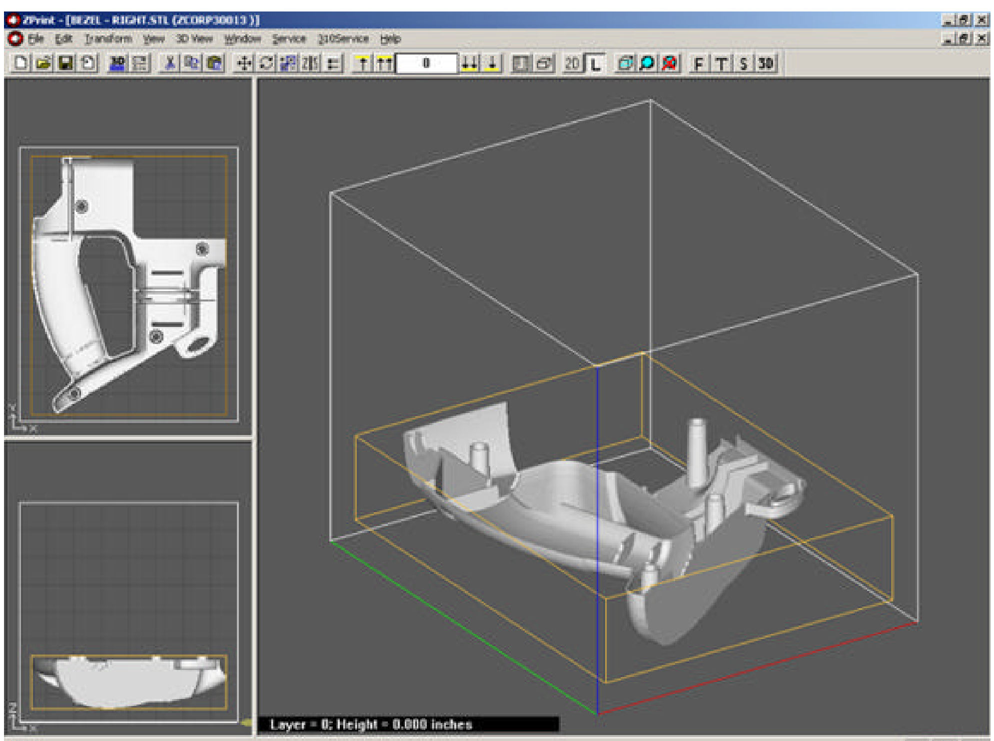
Clearance	0.125" – 0.25" (3.175 – 6.35 mm)
Top Surface Thickness	0.1" – 0.25" (2.54 – 6.35 mm)
Wall Thickness	0.1" – 0.25" (2.54 – 6.35 mm)
Distance Between Wall by X	0.5" – 1.0" (12.7 – 25.4 mm)
Distance Between Wall by Y	0.5" – 1.0" (12.7 – 25.4 mm)
Accuracy Coefficient	High enough to avoid collisions between the part and the fixture (e.g. 8)

• 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’.

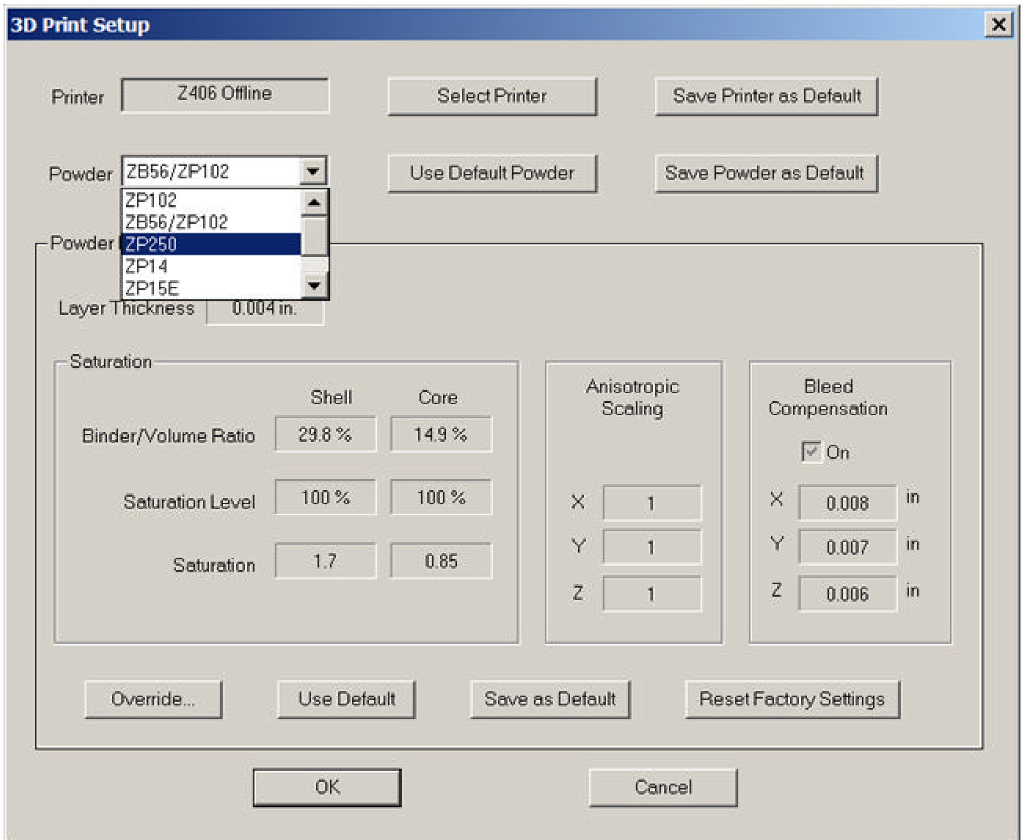




- To create a fixture that completely cradles the entire part, raise the part in the z-axis at least 0.5" (12.7 mm) from the bottom of the build plate in the ZPrint Software. If the part is not raised it will not be fully supported by the fixture after depowdering.



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



Part Removal and Post Processing

1. When printing parts that can be manually handled, allow the part and fixture to dry in the build bed for at least 2 hours before removing. If printing parts that cannot be manually handled, please refer to the Infiltration Addendum of this set of instructions. Parts built deeper than 2 inches (50.8 mm) into the build box may require longer drying time before handling. If the removable build plate was used the part can be gross depowdered and removed prior to two hours and placed in an oven at 150°F (66°C) for at least 2 hours or longer depending on the mass/volume of the part.

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.

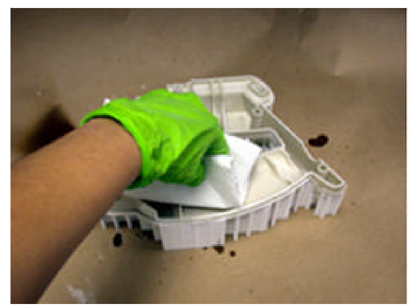
3. Remove part from build plate and place on a clean surface. Then separate the part from the fixture.

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

9. Parts infiltrated with Z-Snap should then be cured for an additional 2 hours in the oven at 165°F (74°C). **Do not place on the build plate.**

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

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). **Do not place on the build plate.**

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

CHAPTER 4

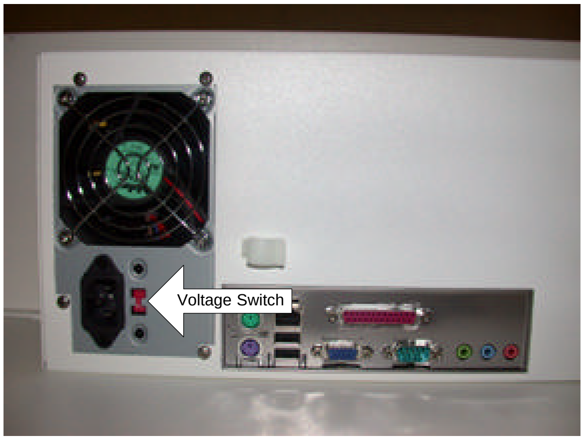
PREPARING THE 3D PRINTER

THIS CHAPTER IS A STEP-BY-STEP GUIDE ON PREPARING THE 3D PRINTER FOR PRINTING. IT COVERS PREPARING THE BUILD AREA, CLEANING THE SERVICE STATION, FILLING THE BINDER BOTTLE, AND REMOVING THE WASTE BOTTLE.

FOR ADDITIONAL ASSISTANCE AND INFORMATION, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM. YOU MAY ALSO VISIT THE Z CORP. USER GROUP WEBSITE AT WWW.ZCORP-USERS.COM

Turning the Printer On

If the Printer is off, you will need to turn it on in order to prepare the printer. **We recommend that you leave the printer on at all times. The Printer periodically exercises the print head for optimal operation.**



1. Check the voltage switch, located on the back of the printer, to make sure it is configured for the correct voltage.

2. Press the power switch located on the back right side of the printer.

3. When the online light, located on the control panel, is on, the printer is ready.

Preparing the Build

Filling the Feed Box

1. Press and hold the feed down button until the online light begins to blink. The feed piston will lower itself until it reaches the bottom.

Warning: Use only powder supplied by Z Corporation. Use of any other material may impact the performance and/or safety of your ZPrinter 310 System and will void warranty and service contracts.

2. Check the overflow bin to see if there is powder to be recycled. If so, remove the powder overflow bin.

If you do not have any or enough powder to recycle from the overflow bin, pour fresh powder into the Feed Box.

3. Open the top cover of the printer.

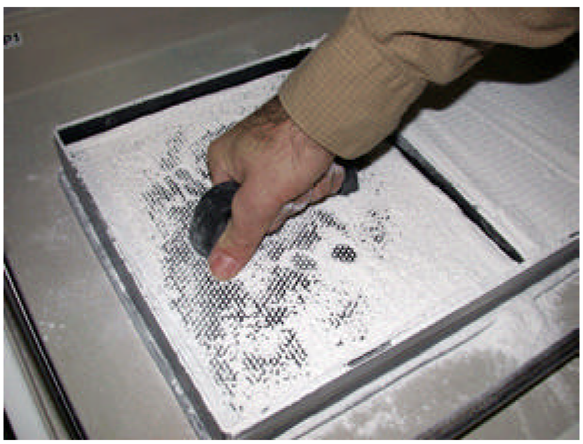
4. Fill the feed box with powder.

TECHNICAL TIP…
• Keep powder containers closed when not in use to keep powder dry and free of contaminants.
• Scoop powder carefully to minimize airborne particles.
• Make sure that you carefully vacuum up excess powder. It only takes a minute, and the cleaner the machine is, the less often it will need maintenance!

Removing Air from Powder and Packing the Feed Box

5. Insert the powder scoop repeatedly a few inches into the loose powder to compact it. Continue for about a minute until it feels firm.

Repeat steps 5 for every two scoops of powder.



6. When the feed box is filled to the top, take the tamper and slowly press it into the powder surface. Be careful not to “slap” the tamper into the feed box, which will produce airborne particles. About 10-15 pounds of force will give it a smooth, flat, and compact surface. Failure to firmly pack the powder will affect part quality.

Preparing the Build Area

7. Press and hold the feed up button until the surface of the powder is even with the top deck.

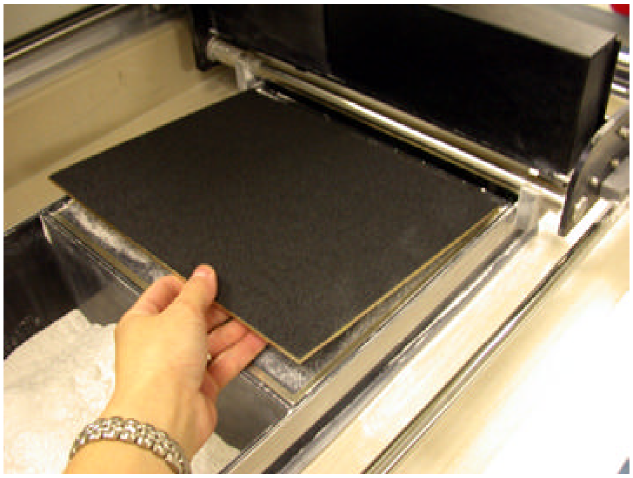
8. Press and hold the build up button until the build piston stops.

9. Make sure the build area is clean.

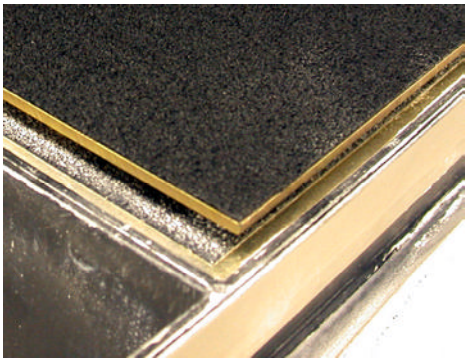
If using a build plate, see directions below:

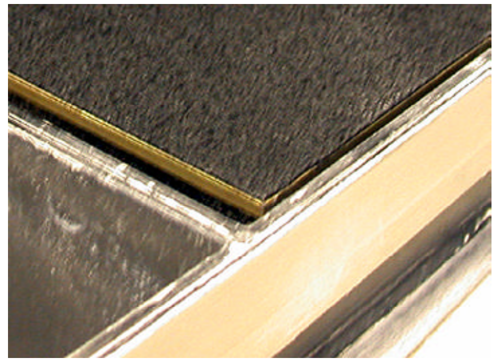
The build plate is a useful tool in making the most out of your 3D Printer. It allows you to lift delicate parts from the printer without handling them. It may allow you to safely remove parts from the machine sooner after they are printed, so that you can start another build while your parts dry outside the printer. You can use the build plate to transfer your parts to an oven to dry them quickly to their full green strength.

Bring build piston all the way to the top and place build plate on top of build piston.



The build plate will project above the top of the build box. In this position, the gantry would hit the build plate if you tried to spread powder.

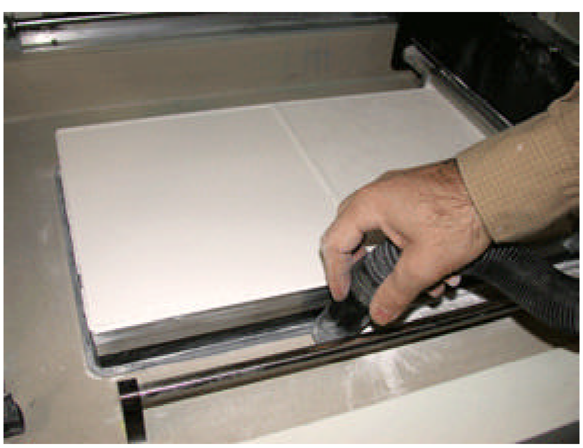




Lower the build piston so that the top of the build plate is slightly below the top of the build box.
WARNING: If the gantry or the spread roller hits the build plate, you may damage your printer.

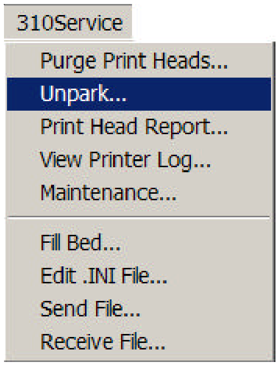
10. Press and hold the spread button for four spreads, on the fifth spread, the automatic 'Fill Bed' routine will take over. This will do 13 more spreads with coordinated piston movements to prepare the build area. Press 'Online' to cancel this operation or press 'Cancel' from the software. You may also choose the 'Fill Bed' option under the 310Service menu in the ZPrint Software.

Cleaning Up



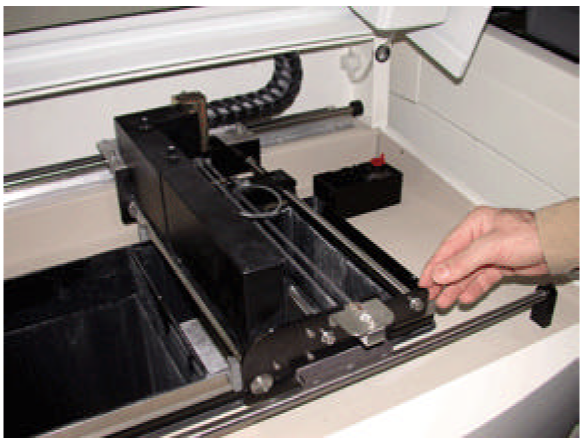
11. Vacuum off any powder on the top deck.

Cleaning the Service Station



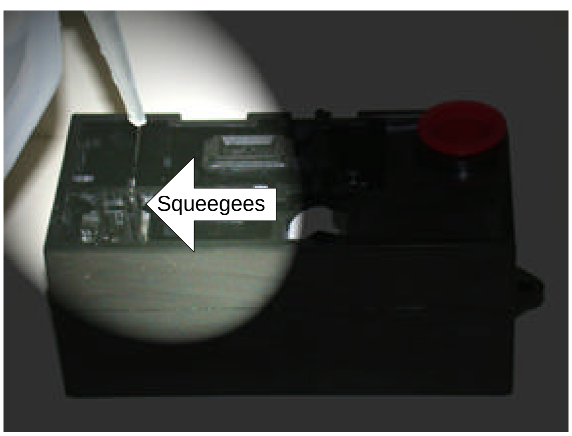
Cleaning the Squeegees and Parking Caps

1. Choose the 'Unpark' option under the ZPrinter 310 Service menu. The gantry will move away from the service station exposing the squeegees and parking cap. (The printer must be online with the top cover closed).



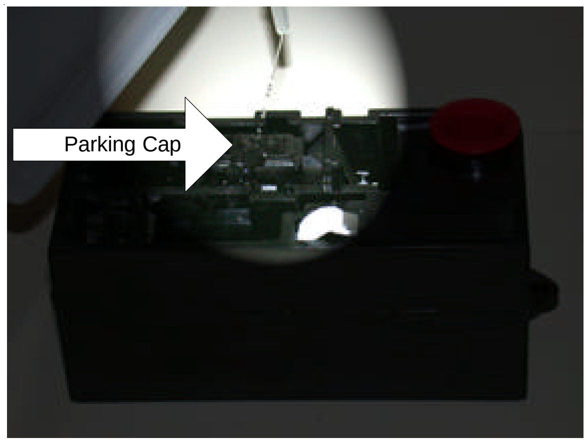
2. Lift the top cover of the printer.

3. Manually move the gantry to the left away from the service station.

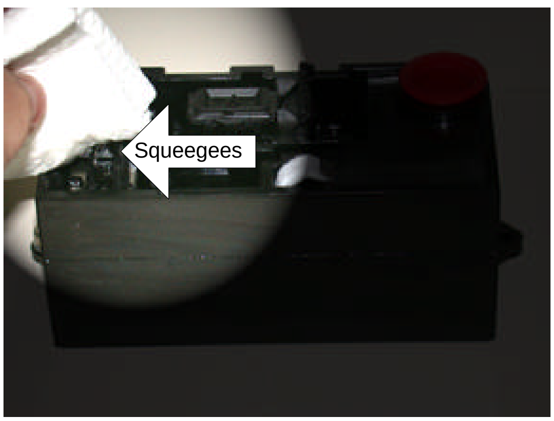


4. Fill wash bottle (supplied in the toolbox) with distilled water.

5. Rinse squeegees with water until all debris has been removed from the rubber squeegee.

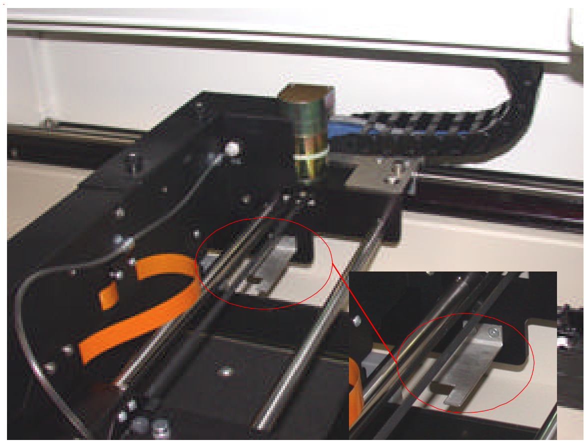


6. Rinse parking cap with distilled water.

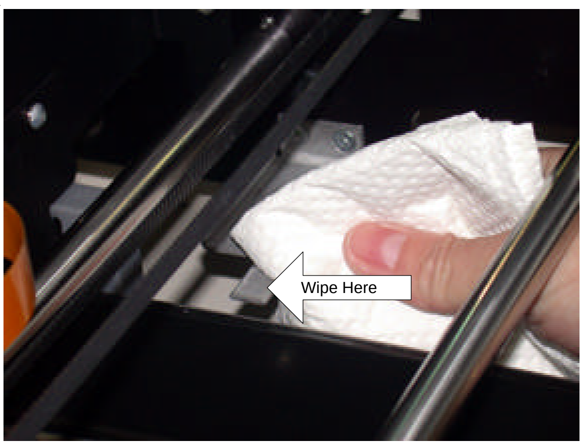


7. With a clean and dry paper towel, wipe residue off the squeegees.

8. With a clean and dry paper towel, remove standing water in the parking cap.



9. Locate the squeegee scraper located in the back of the printer assembly.



10. Using a damp paper towel, wipe off the top and bottom surfaces of the squeegee scraper.

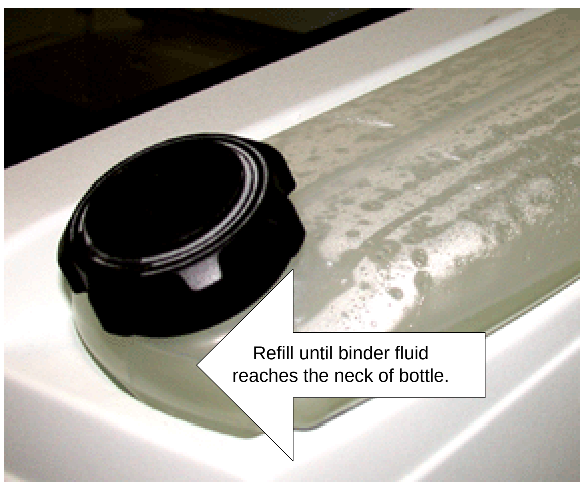
11. Close the top cover.

12. Press ‘OK’ on the ZPrint Software to repark the gantry.

Refilling the Binder Bottle

1. Unscrew the black cover of the binder bottle.

2. Fill with binder fluid until liquid reaches the neck of the bottle. Hold bottle sideways to avoid spilling binder.



3. Replace the binder bottle cover.

> **Warning:** Use only binder supplied by Z Corporation. Use of any other material will impact the performance and/or safety of the ZPrinter 310 System and will void warranty and service contracts.

Changing the Print Head

Change the print head if necessary. The ZPrint Software will alert you if your print head is old and may not complete the build. For more information about changing print heads, please refer to Chapter 8, *Maintenance*.

Technical Tip....
If you fill the binder bottle after you change the print head, there is enough binder to last until the print head's normal life is achieved.

Emptying the Waste Bottle

1. Remove waste bottle by depressing the button on the waste fitting and pulling down on the waste bottle.

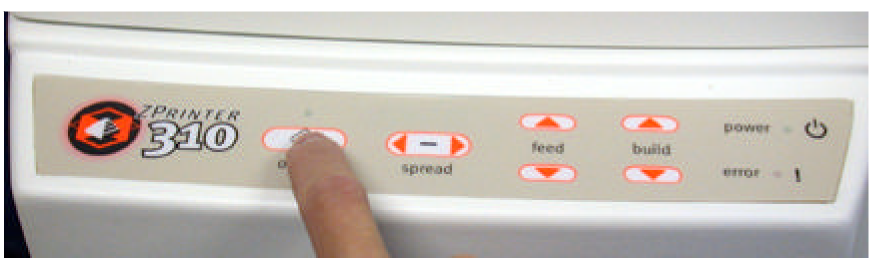
2. Dispose of waste liquid. Binder waste should be treated in accordance with local disposal regulations.

3. Replace waste bottle by inserting the bottle back onto the fitting.

NOTE: Make sure the binder bottle is completely inserted against the fitting. A double clicking sound will confirm that the binder bottle is locked into place.

Warning: Do not recycle waste binder solution. The waste is contaminated with powder and use of this liquid in the ZPrinter 310 System will clog the internal plumbing system and the print head.

Putting the Printer Online



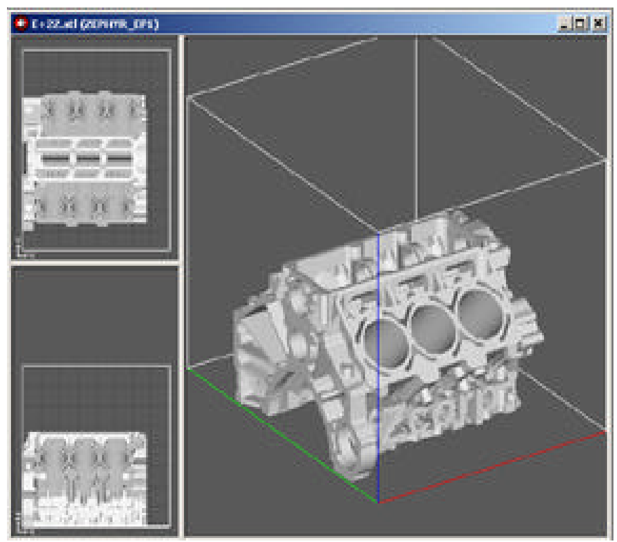
Press the online button. The green online indicator light will illuminate. The ZPrinter 310 System is now ready to print.

CHAPTER 5

USING ZPRINT SOFTWARE

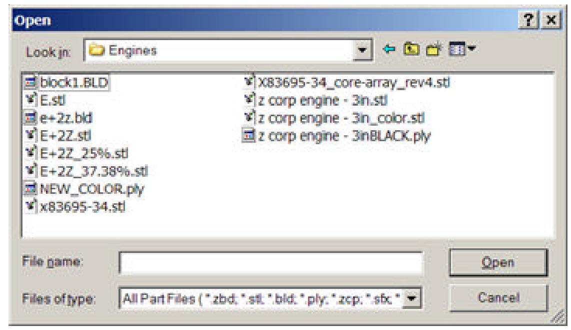
THIS CHAPTER WILL EXPLAIN HOW TO SET UP THE BUILD, CHECK THE 3D PRINT SETTINGS, AND PRINT. FOR MORE INFORMATION ABOUT THE FEATURES IN THE ZPRINT SOFTWARE, PLEASE REFER TO THE ZPRINT SOFTWARE MANUAL.

FOR INFORMATION AND GUIDANCE ON SOFTWARE FEATURES, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM.



PLEASE NOTE: Verify that the ZPrint Software has been installed. Installation instructions are located in Section 1.2 of the ZPrint Software Manual.

Opening or Importing a File



1. Launch the ZPrint Software application. 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.

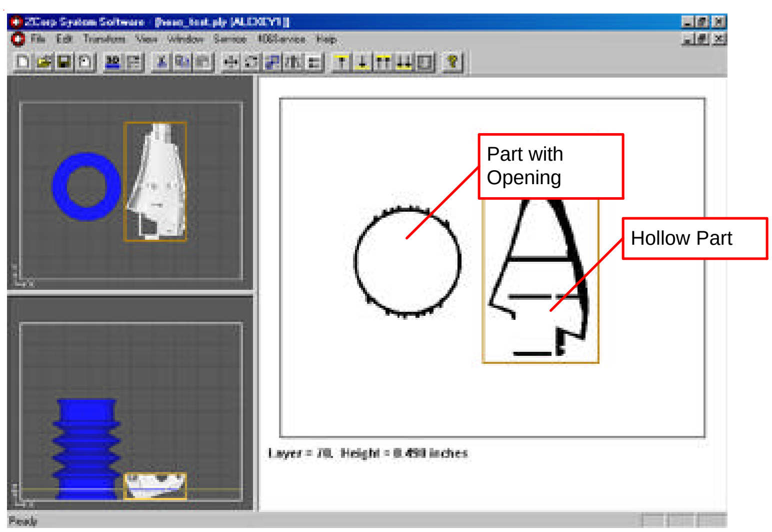
5. Click ‘OK’.

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.

Orienting the Part

Part Containing an Opening or Hollow Area

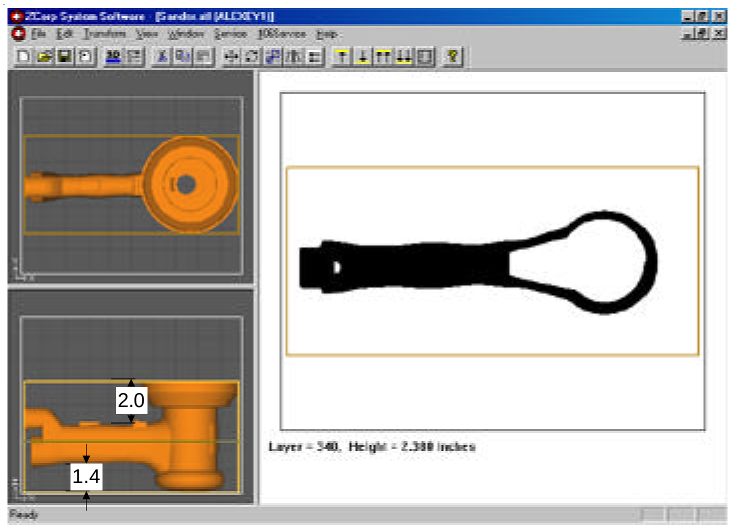
If the part has an opening or is hollow, place the opening or hollow side of the part in position so that it is facing upward. This will allow for the removal of powder during the depowdering process.



Part Containing Overhangs

Unsupported overhangs should be placed on the left hand-side of the build. The plaster powder, being extremely fine, is more fluid in the build box. Placing a fixture underneath overhanging surfaces will reduce the movement of the overhang. For information on generating fixtures, refer to the ZPrint Software Manual.

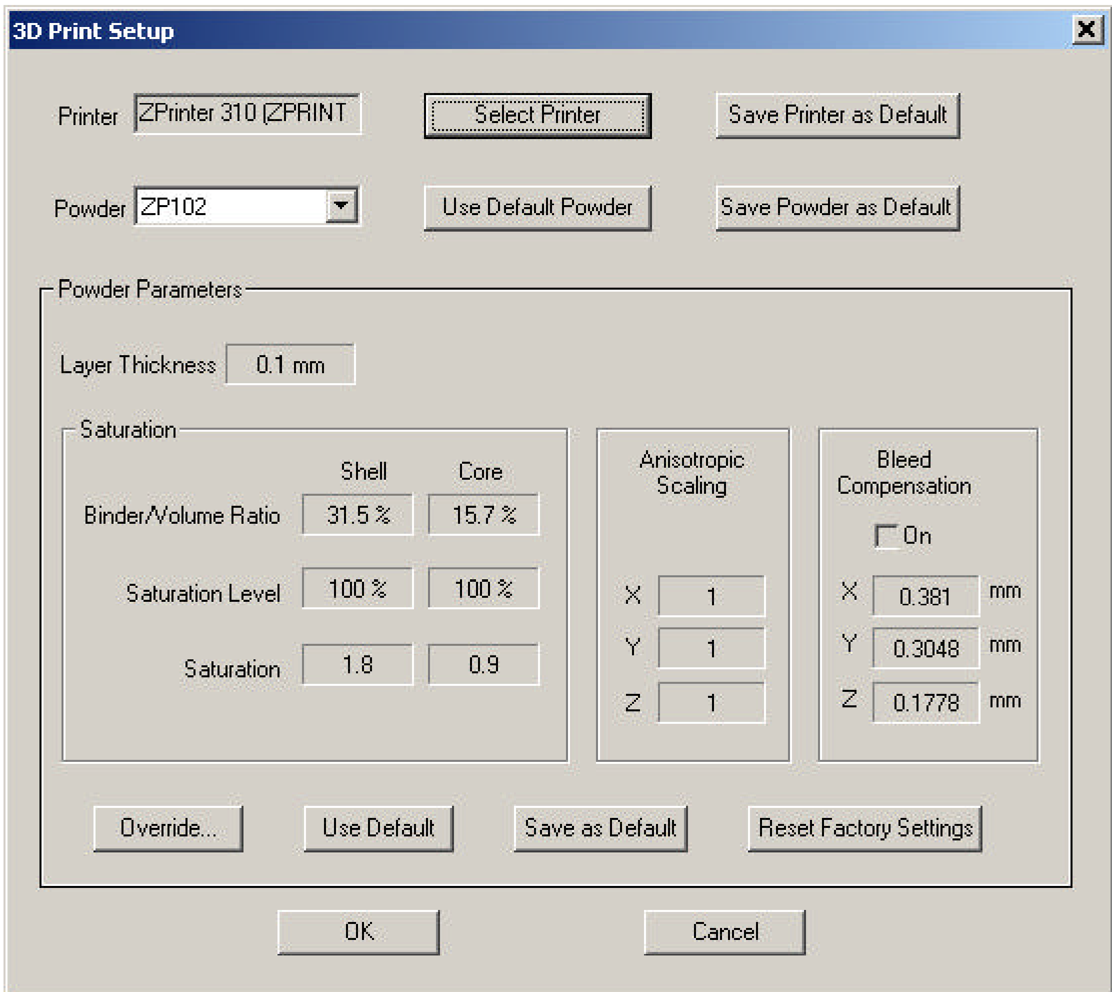
Cylindrical features will be more accurate when their axis is parallel to the z-axis. For example, if you were to print a bottle, the bottle would best be printed standing up, with the mouth of the bottle facing the top of the printer.



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 printer, powder type, and powder settings for the build are correct.
3. If the settings need to be changed, select ‘Override’. Press ‘OK’ to confirm. See Section 5, *Changing Powder Parameters*.

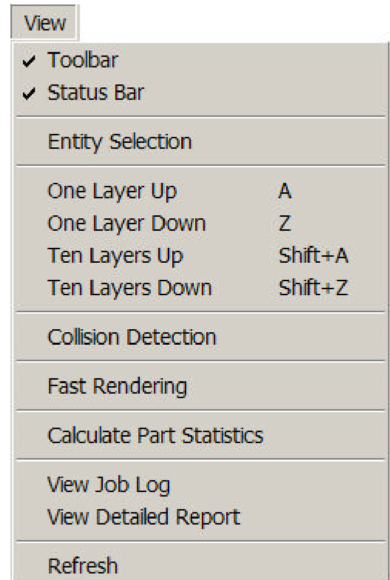


For more information on how to change the settings, please refer to the ZPrint Software Manual.

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

• 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.



Setting Powder Parameters

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 being utilized. 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.

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 Chapter 1, *Overview*. Thus, there are two saturation values, one each 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.

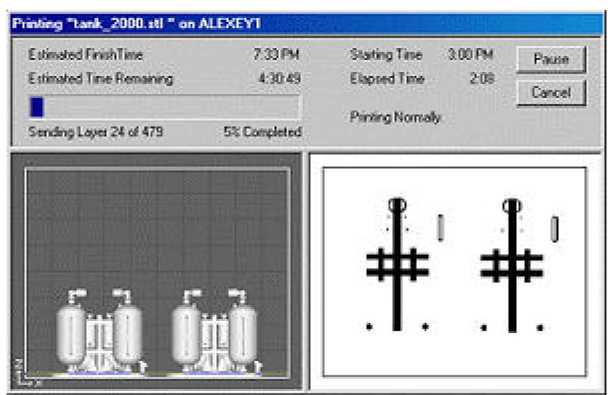
2. *Starch Material System*

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. The ZPrint Software will recommend shell and core saturation values based on the part geometry. If parts come out weak, increase the saturation values by 10%; if parts are difficult to depowder, decrease the saturation values by 10%.

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.

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 to be checked.

3. Press 'OK' to confirm that these have been checked to begin the build.

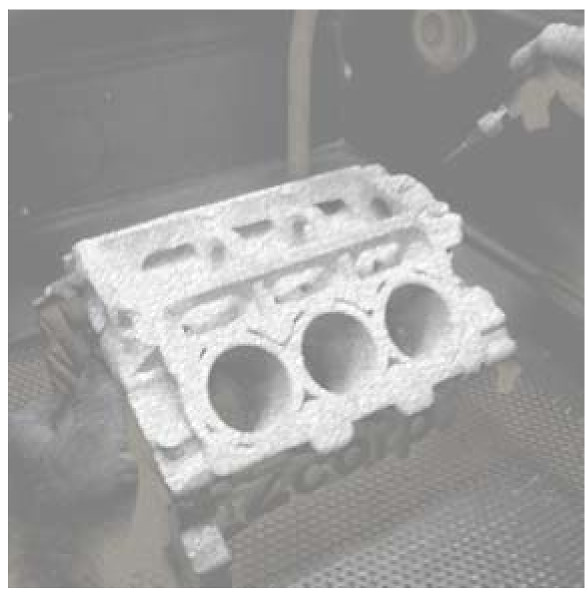
Once the build has begun, a dialog box will appear reporting the status of the build.

CHAPTER 6

POST-PROCESSING

THIS CHAPTER WILL EXPLAIN HOW TO REMOVE A PART FROM THE ZPRINTER 310, REMOVE EXCESS POWDER BY DEPOWDERING, AND INTRODUCE THE USE OF INFILTRATION MATERIALS.

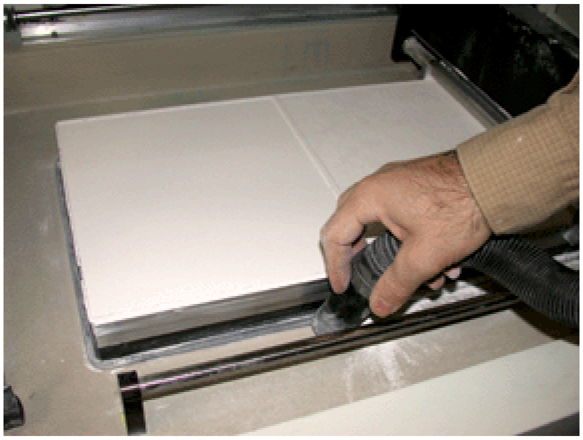
FOR INFORMATION AND GUIDANCE ON INFILTRATION MATERIALS, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM.



Removing the Printed Part

1. With starch-based parts, wait approximately ten to fifteen minutes to ensure that the uppermost layers of the part have had a chance to dry. With plaster-based parts, leave the part in the bed for approximately 30-60 minutes.

2. Take the machine offline by pressing the online button.



3. Lift the top cover.

4. Vacuum off any remaining powder on the deck.

5. Press the ‘Feed Down’ button to lower the feed piston.

6. Place a tray on the top of the feed area.

7. Take a moment to look at the computer screen and determine exactly where parts lie in the build box. 3D View in the ZPrint Software makes this easy to perform.

8. Without raising the build piston, begin vacuuming powder out of the build box. Hold the end of the hose on a 20° to 30° degree angle over the powder so the hose inlet is 1/4" to 3/8" above the surface of the powder. This generates enough of a draft to lift loose powder without damaging the parts.

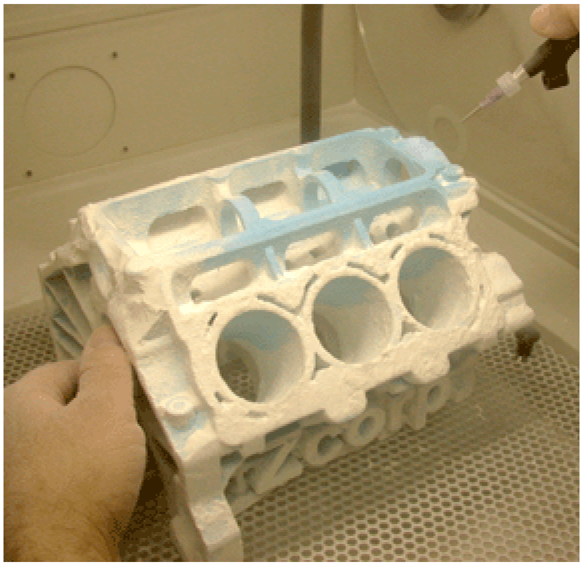
9. Vacuum powder away from the buried parts, and clean powder out of the margins against the walls of the build box.

10. To gain access to the sides of the parts, raise the build piston by holding the ‘Build Up’ button.

11. Remove the part or build plate and place on the tray. The part is now ready to be depowdered.

WARNING: When performing any vacuuming operation, use the vacuum provided as part of the ZPrinter 310 System. Vacuuming powder can generate static electricity, and use of a non-grounded vacuum hose will create static charges, which may affect the operation of the printer and harm the operator.

DEPOWDERING THE PART



1. Place parts inside the depowdering unit.

2. Using the compressed air system included in the depowdering station, remove any excess powder that remains on the part.

TECHNICAL TIPS…. The air pressure on your depowdering station is adjustable. For bulky parts, turn the air pressure up. For more delicate parts, turn the air pressure down.

DRYING THE PART

To infiltrate parts with wax, the parts must be hot and dry. Preheat part at 165ºF (or 74ºC) in a Z Corp. waxing system or in a drying oven. Remember that drying time and part wall thickness are directly related. If the average wall thickness is ¼" (6.35 mm), then the part should be in the drying oven for 30 minutes. If average wall thickness is ½" (12.7 mm) inch, the part should be in the drying oven for 45 minutes. Use the chart below as a guide.

Average Wall Thickness	**Drying Time**
1/8 inch (3.175 mm)	15 minutes
1/4 inch (6.35 mm)	30 minute
1/2 inch (12.7 mm)	45 minutes
1 inch or greater (25.4 mm)	90 minutes

For instructions on how to use the ZW4 or ZW3 Waxing Systems, please refer to the respective product's user manual.

Infiltrating the Part with Z-Kote Resins

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 Z Corp. System is derived from the spectrum of material properties that can be achieved by applying one of our infiltration materials to parts. 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. Here you will find a variety of application stories and technical tips that describe the many ways that our system can benefit your operation.

Using Z-Max™ Epoxy

Z-Max epoxy is a high strength epoxy infiltration system specifically formulated for Z Corporation. Z-Max epoxy is a low viscosity, high strength, infiltration system designed to fortify both starch and plaster-based parts built on all of Z Corporation's three-dimensional printers. Z Corp. parts infiltrated with Z-Max epoxy are easily sanded and are surface machinable.

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.
- 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.
- Please read the Material Safety Data Sheet for Z-Max epoxy prior to the use of this material.

Mixing Instructions

- 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

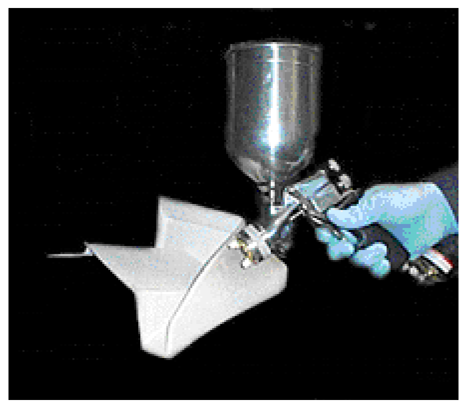
- Material can be brushed or sprayed.
- Material will penetrate between 0.079- 0.28 (2 – 7 mm).
- Do not over apply the material, as it will pool off the part during curing.
- Better penetration depth is achieved by applying several light coats of material.
- Allow all mixed materials to cure prior to disposal.

Spraying Instructions

1. Use a **Gravity Feed High Volume/Low Pressure or HVLP Sprayer**. We recommend a DeVilbiss Sprayer with 14 – 18 mm tip. The DeVilbiss Sprayer is available from Z Corp. with disposable canister liners and will minimize the amount of cleanup.

2. Have the sprayer, parts and materials ready before mixing the resin.

3. Mix resin and pour into the disposable liner in the canister.



ALWAYS SPRAY IN A VENTED HOOD.

4. Spray resin between 15 – 20 psi (1-1.4 bar).

5. When finished, remove the disposable liner and clean the sprayer with a mild solvent, such as isopropyl alcohol or acetone.
Remove the tip and thoroughly clean by hand to avoid resin build up. (Cleanup takes approximately 15 minutes).

CURING INFORMATION

- 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.
- Allow the part to cure for 1 hour at ambient temperature prior to placing in the oven for accelerated cure to avoid discoloration due to exothermic reaction.
- The part should be placed on a non-stick, (wax paper, Teflon, etc.) material or it will adhere 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.

PAINTING PARTS

• Parts can be painted to enhance surface finish and appearance. Z Corp recommends coating all surfaces with Dupont Fill 'N Sand Acrylic Primer-Surfacer #131S, a lacquer-based primer ideal for improving the adhesion of most paints. This material can be purchased at most auto body supply stores.

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.

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.

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 0.08 - 0.12 inches (2–3 mm).

• Do not over apply the material, as it will pool off the part during cure cycle.

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 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 top of the part begin squeezing the trigger.

• Adjust the tip of the sprayer until the desired spray pattern is reached.

• Apply Z-Bond 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 accelerator.

CURING INFORMATION

• The part should be placed on a non-stick material (wax paper, Teflon, etc.) or it will adhere 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.

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 epoxy 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 zp250 parts see Chapter 3, *Using zp250 Powder.*

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.

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*.**

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.

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.

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.

Safety Precautions

- Liquid wax is hot and may cause burns. Follow all recommended safety precautions for your Z Corp. Waxer.
- Wear gloves when handling hot parts.

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 liquid wax tank (follow all tank manufacturer's instructions).
- Remove infiltrated part from waxer.
- 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.

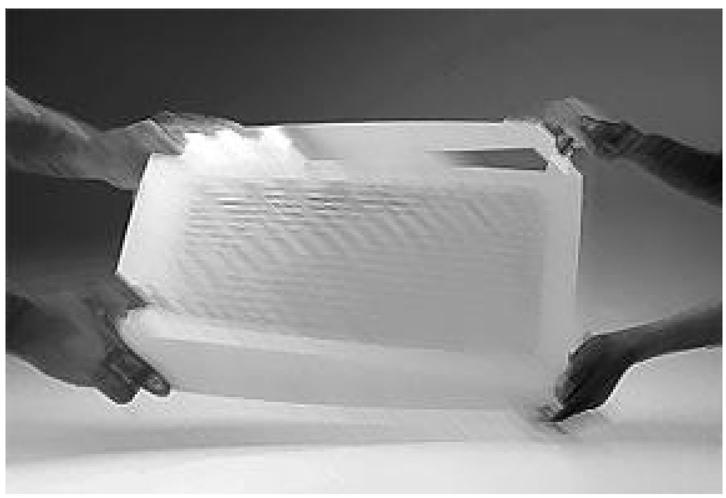
Curing Information

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

CHAPTER 7

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.

Maximize Versatility
With
ZCORPORATION 3D PRINTERS

FEA Analysis
- Move from digital 2D representation to 3D model to assist in part and tooling design
- Boost communication among project teams and aid in the discovery of design flaws early in the design cycle
- Create physical models directly from most FEA packages using a VRML file export

Presentation Models
- Enhance models with paint & decals to produce exact production replicas
- Sell your design to the project team with 3D models
- Provide demonstration models for your sales people and customers

Investment Casting
- Benefit from the fastest method of pattern creation while using traditional lost pattern methods for casting
- Fabricate patterns for low production quantities without making pattern tools

Elastomeric Parts
- Create flexible prototypes quickly
- Prototype most any flexible part including gaskets, tubing & shoes

Functional Prototypes
- Test your designs in real-time before production
- Machine, drill and tap prototype parts to be assembled with manufactured production parts
- Utilize Z Corp.'s high end Z-Kote™ infiltrants to withstand high temperature, humidity, impact and vibration

Electroplated Parts
- Deliver a prototype with the appearance of a polished metal part
- Produce parts with corrosion resistance, electrical conductivity and solderability

ZCast™ Direct Metal Casting
- Quickly prototype metal parts by directly printing molds & complex cores
- Eliminate costly pattern & tool production for prototype castings
- Produce production run casting cores
- Cast difficult geometries without the need for patterns

Tooling Checks
- Save time and money by identifying potential changes to product designs requiring expensive tools

RTV Molding
- Quickly create patterns for RTV molding with excellent surface finish to produce a wide range of cast urethane parts

Concept Modeling
- Create physical models directly from digital data in a few hours
- Solicit feedback from focus groups using near net shape 3D models
- Easily jump to 3D when communicating design ideas

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Applications Support: applications@zcorp.com

ZCORPORATION

Gluing multi-piece parts

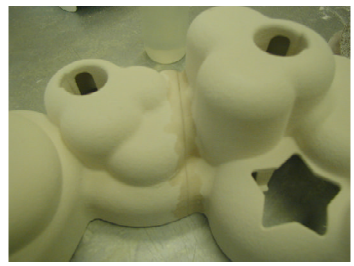
Instructions:

1. Remove, depowder, and dry parts out of printer as described in Chapter 6, *Post Processing 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.

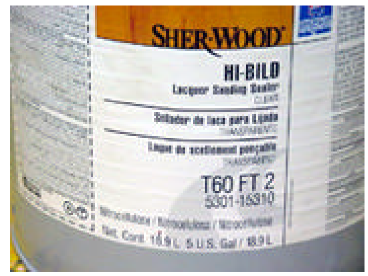
Painting Parts

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).



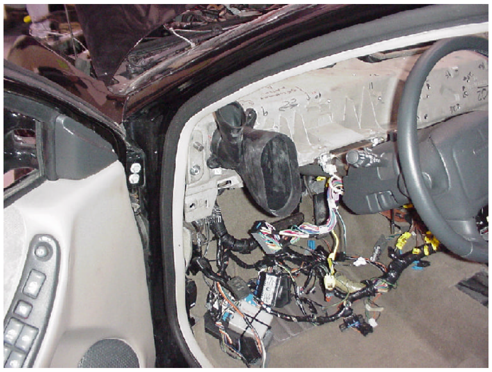
4. Infiltrate with one coat of BCC Proto-Kast urethane mixture by dipping, dripping, or brushing.

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

6. Apply laquer 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.

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 (minimum)

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.

Electroplating

Parts printed on the ZPrinter 310 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, as well as 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 uncoated. 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 Jason Channell at Associated Electroplaters, Inc. Phone Number (248) 547-5520.

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.

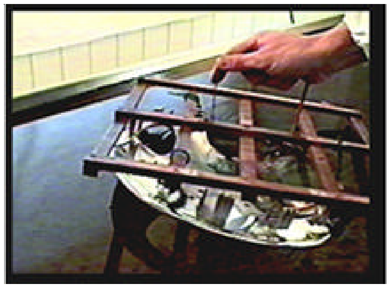
There is some equipment to purchase and set-up to be able to perform this printing process in-house, however there are several service bureaus that will dip parts for a fee. Any image can be transferred to the object, however, standard patterns and color combinations prevail at most service bureaus. 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. <u>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.</u>

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.

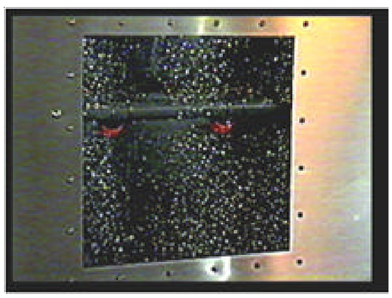
Priming: Z Corp. parts should be primed and painted in a base color (e.g. brown for parts which are to be printed in a wood grain decor).



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 30°C. The film dissolves and only the ink image remains floating on the water.

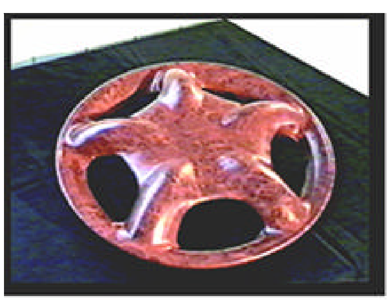
Activating: The ink is sprayed with an activating material so that it becomes adhesive. After spraying with activator, the ink must sit for 3 minutes.

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

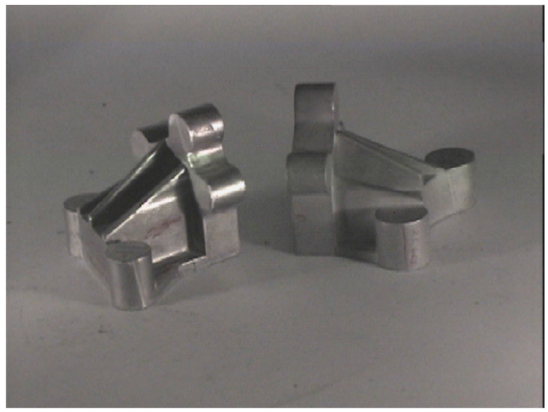
Suppliers / Service Bureaus

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.**

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 Corp. 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 Corporation 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 Corporation 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 Corp. 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 Corp. 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.

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.

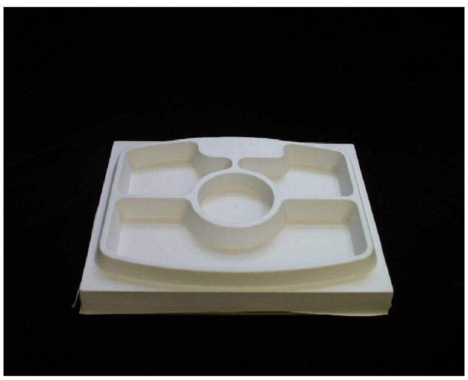
6. Let the parts sit on wax paper to cure. Make sure excess material is not dripping into a puddle on the wax paper. This will be difficult to remove after it cures.

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" or 0.15 mm) 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.

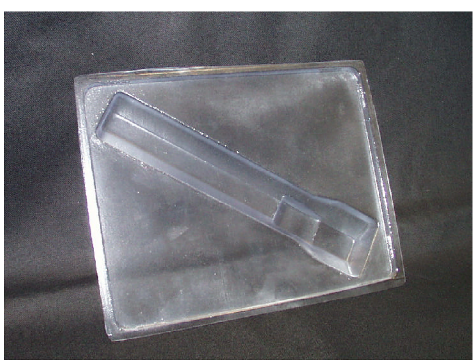
In the example below, the industrial designer wanted to get a feel of his design in the actual material. He was able to generate a mold and produce a sample in a period of days.



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.

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.

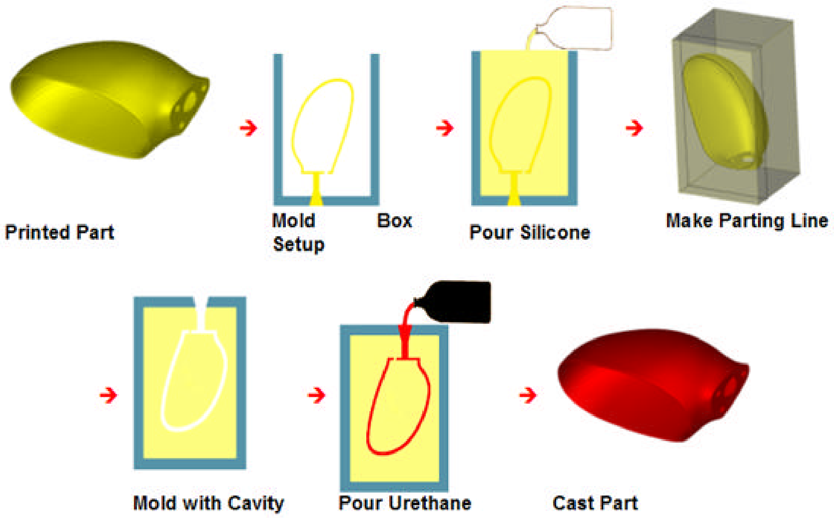
RTV molding requires the production of a single master pattern, which is encased in low durometer[4] silicone rubber. Using a part printed on a Z Corporation 3D Printer is the fastest and least expensive method for creating a pattern for RTV molding. Once the silicone rubber, encasing the pattern, cures (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.

Process Overview



[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.

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[1]. 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.

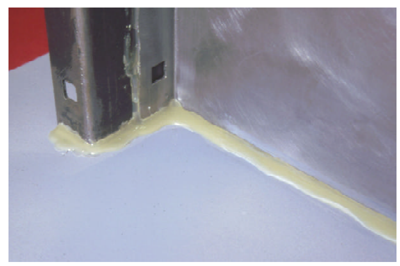
Platinum catalysts have a cure cycle that can be accelerated with heat and have virtually no shrinkage, however they have a higher durometer.

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, Plexiglass, 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.

Preparing and Pouring the Silicone Mold

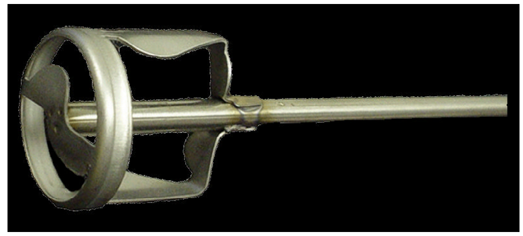
Preparing the silicone is relatively easy but must be performed properly to ensure a good mold. Pay close attention to the mix ratio of the two components of the silicones. Be sure to prepare a large enough volume to completely encase the pattern. The open time[2] of RTV silicone is typically 1-2 hours (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.

[1] 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.

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

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)

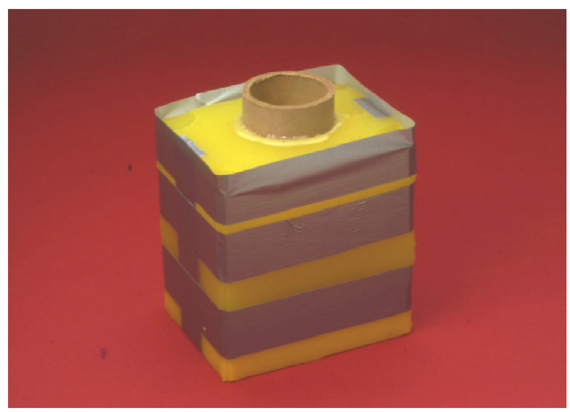
Removing the Master Pattern and Creating the Parting Line

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[1] from the cast urethane).

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

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

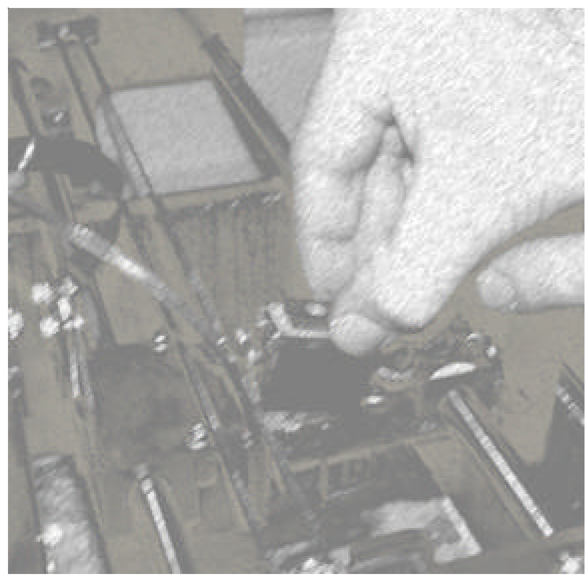
RTV molding is an extremely efficient method of generating multiple parts with thermoplastic properties. There is no faster method of generating the master pattern than with a Z Corp. 3D Printer, which will reduce the overall time it takes to get your final cast part. Whether a Z Corp. 3D Printer is 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.

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

CHAPTER 8

MAINTENANCE

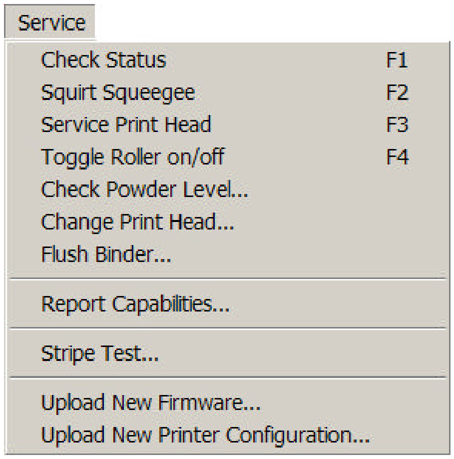
THIS CHAPTER COVERS ROUTINE MAINTENANCE STEPS AND PROCEDURES THAT ARE RECOMMENDED TO KEEP THE ZPRINTER 310 OPERATING IN OPTIMAL CONDITION. IT INCLUDES PROCEDURES ON CHANGING THE PRINT HEAD, OILING THE FAST AXIS, FILLING THE WASH FLUID RESERVOIR, AND GREASING THE SLOW AXIS AND PISTON SCREWS. IT WILL ALSO EXPLAIN THE PROCESS OF CHANGING BINDER FLUID, AND BLEEDING AIR FROM THE FLUID SYSTEM.



FOR INFORMATION AND GUIDANCE ON ADDITIONAL MAINTENANCE STEPS, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781) 852-5050, TOLL-FREE AT (877) 88-ZCORP OR VIA EMAIL AT SERVICE@ZCORP.COM.

Changing Print Heads

The life of a print head usually exeeds 30 billion pixels. If you begin to see striping on your part or if your part is weak, it is time to change the print head. The ZPrint Software will also alert you if the print head may not last through the complete build.



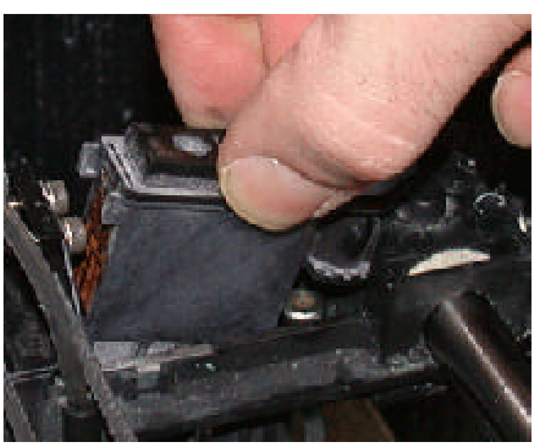
Technical Tip...

If you fill the binder tank when you change the print head, you will not have to fill it again until you change the print head again.

1. Select the ‘Change Print Head’ option under the Service menu in the ZPrint Software. Then press ‘Start’ to begin the print head change process.

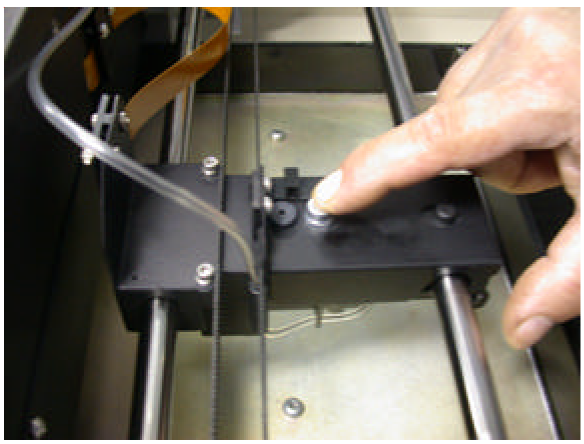
2. Wait for carriage to stop moving, then lift the top cover of the printer.

3. Lift the carriage cover to expose the print head. Slide the latch back to disengage and open the cover.



4. Remove the print head by holding the printhead on two sides and pulling it directly up.

6. Place the new print head in the carriage and push down to secure the print head. The print head should seat firmly in the carriage.



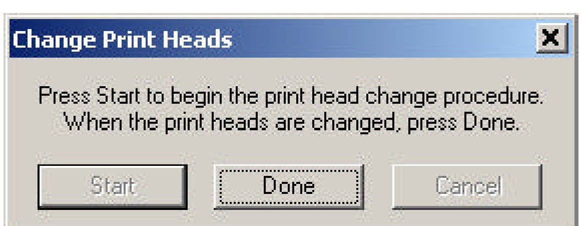
7. Close the carriage cover and press on the carriage cover lock until it clicks to ensure the cover is properly latched.

8. Close the top cover of the printer.

9. Press ‘Online’ on the control panel or ‘Done’ in the software when complete.

10. Fill up the binder bottle.

11. Make sure waste bottle is empty.



12. To purge the print head of HP ink choose the ‘Purge Print Head’ option under the ZPrinter 310 Service menu. When the purge cycle is completed. The printer will stop beeping.

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.

Cleaning Pogo Pins

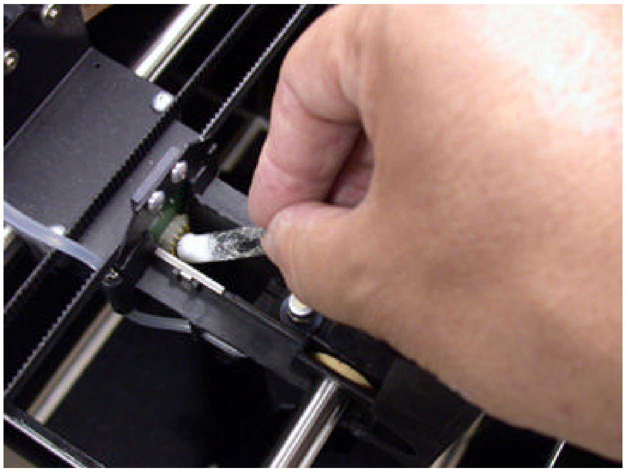
In general, there is no need to clean the pogo pins upon replacing the print heads. At times, they may need to be cleaned due to errors in communication between the print head and printer (such as when receiving Head ROM errors) or when it is dirty.

To clean the pogo pins, follow the instructions below:

1. Use the alcohol swabs which can be ordered from Z Corporation (part number 12073).

2. Remove the alcohol swab from the packaging.

3. Crush the plastic casing to release alcohol into the swab.



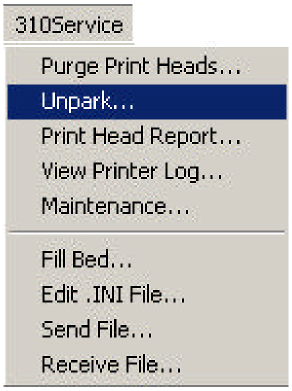
4. Open the carriage cover.

5. Wipe the pogo pins.

6. Close the carriage cover.

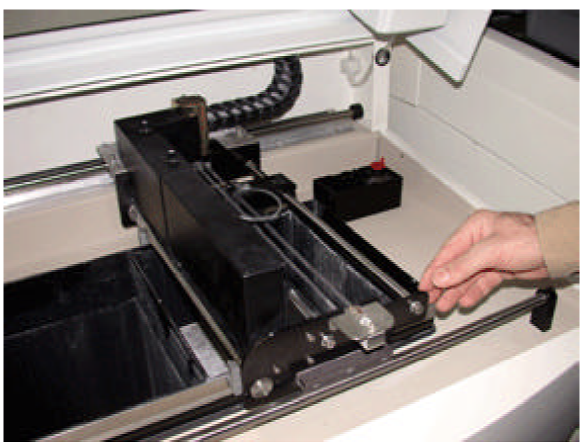
Oiling the Fast Axis

The ZPrint Software will alert you when it is time to oil the fast axis if the maintenance reminder feature has been enabled. **Warning: DO NOT use grease on the fast axis.**



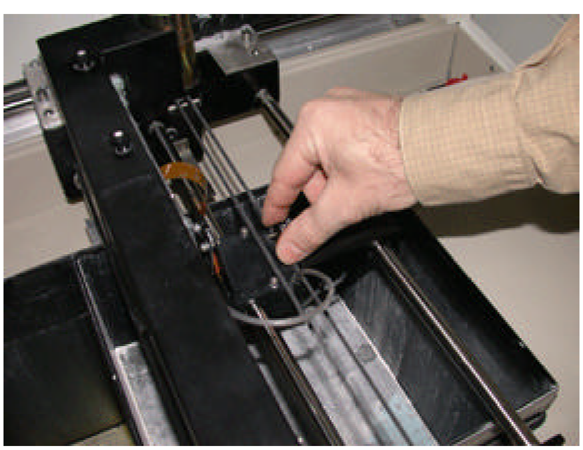
1. Select the 'Unpark' option in the ZPrint Software under the 310Service menu.

2. Take the printer offline.

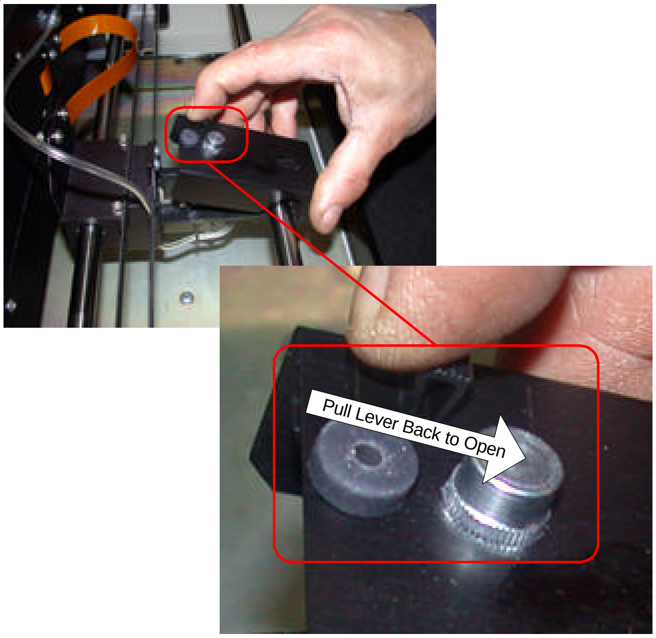


3. Lift top cover.

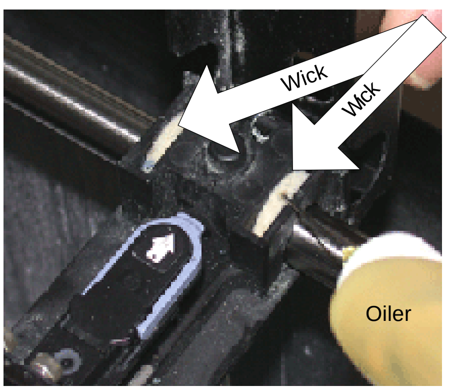
4. Manually move the gantry to the middle of the printer.



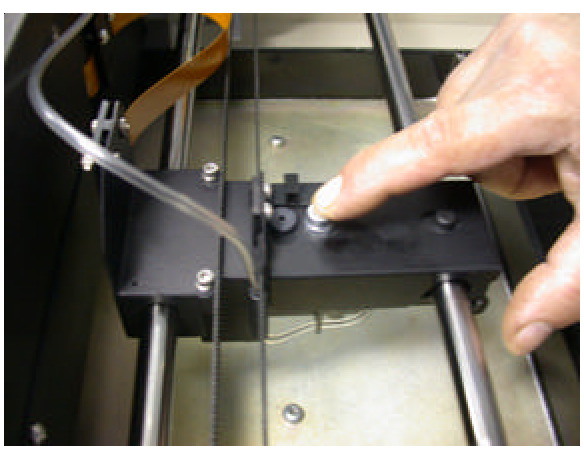
5. Manually move the carriage to the middle of the printer.



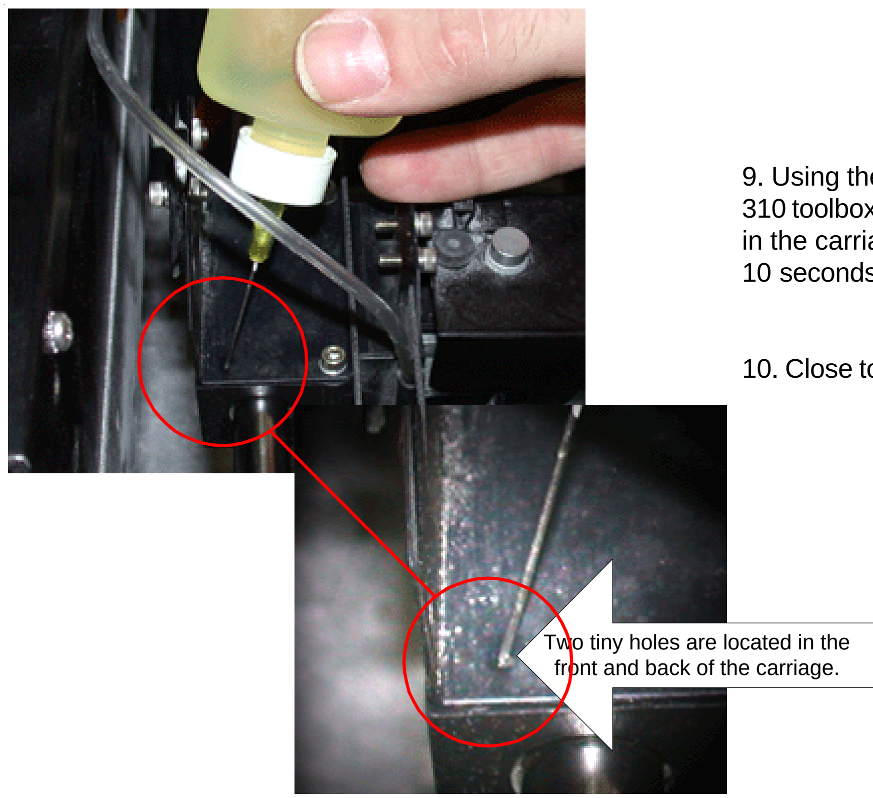
6. Lift the carriage cover to expose the two oil wicks, located on the right side of the print head.



7. Using the oil canister supplied in the toolbox that accompanies each ZPrinter 310 System, squeeze oil onto the wicks until saturated - approximately 10 seconds.



8. Close the carriage cover and press on the carriage plunger until it clicks.



9. Using the oil canister supplied in the ZPrinter 310 toolbox, squeeze oil into the two holes found in the carriage above the fast axis rail for about 10 seconds.

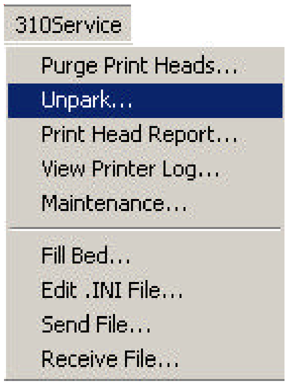
10. Close top cover.

11. Place the printer back online.

12. Press ‘OK’ to repark the gantry.

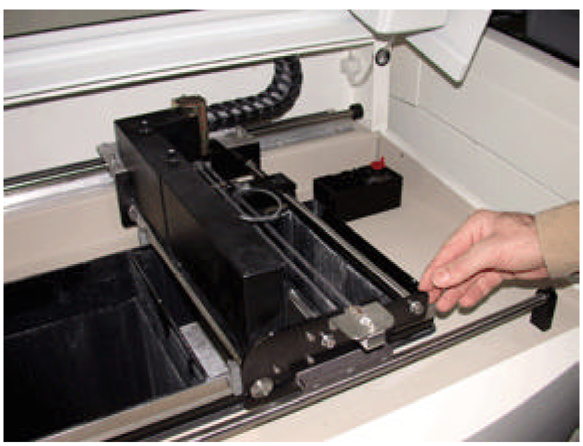
Refilling the Wash Fluid Reservoir

Refill the wash fluid reservoir with zc10 wash fluid when alerted by the ZPrint Software, or refill if the wick on the service station has dried out. One bottle of wash fluid will fill up the entire reservoir. The ZPrint Software will alert you when it is time to refill the wash fluid if the maintenance reminder feature is enabled.



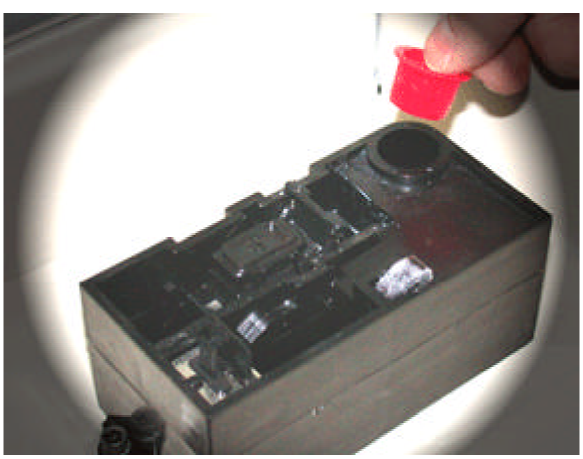
1. Select the ‘Unpark’ option in the ZPrint Software under the 310Service menu.

2. Take the printer offline.



3. Lift the top cover of the printer.

4. Manually move the gantry to expose the service station.



5. Remove the red wash fluid reservoir cover.

6. Refill the reservoir using the wash fluid supplied in the toolbox. One bottle will fill up the reservoir. Remember to reorder zc10 wash fluid.

7. Close the top cover of the printer.

8. Put printer online.

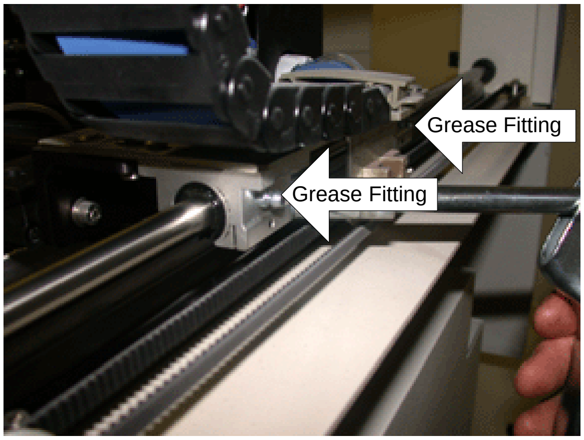
9. Press ‘OK’ on the ZPrint Software to re-park the gantry.

Greasing the Slow Axis

The slow axis will need to be greased occasionally to prevent slow axis errors. The ZPrint Software will alert you when it is time to grease the slow axis if the maintenance reminder feature is enabled.

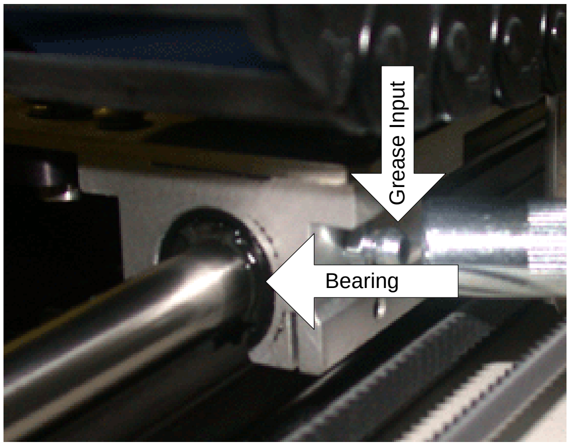
If this is the first time greasing the slow axis, assemble the grease gun. Follow the instructions on the packaging.

1. Remove the back cover of the printer, by removing seven screws.



2. Locate the two grease fittings.

3. Snap the grease coupler onto the fittings.



4. Add grease until it begins to come out the side of the bearing (typically two pulls of the trigger).

5. Replace the back cover of the printer.

6. Store grease gun for future use.

Greasing the Piston Screws

The ZPrint Software will alert you when the build and feed pistons need to be greased if the maintenance reminder feature is enabled. More information on this feature can be found in the ZPrint Software Manual.

1. Lower both the feed and build pistons all the way down.

2. Turn off and unplug the printer.

3. Remove the overflow bucket and locate the two piston screws.

4. Take grease supplied in the toolkit and apply grease onto entire the length of both feed and build piston screws.

5. Take a paper towel and lightly wipe the feed and build piston screws in order to distribute grease.

6. Replace the overflow bucket.

Changing Binder Tank

At times, you may choose to change material systems. You may use a second binder tank to facilitate the change over.

1. Carefully lift and move the binder bottle towards the front of the printer.

2. Press release latch and pull the tubing out.

3. Insert tubing into latch from new binder bottle and secure binder bottle in place on top cover.

4. Perform bleed air procedure to remove old binder and air from tubing.

5. Purge or change the print head to flush the remaining old binder from the fluid system.

Changing Binder Color

Add the following mixtures of color binder to the ZPrinter 310 feed bottle (3/4 full with clear binder) to achieve your desired color. These ratios are based on the 1.5 liters of clear binder in the feed bottle prior to adding any color.

	Quantity of Color Binder Added to Feed Bottle with Clear Binder			
Desired Color	Cyan	Magenta	Yellow	Black
Red	-	18 Squirts	9 Squirts	-
Magenta	-	18 Squirts	-	-
Orange	-	3 Squirts	12 Squirts	-
Yellow	-	-	18 Squirts	-
Green	3 Squirts	-	12 Squirts	-
Blue	18 Squirts	3 Squirts	-	-
Violet	9 Squirts	18 Squirts	-	-
Gray	-	-	-	6-12 Squirts

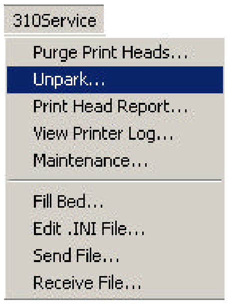
Hold the color binder bottle, with pump attached, up to the opening of the ZPrinter 310 feed bottle and add the desired amount of color binder. Each squirt is approximately 1 ounce of binder.

Darker or lighter shades of colors can be achieved by adding more or less of the corresponding desired color ratio (pink can be achieved by cutting the quantity of total color binder added by two). A part will appear more vibrant after infiltration.

PLEASE NOTE: Higher concentrations of color binder than those stated above will reduce print head life (less than 30 billion pixels). The reduction of print head life will lead to premature head over temp errors and striping during print jobs.

Bleeding Air from the Fluid Lines

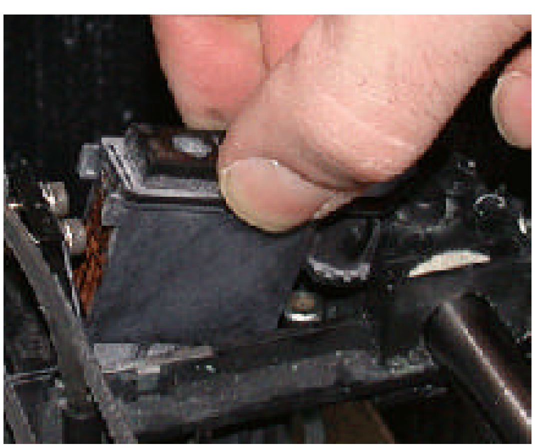
If air gets into the tubing due to inadequate supply of binder or through removing the binder bottle, bleed the air to prevent damage to the print head.



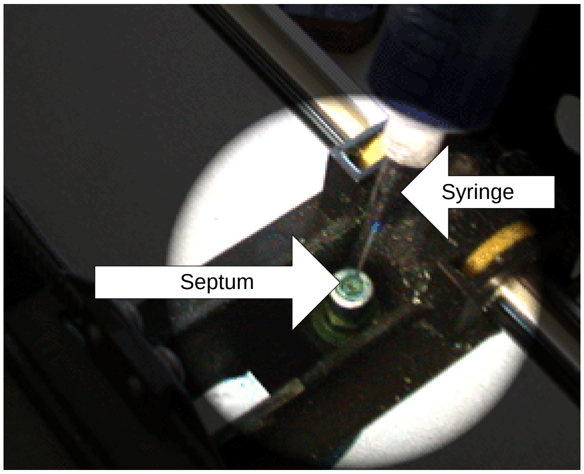
1. Select the ‘Unpark’ option in the ZPrint Software under the 310Service menu.

2. Lift the top cover of the printer.

3. Open the carriage cover to expose the print head.



4. Remove the print head.



5. Insert syringe into septum and remove the air and 10 cc of liquid.

6. When completed, re-insert print head, close carriage cover, close the top cover of the printer, and press ‘Done’ on the ZPrint Software to re-park the gantry.

Machine Status

State	Power LED	Online LED	Error LED	Beep
Off	off	off	off	off
Booting	solid	off	off	off
Online	solid	solid	off	off
Offline	solid	off	off	off
Printing	solid	solid	off	off
Sleeping	solid	slow flash	off	off
Error[1]	solid	off	solid	off
Booted, can’t find network[2]	solid	off	solid	off
Cover open – close to continue	solid	fast flash	fast flash	solid
Cover open – print head not parked	solid	on or off	off	once every 30 seconds
Auto parking	solid	on or off	off	3 fast beeps
Piston auto dropping	solid	medium flash	off	off
Filling bed	solid	medium flash	off	off
Changing the print head	solid	medium flash	off	off
Purging the print head	solid	medium flash	off	slow

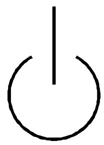
[1] Press the online button to recover from an error. If the error is unrecoverable, the printer will reboot.
[2] Press the online button to revert to serial port communication.

CHAPTER 9
SYSTEM DETAILS

THIS CHAPTER COVERS THE SYSTEM DETAILS AND MATERIAL STORAGE PRECAUTIONS. FOR MORE INFORMATION, PLEASE CONTACT THE Z CORPORATION SERVICE DEPARTMENT AT (781)852-5050 OR TOLL-FREE AT (877)88-ZCORP. OR VISIT THE USER GROUP WEBSITE AT WWW.ZCORP-USERS.COM.

Symbols Used

THE FOLLOWING SYMBOLS ARE USED ON THE ZPRINTER 310 SYSTEM:



This is the international symbol for ‘standby power’. It is used on the ZPrinter 310 power switch. The 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.

System Specifications

Operating Conditions: 68 to 85ºF (20-29ºC), 20 to 60% Relative Humidity, non-condensing.

Lithium Battery: Internal to the ZPrinter 310 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 <u>not</u> in a user accessible area and is <u>not user replaceable</u>. 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.

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.

INDEX

ZCast™ Direct Metal Casting

DESIGN GUIDE

September 2003

Table of Contents

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 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.

2 Cautions & Warnings

2.1 CAUTION

- **MOLD MUST BAKED DRY PRIOR TO POURING**
- **DO NOT INFILTRATE THIS MATERIAL WITH RESIN OR WAX!!**

ZCAST PARTS 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, RISKING SERIOUS PERSONAL INJURY OR DEATH!! CAREFULLY READ THIS DOCUMENT BEFORE ATTEMPTING TO USE ZCAST POWDER.

2.2 WARNING

NO ATTEMPT SHOULD BE MADE TO POUR FERROUS METALS IN ZCAST 500 MOLDS.

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 print 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 often can take several weeks and be prohibitively expensive. These constraints often 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 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 Materials

ZCast 500 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 Z®810 Large Format 3D Printer, the Z406 3D Printer and the ZPrinter™ 310 3D Printers.

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 to 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 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:

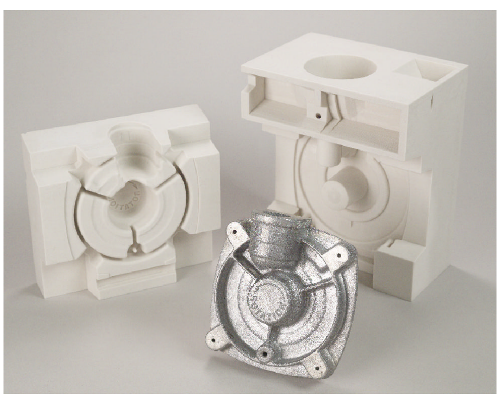


Figure 1: Cover Plate mold and casting

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 manager for a copy). These documents as well as other instructions accompany the mold. The goal of this exercise is to make your foundry comfortable with the ZCast process. You would typically 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 Corporation sales manager to help you locate an experienced foundry.

5 Designing with ZCast – Mold Design

ZCast 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 using other methods. ZCast's unprecedented flexibility allows the designer to choose the technique that's the most proper for the application at hand.

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'll be at designing complex and challenging parts. By contrast, simple parts require simple gating and more straight forward. If you don't have the experience, but have the 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 use. Some of the special properties of ZCast powder affect some of the design considerations, and 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 on during solidification. To make high-quality castings, a strong emphasis should be placed in the design of risers.

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 using the ZCast process 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 ½" 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 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.

The printed mold pieces consist of cores and a uniform shell (at least 12mm or ½" thick) 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.

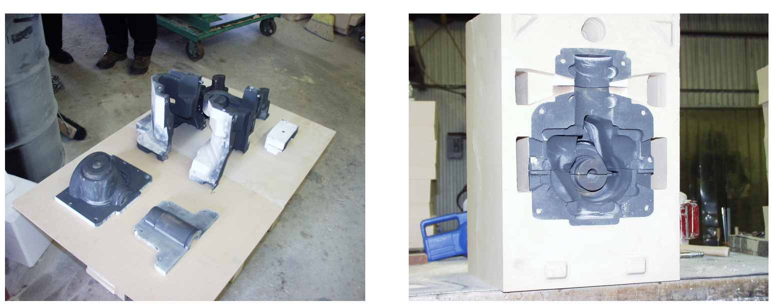


Figure 4: Shell Method – ZCast components of a shell mold (left). Assembled mold with ZCast components packed in foundry sand. Note the risers, runners and sprue have been formed in the foundry sand (right).

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 Corporation 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 ZCorp materials; most preferably with zp100-series plaster-based materials as shown below[1].

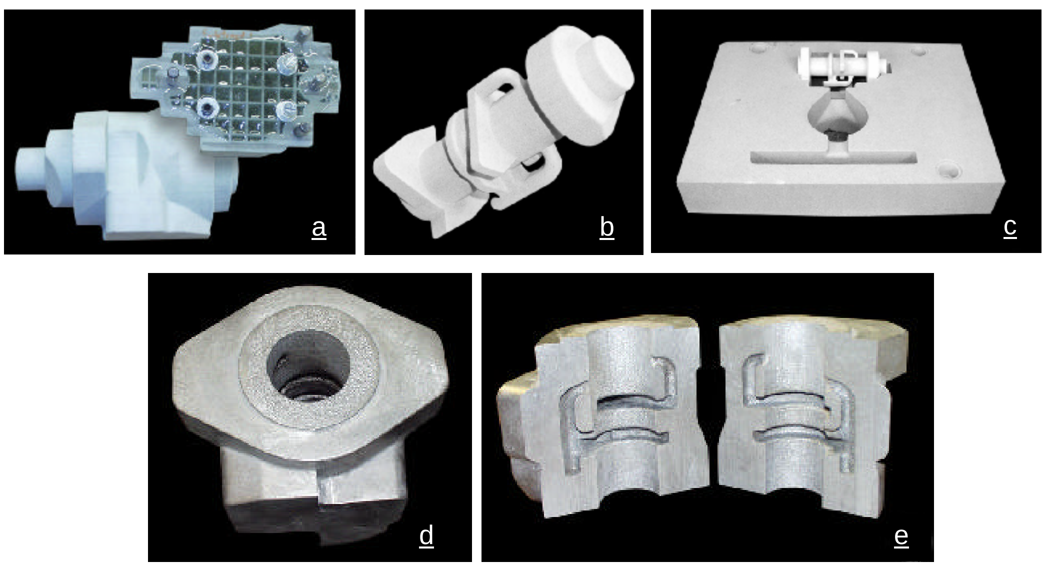


Figure 5: Combination Method – a) zp102 patterns infiltrated and backed with epoxy; b) ZCast500 core; c) traditional foundry sand mold half with ZCast core; d) and e) finished casting.

5.3 Designing Molds in your CAD System

Regardless of the method you select, it's 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 in the real world from a 3D print.

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

5.3.1 Direct Pour

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 Rapid Prototyping. Processing tends to be much slower when working with .STL files.
2. Add finish stock to machined surfaces, typically .080" (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" (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).

5.3.2 Shell Method

If you plan to use the shell method you'll need to:

1. Begin with steps one through five from previous.
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** command to support unsupported hanging features. ZCast 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 using ZCast as shown in figure 5a.

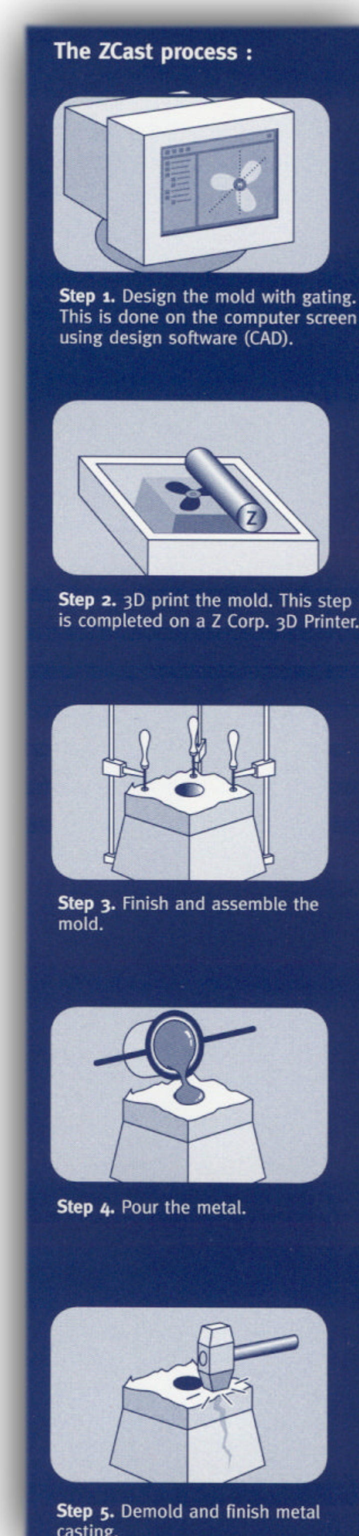


Figure 5: Steps involved in using ZCast

6 Design Techniques with ZCast

6.1 Direct Gating

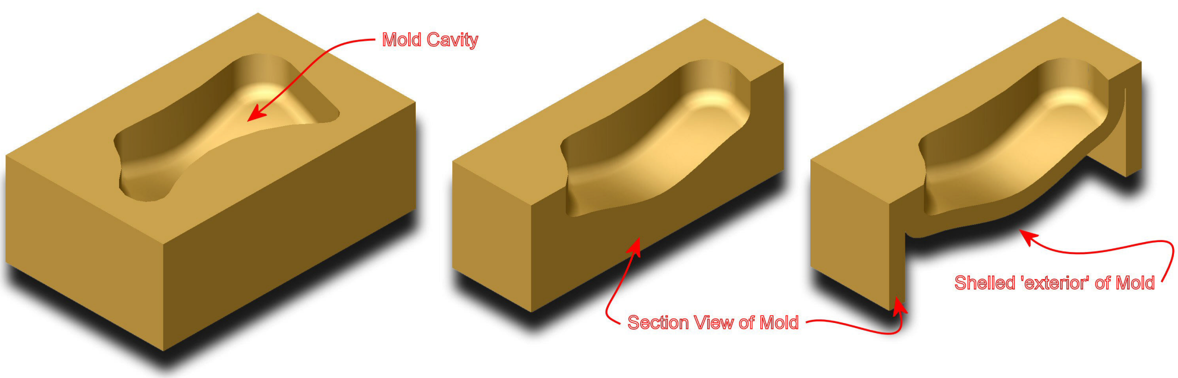
Conventional methods of runner design are based on having a flat pattern that must be drawn out of a sand mold. This forces the runners and gates out sideways resulting in a mold that covers a larger area. Such a design can exceed the size of the build volume of the printer. Consider bypassing the runner 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's quite possible that your molds will exceed the size of the build volume of your Z Corp. printer. Multiple sections of the mold can be printed and assembled seperately. Use core paste between the shell seams to 'bridge' the shell section together. Clamp the mold halves together with dowel pins for alignment.

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, 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's easier for the heat to thoroughly disperse throughout the mold.



Figures 6a: Unshelled solid

Figures 6b: Unshelled section view

Figures 6c: Shelled section view

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 (½") in thickness (for ZCast 500). Rib spacing is subjective however, as a guideline, distances greater than four inches (4") should not be spanned without placing a rib in between walls or adjacent ribs.

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

Arching is a phenomenon that occurs on the first few layers printed. It diminishes as the part continues to build. To minimize arching, print the non-critical faces of your mold facing downwards.

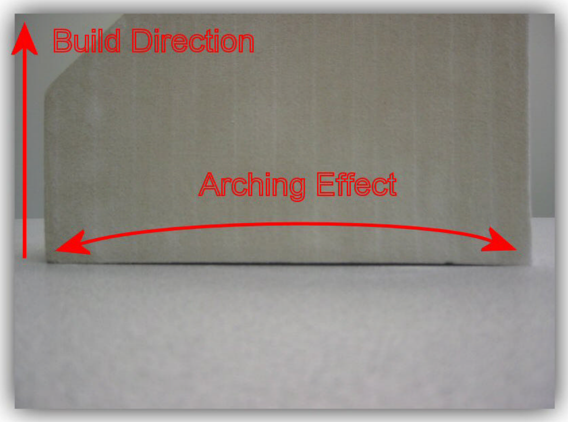


Figure 8: Arching

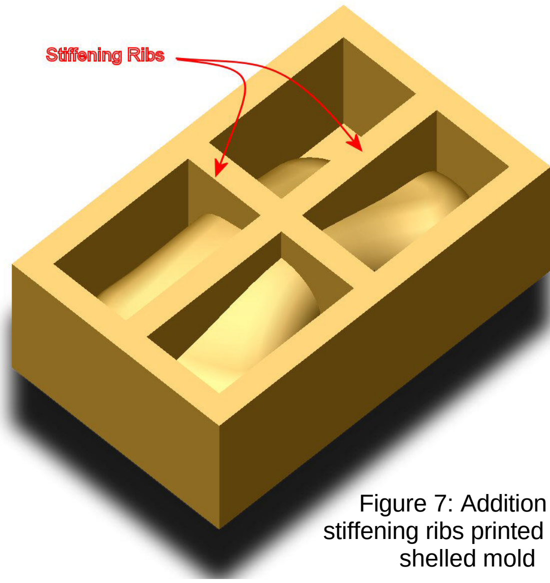
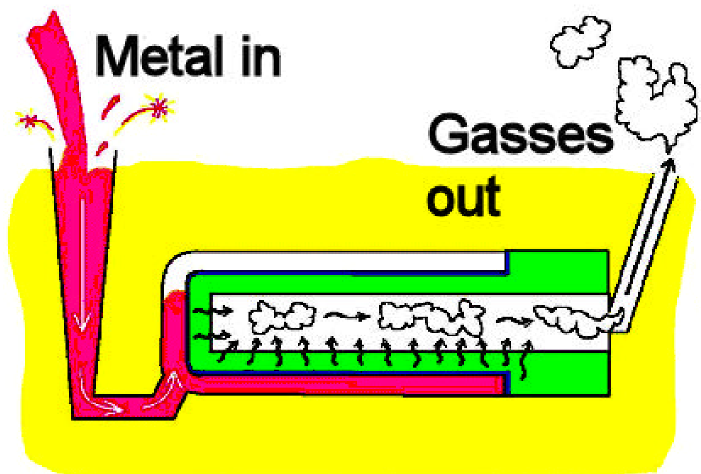


Figure 7: Addition of stiffening ribs printed in the shelled mold

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 on the casting) extending through the cope to the atmosphere. These are often small enough (.125" (3mm) 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 were solid, the gas would have nowhere to go but 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. The core vents should be

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 .250" (7mm) wall thickness where possible.

- Any single wall of the core should be no thicker than .500" (14mm), or thinner than .140" (3.5mm). very slender cores with thinner walls are possible over short lengths, distortion will limit how long they can be.

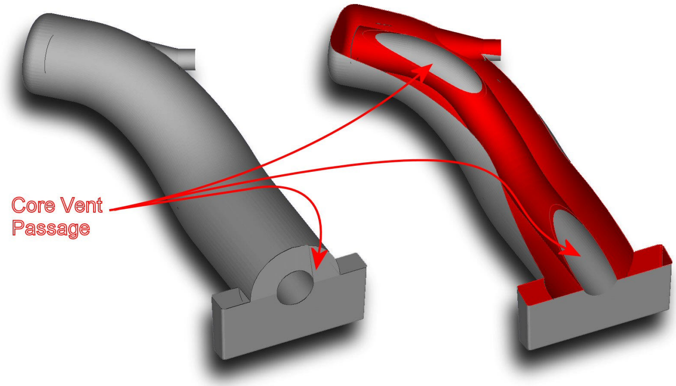


Figure 9: Venting the core

- 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).

- Depowdering very contoured core vents can be a challenge if 3mm DIA vents curve into a tight radius

6.5.2 Venting the Mold

- For the majority of the mold, there should be least a 0.500" (14mm) wall thickness between the metal and the outside of the mold.

- 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.

- Vents should be approximately .125" (3mm) in diameter and open to the atmosphere.

- Vents DO NOT need to break through to the casting surface. If they pass to within .1" to .2" (2.5 to 5mm) from the casting surface, the gas generated inside should permeate through except in extreme cases.

- 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.

- 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 the foundryman to "improvise" the venting of the mold in this manner.

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.

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 removed 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.

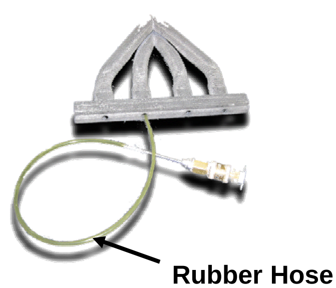


Figure 10: Attach a **flexible plastic** hose like the one shown above to reach ‘blind spots’

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” O.D. and 1/16” I.D. urethane tube is ideal because it slides firmly over the nozzle on the ZD4™ or ZD8™ depowdering units.

6.8 Mating Surfaces

The mating surfaces of the mold should be offset to accommodate for surface imperfections. *A total gap of 0.020" (0.5mm) 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 radius 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.

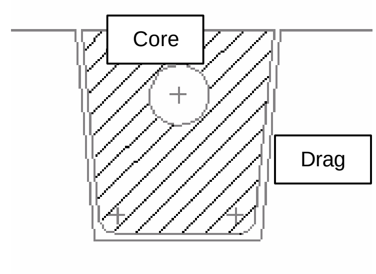


Figure 11: Tapered core and core print. Core has radiused bottom edge. Add offset between mating surfaces.

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 500 molds, the following are the geometric limitations:

- Minimum core size – 3.5 to 4.0mm. some distortion will occur of small cores project across large distances.
- Minimum cast feature size (positive feature) – 3.0mm (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” (12mm) thick, and no more then 1” (25mm) 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” (12mm) thick.
- Maintain large enough areas for clamping.
- Use off the shelf pouring cups and risers

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 integral as part of your ZCast mold. Be sure to make allowances for filter insertion to help alleviate impurities when pouring.

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 printer and the ZPrint System Software Manual.

- When choosing your powder type (in “3D Print Setup”), simply select ZCast 500 from the powder list (it will show up on the list for any printer that is capable 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. This will not affect the rest of the part, so putting non-critical surfaces down will eliminate any risk.

- 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.

- 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 500 powder with zb56 binder:

Saturation Settings	
Shell	1.4
Core	0.7
Layer Thickness	0.004"

Bleed Compensation Settings	
X	0.018
Y	0.018
Z	0.018

Table 1

6.14 Degassing and Filtering Metal

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.

Figure 12: Refractory sleeves and filters

[3] See Table 1
[4] See Figure 8

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

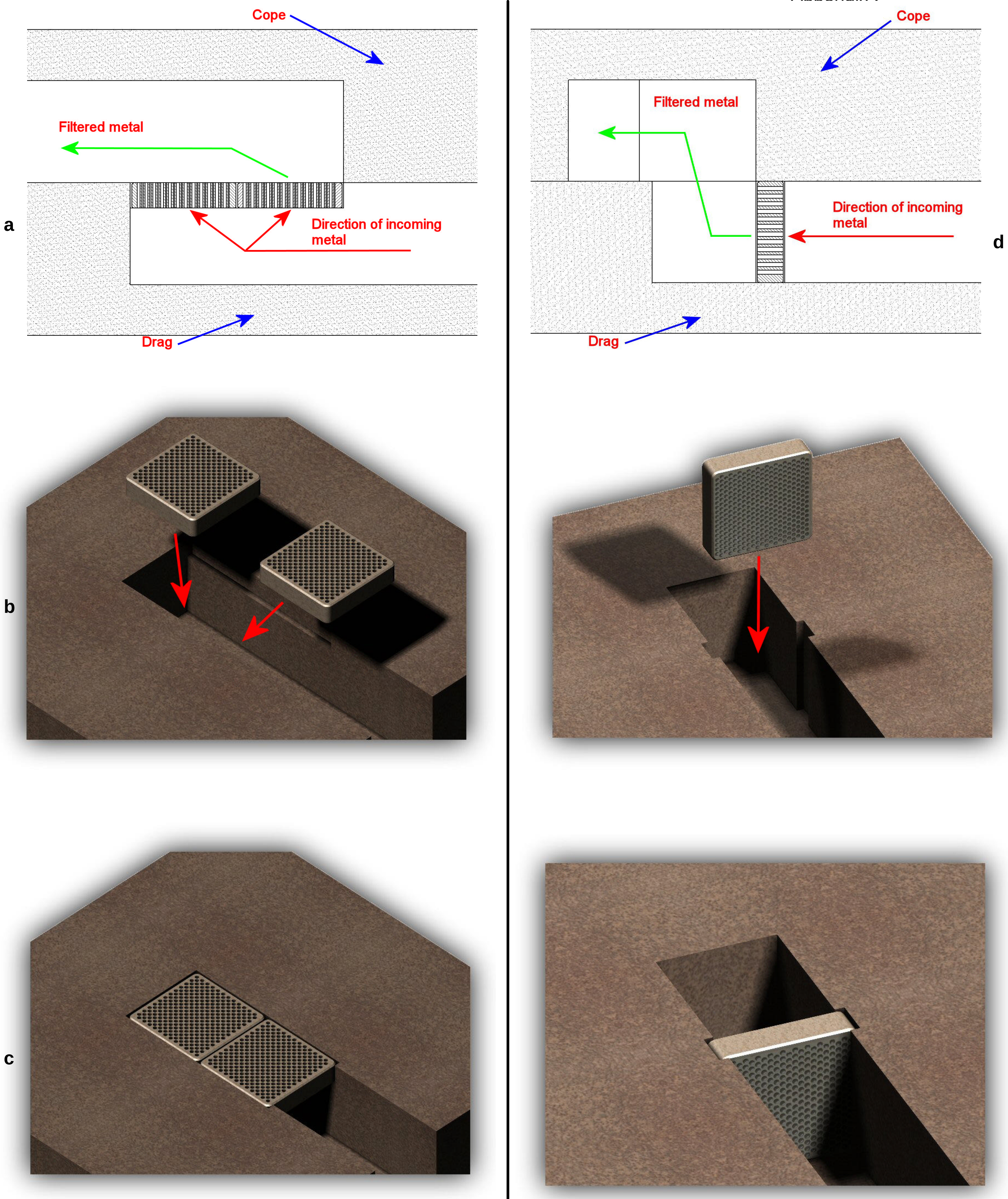


Figure 13: a,b,c: Horizontal filter orientation – Metal rises up through filters (maximum are achieved with horizontal placement.
d,e,f: Vertical filter orientation

7 Mold Preparation

After the mold is designed and printed in a Z Corporation 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 180°C (350°F) to 230°C (400°F) 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**.

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

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.

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).

Pour – The mold is now ready for metal.

8 Pouring Metal

8.1 Metal Types

*The current product offering is ZCast 500 powder and is designed for low temperature, non-ferrous metals (**MAX TEMP 1100°C (2000°F)**).* The higher the temperature of the metal, the more gassing on contact there will be. It becomes a serious risk that the mold will gas violently, potentially exploding, as these temperatures are exceeded. Therefore, do not attempt to pour non-ferrous metal into ZCast 500 molds.

Z Corp. tested and approved materials:

Alloy	Pouring Temprátures	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 500 MOLDS

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.

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

9.3 Powder Recycling

Unprinted ZCast material can be recycled. Z Corp. recommends that you add approximately 30% new powder with recycled powder.

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

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 .080" (2mm)). Holes may need to be drilled out and tapped. The surface may be bead blasted or sand blasted. Castings may be heat-treated.

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.

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's 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 is 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**

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.

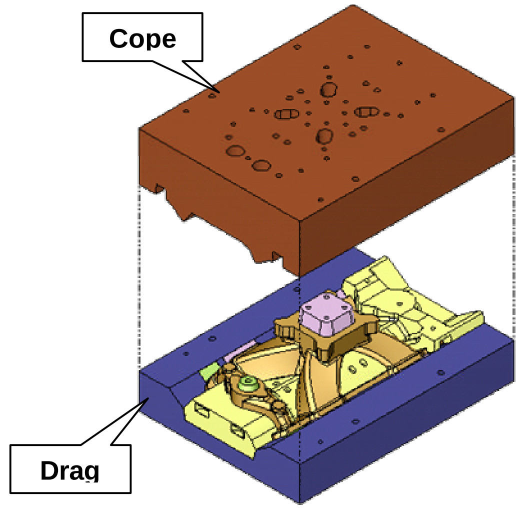


Figure 15: Cope and drag – manifold

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.

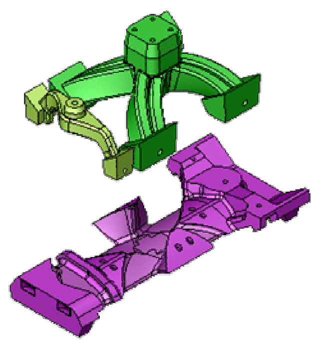


Figure 16: Cores for manifold casting

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 cores 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.

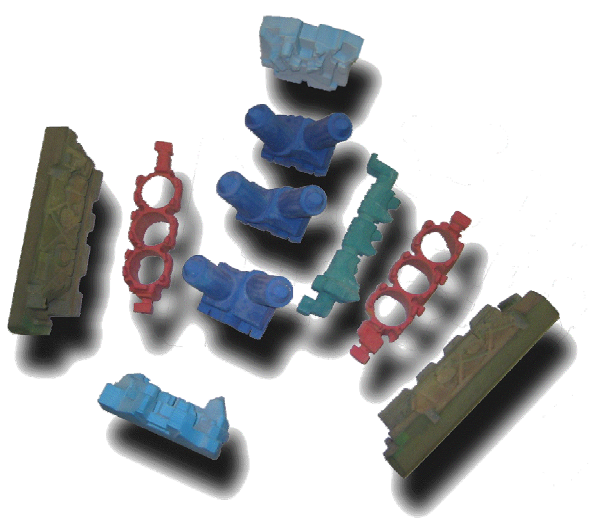


Figure 17: Multi-piece core

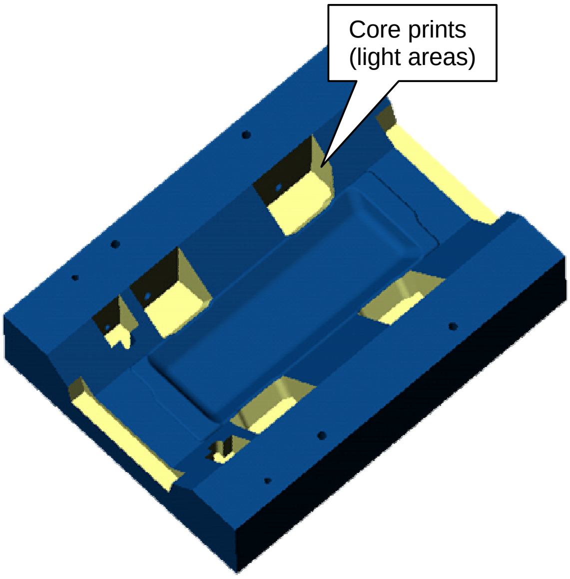


Figure 18: Core prints – pockets where cores lock in place (drag of manifold from figure 15)

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 better optimize the feeding of metal into the mold and minimize the amount of turbulence produced in the metal stream.

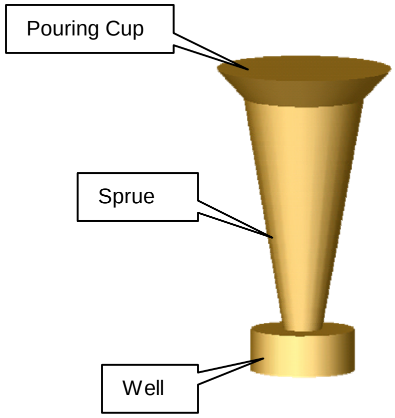


Figure 19: Pouring cup, sprue and well. The well is typically where the filter would be placed

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 thould be at least 4" 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.

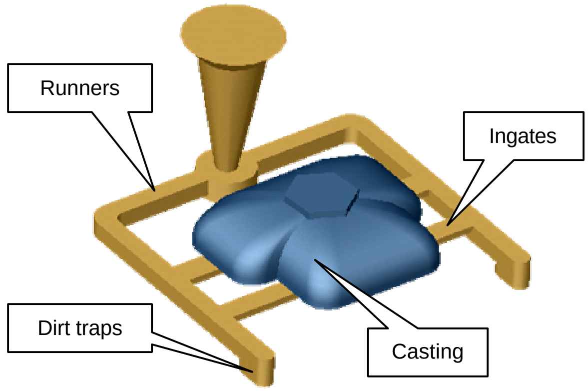


Figure 20: Runners lead out from the well. Ingates connect the runners to the casting. Runners dead end at dirt traps.

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.

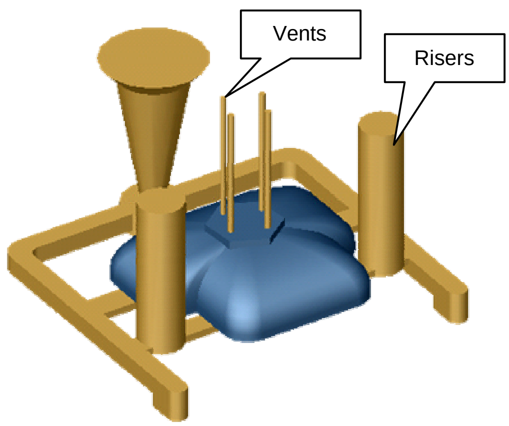


Figure 21: Risers are often placed at the ingates, but could be put anywhere. Vents are shown coming off the high points. Their diameters are small, so they will likely freeze off before they reach the upper surface of the cope.

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

For more on risering 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

With the information in this document, the design and pouring of your prototype metal parts is only a step away. If you or your foundry has questions about any of the information contained herein, or need additional information, please contact us:

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