FDM Support Removal

1. Materials Overview

FDM (fused deposition modeling) Technology™ lets you 3D print parts in a broad range of well tested plastics. FDM materials offer specialized properties like toughness, elastomeric flexibility, electrostatic dissipation, translucence, biocompatibility, UV resistance, VO flammability and FST ratings. This makes them perfect for demanding designers and engineers in aerospace, automotive, manufacturing, medical and other industries.

Stratasys offers a diverse variety of model materials (see Table 1-2) which are used in conjunction with two types of FDM support materials. Soluble Release Support (SR) material can be washed away in a solution of heated-water and a cleaning agent, while Breakaway Support Structures (BASS) are manually removed. Notable differences between soluble support and BASS materials are as follows:

Support Materials Comparison	
Soluble Support	**Breakaway Support Structures (Bass)**
SR-20, SR-30, SR-35, SR-100, SR-110, QSR, P400-SR	PC-BASS, PPSF-BASS, ULTEM™ 9085 resin support material, ULTEM™1010 resin support material, SUP8008B, P400-R
Supports wash away in a detergent bath	Supports removed manually
Build internal cavities/channels	Do not require the use of a tank
Hands-free support removal	Faster for simple support structures, which may require the use of hand tools to reach and remove all support material and may be time consuming

Table 1-1

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Materials Highlights	
Model Material	**Support Material**
ABSi	Used with SR-20 support material
ABS_ESD7	Used with SR-30 support material
ABS-M30	Used with SR-20, and QSR[1] or SR-30 support material
ABS-M30i	Used with SR-20 or SR-30 support material
ASA	Used with SR-30 and QSR[1] support material
Antero 800NA	Used with SUP8000B support material
FDM Nylon 6	Used with SR-110 support material
FDM Nylon 12	Used with SR-110 support material
FDM Nylon 12CF (carbon fiber)	Used with SR-110 support material
PC-ABS	Used with SR-20 and QSR[1] support material
PC	Used with SR-100 or PC-BASS support material
PC-ISO	Used with PC-BASS support material
PPSF	Used with PPSF-BASS support material
FDM TPU 92A*	Used with QSR[1] support material
ULTEM™ 9085 resin	Used with ULTEM™ 9085 resin support material
ULTEM™ 1010 resin	Used with ULTEM™1010 resin support material

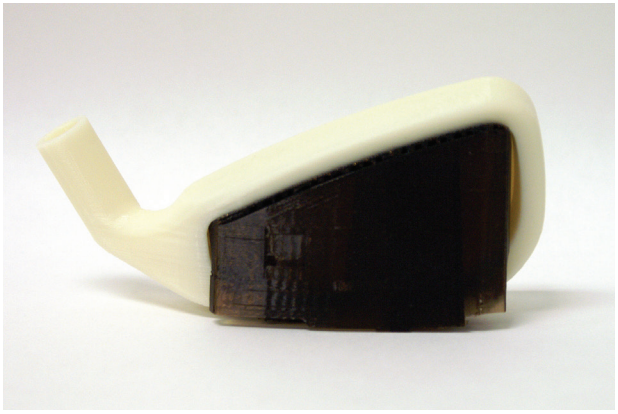
[1] QSR material is used on the F-Series printers only.

*Note: It is recommended to tank-clean FDM TPU 92A parts for optimal surface finish. However, tank immersion may cause swelling up to 0.5% resulting in the part temporarily being out of dimensional tolerance. Parts will shrink back to nominal size, but it may take up to 72 hours for this to happen depending on part size and geometry.

1.1 SR vs. BASS

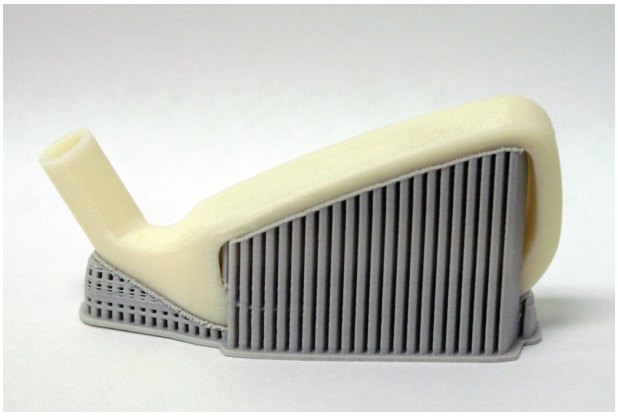
Soluble Release (SR) support materials are very similar; however, they do offer some differences:

- SR-20 tends to discolor the support removal solution faster than SR-30.
- SR-30 is less likely to shatter and dissolves 69% faster than SR-20.
- SR-30 doesn't expand as much as SR-20 in solution. Therefore, fragile parts won't break from support expansion.



SR-20

SR-30



BASS

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- SR-35 is easier to break off in larger pieces. It also dissolves faster and maintains solution bath life longer compared to SR-30.

1.1.1 BASS Removal Tips

WARNING
Always wear safety glasses and safety gloves when removing support material by hand. The support material can be brittle and may cause cuts when manually broken off.

Breakaway support structures are removed manually, rather than by use of a tank containing a solution of heated-water and a cleaning agent. This method is ideal for parts built using simple support structures. Depending on the part built it may be difficult to reach all support structures in order to break them away, resulting in a greater amount of time spent removing supports. The following tips will help expedite the process of removing BASS.

Tools

The use of hand tools can greatly reduce the amount of time spent removing BASS from finished parts (suggested tools shown below). However, care should be taken to ensure that you do not scratch or gouge parts when using tools. For fragile parts, it is always best to take your time in order to eliminate the risk of damaging the part.

You may find that traditional tools are insufficient for removing supports from your parts. If so, you may need to fabricate custom tools to better suit your support removal needs.

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Agitation

Agitation aids in support material removal. Stratasys recommends using either a circulation or ultrasonic tank.

Heat

ULTEM™ resins, PPSF and Antero 800NA support materials are much easier to remove if heated. (PC-BASS does not require re-heating as this material is generally easier to remove than ULTEM™ resins and PPSF supports). Placing a finished part into an industrial oven and allowing the part to heat will make support material easier to remove. However, if you decide to heat a part, do not place low temp parts (such as ABS-M30) into a high temp oven (such as 160° C (320° F)). This can damage the part, possibly making it unusable. Please also keep in mind that the more heating/cooling cycles conducted, the more difficult it will be to remove supports. In general, materials should be heated to the temperatures specified in Table 1-3.

Reheating Specifications	
Model Material Type	**Temperature**
Antero 800NA	Up to 130 °C (266 °F)
ABS-M30/ABS-M30i*	Up to 80 °C (176 °F)
PC-ABS*	Up to 80 °C (176 °F)
PC (with PC-BASS support material)	Up to 100 °C (212 °F)
PPSF	Up to 180 °C (356 °F)
ULTEM™ resins	Up to 160 °C (320 °F)

Table 1-3

* Model material utilizes soluble support material, not BASS. Reheating temperatures are provided as a guideline although support materials are generally not removed by hand.

2. WaterWorks Best Practices

Removing FDM support material incorrectly may affect the physical properties of the model material. Using chemicals that have not been verified to maintain those mechanical properties, immediately and over time, is not recommended. It is always recommended to follow post-processing best practices recommended for that material including time and temperature.

This is why Stratasys recommends WaterWorks. Stratasys has tested the model materials for mechanical properties after soluble support removal using WaterWorks and found no adverse effects if used as recommended.

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2.1 Choosing a Support Removal Tank

A variety of support removal tanks can be utilized to aid in the process of removing support materials from finished parts. Support removal tank options vary by method. You can choose a tank that circulates the removal solution, an ultrasonic tank that vibrates using high frequencies or an option that has both. The key is that the alkaline solution needs some sort of agitation, or cavitation as well as heat, to enable the support material to break away from the model material efficiently. Stratasys recommends using either a circulation or ultrasonic tank.

Parts can be secured in the tank using stainless steel, porous baskets or other containers, which lessens the chances of parts being damaged.

The choice on which type of tank to use can depend on the types of geometries or size of parts you will be printing. Also, factors such as noise or other environmental factors in your location may influence your decision.

Flow tanks and ultrasonic tanks work at the same rate for some geometries and differently for others.

A stainless steel tea infusing ball (3 inches), or similar container, works well for small parts. Larger parts with fine feature details can be secured to a basket with plastic cable ties, and even wrapped in a suitable plastic mesh material to keep them in place or from wearing together in the support removal tank. See “Placing Parts in the Tank” (Section 2.5.3) for more information.

2.1.1 Circulation Tanks

- Uses heat and circulation.
- Circulation amount and strength varies for each tank.
- Generally used with lids, and therefore has less evaporation than ultrasonic tanks.
- Quieter than ultrasonic tanks.
- Secured parts may need to be checked periodically to ensure that they are fully submerged/stay submerged in the tank.

2.1.2 Ultrasonic Tanks

- Uses heat and sound waves to create scrubbing bubbles, which gently clean parts.
- Must be monitored to avoid solution overheating. Users often leave the lids off to dissipate the heat but tanks must still be monitored.

  WARNING
  Bath solution will have a high pH, use caution to avoid contact with skin.

- Louder than circulation tanks.
- Ultrasonic tanks are best for small or fragile parts with fine features and parts with thin channels, small holes and trapped cavities such as tubes.

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NOTE
Parts made with FDM TPU 92A with internal cavities such as tubes and manifolds are cleaned more effectively in an ultrasonic tank. However, be aware that cleaning tanks typically used with F123 printers that use TPU 92A material use circulation and are NOT ultrasonic.

2.2 Safety Guidelines

When using WaterWorks soluble concentrate and a support removal tank observe the following safety guidelines:

- Follow the manufacturer's documentation on tank operation and safety. Understand how to properly and safely use the tank before operation.
- Always wear safety goggles (indirectly vented and chemical splash resistant).
- Use rubber gloves that can withstand the high solution temperature and high alkaline solutions. (Gloves that are cuffed at the elbow are recommended.)
- Follow your company and local regulatory statutes regarding safety practices.
- Never place hands in a tank filled with solution and/or hot water.
- Never turn on power to the heater or ultrasonics without water/solution in the tank.
- Always use a proper tool to remove parts from the tank. Plastic or stainless steel removal tools are recommended that can withstand the high solution temperature and high alkaline solution in the tank.
- If using a basket, remove the entire basket from the tank before removing parts.

2.3 WaterWorks Overview

WaterWorks™ (for use with F123 Series and Fortus® printers) in combination with Stratasys' soluble support materials, dissolves FDM soluble support structures with a water based solution (rather than requiring you to manually remove supports). See Table 1-2 for model and support compatibility information.

Stratasys software automatically creates any needed support structures to build specific parts. When applicable, WaterWorks provides the final step, enabling complex geometries and fully functional assemblies in a single build.

WaterWorks concentrate comes in 1 liter bottles, and in cases of 12 bottles. Each bottle treats 42 liters (11 gallons) of water.

NOTE
WaterWorks may only be shipped via ground transportation.

2.4 How to Choose a WaterWorks-Compatible Tank

Stratasys offers a range of circulation, ultrasonic or combined options. Choosing the right size tank, or tanks, and technology will depend on a variety of factors. We offer something to match the build size of every printer we sell. You also need to factor in your part production rates and your throughput needs.

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Consider your part sizes. While the SCA 3600 is perfect for the F123 series of printers, it may also work for Fortus 380/450 users if they are doing only batches of smaller parts and not filling the entire build envelope. If you will be regularly filling the build envelope of the Fortus 450mc with taller, wider parts, you will need a larger tank.

Also consider your ratio of post-processing equipment to printers. A 1:1 ratio may be necessary if you purchase the smallest tank, or you may be able to have up to three printers for for one larger tank.

2.5 Removing Support Material

> **WARNING**
> Always wear safety glasses and safety gloves when removing support material by hand. The support material can be brittle and may cause cuts when manually broken off.

Some parts have support materials that are hard to remove (e.g., parts with thin, deep channels), resulting in longer dissolving times.

To get longer life from your support removal solution it is always best to remove as much support material by hand before you put parts in the tank (except when using SR-100). It takes just a short amount of time to remove excess support material before putting the part in the tank.

Be aware of fine or fragile portions of your parts and do not use excess force. Just break off what will come off relatively easily before placing the parts in the support removal tank.

While some parts have support material that cannot be removed (e.g., hollow parts with non-accessible interiors). Therefore, it is suggested but not required that you remove some support by hand in order to save tank time and water life span, except when using SR-100.

When using SR-100 it is necessary that you manually remove small amounts of support material prior to placing parts in the tank. This will help eliminate any likelihood of part breakage while in the tank. Thin-walled or small feature part geometries (less than or equal to 0.02 in. (0.50 mm)) with encapsulated regions of support may be susceptible to breakage or cracking. This is due to slightly faster thermal expansion of the SR-100 soluble support material compared to the thermal properties of the polycarbonate (PC) model material.

> **NOTE**
> FDM TPU 92A parts should always be tank-cleaned to remove support material. Removing support material by hand from FDM TPU 92A parts may result in an unsatisfactory surface finish.

2.5.1 Adding Solution to the Tank

> **WARNING**
> Always wear safety goggles and heat, alkaline, and water-resistant safety gloves when handling WaterWorks soluble concentrate.

To begin, fill the tank with water.

- The ratio of water needed is 11 gallons (42 liters) of water per one bottle (2.1 lbs/950g) of soluble concentrate.

FDM Support Removal

Make sure to fill the tank according to the operating instructions set by the manufacturer to avoid burning out the tank's heater (or transducer in ultrasonic units).

Carefully open one bottle of soluble concentrate (per 11 gallons of water) and slowly spread the powder over the entire water surface in the tank.

> **NOTE**
> Always add the soluble concentrate to the water; never add water to the concentrate. Use caution to ensure that you do not breathe in powder when mixing soluble concentrate with water.

When finished, seal and store bottles with remaining concentrate. Dispose of empty bottles appropriately.

> **NOTE**
> Soluble concentrate bottles are made of recyclable plastic and can be recycled according to local recycling programs.

Over time evaporation can occur; periodically check for evaporation of water. If evaporation occurs add more water, do not add more soluble concentrate.

2.5.2 Tank Temperature

> **CAUTION**
> Never turn on power to the tank heater or ultrasonic units without water or solution in the tank.

Always power the tank ON according to the operating instructions set by the manufacturer.

When dissolving support material, set the tank's temperature according to the information listed in Table 2-1. Verify that the tank's temperature configuration is correct for the type of support material being removed before placing parts in the tank. Always allow the solution to reach proper temperature before placing parts into the solution. Support material dissolves the fastest at the designated support material temperature. Filling the tank with hot tap water will help accelerate the time needed to reach designated operating temperatures.

Very high-volume users, such as service bureaus that process hundreds of parts a day, often elect to install a separate water heater in their post-processing labs. They do this to accelerate the heat-up phase when it is necessary to change out the support removal solution.

> **NOTE**
> Setting or allowing the tank temperature to reach a higher than indicated temperature is likely to damage printed parts.

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Tank Temperature Settings	
(Soluble) Support Material Type	**Temperature**
SR-20	70 °C (158 °F)
SR-30	70 °C (158 °F)
SR-100	80-85 °C (176-185 °F) or 70 °C (158 °F) with a longer dissolve time
SR-110	Thin wall mode parts: 50 °C (122 °F), Normal mode parts: 60 °C (140 °F), Brick mode parts: 70 °C (158 °F)
SR-35 / QSR	70 °C (158 °F)
P400-SR	70 °C (158 °F)

Table 2-1

2.5.3 Placing Parts in the Tank

CAUTION

Make sure that parts are fully immersed in the solution. Parts can crack if they are not fully immersed or are 'bobbing' in and out of the solution. This is especially critical for small parts.

Follow the operating instructions set by the tank manufacturer as to where parts can be placed within the tank (e.g., free moving or secured in a basket or other porous container). In some tanks, for example, parts cannot be placed on the bottom. Multiple parts may be placed in the tank but there must be sufficient room within this tank to allow for adequate agitation.

Enclosures should be used to ensure that fragile parts are not damaged while in the tank. Always keep parts fully submerged within the tank's solution; if parts do not stay fully submerged grime can build-up on the part's surface.

Sparse filled parts will absorb solution; therefore, adding holes for draining is advised. Sparse filled parts will float within the tank's solution so they should be anchored within the basket or tank to ensure they stay fully submerged.

2.5.4 Material Specific Guidelines

PC Material: PC parts left in a tank for excessive time may see a 5-15% drop in mechanical properties. It is good practice to allow PC parts to soak in the tank for 4 hours, and then check parts frequently to ensure that they are not left in the tank for too long.

FDM Nylon 6, Nylon 12 and Nylon 12CF Materials: Nylon 6/12/12CF materials may be brittle out of the oven. A very specific process should be followed when placing parts made with these materials into a tank containing WaterWorks solution.

1. After removing nylon parts from the printer's oven, always leave the part on the build sheet. Allow the part to cool on the build sheet until it is room temperature.
2. Carefully pull the part off of the build sheet once it is room temperature. The part may be fragile so care must be taken.

All nylon parts must be placed into a WaterWorks solution bath; a minimum of 4 hours of re-hydration is suggested.

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2.5.5 Inspecting Parts and Solution

Various factors determine how long it takes to remove support material in the tank. To ensure timely and efficient support removal:

- Minimize the volume of support material on the part prior to placing it into the tank (see “Removing Support Material” - Section 2.5).
- Minimize the amount of time parts spend in the solution tank.
- Minimize the amount of dissolved solids in the solution tank.
- Maximize the pH level in the solution tank.
- Maximize solution agitation around parts.

For best part quality, inspect parts after 2 hours and then periodically until their clean cycle is complete.

> **NOTE**
> Polycarbonate parts left in the tank for excessive periods of time may see a 5% to 15% drop in mechanical properties. It is highly recommended that you check PC parts every 4 hours, and avoid leaving PC parts in the tank solution longer than 24 hours. This will alleviate any potential degradation of the part’s mechanical property.

Due to air pockets and circulation patterns it is recommended that you rotate the basket or free moving parts to dissolve support material faster. Inspect the tank periodically for over- heating and solution evaporation. The solution level must always cover the parts. Add more water if necessary; do not add more soluble concentrate.

2.5.6 Removing Parts from the Tank

> **WARNING**
> Always wear safety goggles and heat, alkaline, and water- resistant safety gloves when handling the concentrate.

To begin, turn OFF power to the tank. Allow the tank’s cover to drip for a few moments before removing the lid completely. Carefully remove parts from the tank; plastic or stainless steel removal tools (such as tongs) are recommended for removing parts. Removal tools need to be able to withstand high water temperature and high alkaline solution.

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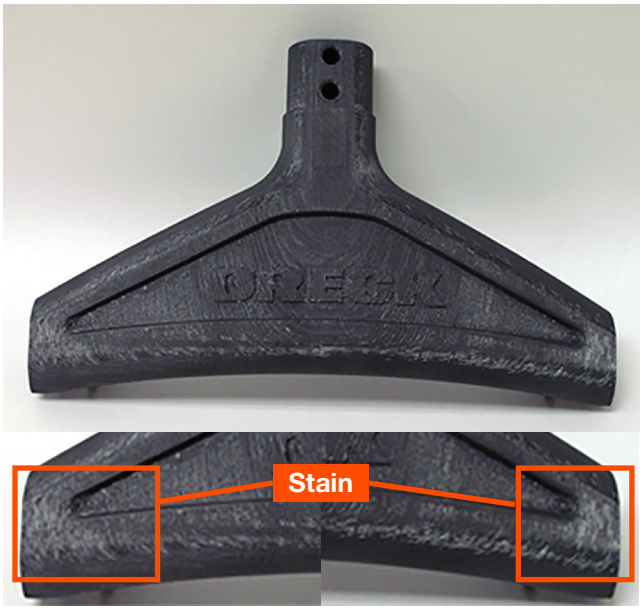
Parts must be rinsed after they're removed from the tank, rinse parts as follows:

- White Parts: Rinse parts thoroughly with water until part surfaces are no longer slippery (1-2 minutes). To reduce the possibility of staining, some white parts may need to soak for an hour to help pull soluble concentrate from part surfaces. Also, soaking parts in a dishwasher rinsing aid and water and then rinsing the parts will break the surface tension.
- Color Parts: Soak parts in water for one hour to dissolve and pull soluble concentrate from part surfaces. Also, soaking parts in a dishwasher rinsing aid and water and then rinsing the parts will break the surface tension.
- Soft Water or Deionized Water: Sparse parts need to be drained and re-rinsed. A vacuum chamber can be used to pull solution out of the part.

NOTE

Failing to rinse or soak parts long enough can leave them with a white residue and/or streaks. If this occurs, rinse or soak the parts again to remove the residue. Part surface aesthetics can also be negatively impacted as a result of inadequate tank solution. Check the tank's solution and change it if necessary (see "Changing Solution in the Tank" - Section 2.5.7).



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For parts built using the sparse build style, allow parts to drain fully as solution can get trapped inside the part. Allow parts to dry thoroughly and then rinse parts (for 1-2 minutes) under hot water, once again making sure that you do not allow any water to get trapped inside the part.

Dry parts with paper towels, compressed air, or let them air-dry. If colored parts turn slightly white after drying, rinse them under hot water or soak them again as previously instructed.

2.5.7 Changing Solution in the Tank

How often the solution is changed is dependent on the tank used, how it is maintained, and the complexities of the parts built.

Once mixed to the correct dilution, the PH level in WaterWorks is around 12.6. The solution will need to be changed when the PH drops below 11.5, or if the solution is saturated with dissolved solids.

It is possible for the solution to register the correct PH level, yet still not be cleaning the soluble support off the parts. This is when you need to check the saturation level of the solution.

Waterworks can handle roughly 1lb. of support to every 5.5 gallons of diluted solution in a tank. After that it becomes less effective. Some larger labs use TDS (Total Dissolved Solids) meters to evaluate tank changes in addition to checking the PH levels. This is why Stratasys recommends manually breaking off as much support as practical.

The following conditions indicate that the solution should be changed:

- The tank begins to cloud or exhibit low clarity. Some white parts (ABS) may turn brown or yellow.
- Parts have a sticky residue and/or stick together in the tank due to excess dissolved solids in the tank.
- Functional parts with moving features are not functioning properly.
- Support material is not fully removed after a long cleaning cycle.

2.5.8 Disposing of Soluble Concentrate

The soluble solution has been specially formulated to be safely disposed after dilution and neutralization to an acceptable pH level. The pH level of fresh solution is similar to that of typical laundry detergents, dishwasher detergents, and common household cleaners.

pH Levels Comparison

Product	pH Level
Fresh soluble solution	12.6
Laundry detergent	11 - 12
Dishwasher detergent	10 - 11
Common household cleaners	9 - 12

Table 2-2

FDM Support Removal

Check your local, state, and/or international regulatory statutes for what pH level is acceptable for disposal. Stratasys recommends that disposal procedures be verified by the proper authorities in your region. Stratasys cannot anticipate local, state, or international regulatory statutes. Stratasys cannot be held liable if the solution is not handled and disposed of properly. You may need to document how you dispose of the used solution.

2.5.9 Soluble Solution Drain Effluent

Dilute the solution with water using the appropriate ratio to meet acceptable pH levels. The Drain Effluent data below is based on a dilution of 1 part soluble concentrate to 5 parts water containing approximately 28 cubic inches (459 cc) of soluble release material dissolved in 11 gallons (42 liters) of water, resulting in a pH of 11.8.

Drain Effluent Specifications

Parameter	Test Method	Units	Tank Value	Diluted Value*
pH	EPA 150-1	EPA 150-1 --	12.6	11.8
COD**	EPA 410-1	mg/L	14,000	2,400
BOC***	SM 5210B	mg/L	820	250
Total Solids	EPA 1603	mg/L	27,000	4,500
Total Suspended Solids	EPA 160.2	mg/L	430	54
Cadmium	SW-846, 6010A	µg/L	<5	<5
Chromium	SW-846, 6010A	µg/L	<5	<5
Copper	SW-846, 6010A	µg/L	<10	<10
Nickel	SW-846, 6010A	µg/L	<10	<10
Lead	SW-846, 6010A	µg/L	<40	<40
Zinc	SW-846, 6010A	µg/L	<20	<20
Mercury	SW-846, 7470A	µg/L	<2	<2

Table 2-3

* These values remain constant if the same ratios apply (e.g. 5.5 gallon cleaning device containing approximately 14 cubic inches of soluble release material with the same dilution ratio of 1 part soluble concentrate to 5 parts water).

** Chemical Oxygen Demand

***Biological Oxygen Demand

Check your local, state, and/or international regulatory statues for what pH level is acceptable for disposal. Stratasys recommends that disposal procedures be verified by the proper authorities in your region. Stratasys cannot anticipate local, state, or international regulatory statutes. Stratasys cannot be held liable if the solution is not handled and disposed of properly. You may need to document how you dispose of the concentrate.

2.5.10 Neutralization

The soluble solution can be further neutralized to lower the pH level by slowly adding acid (e.g., malic acid) to the tank before draining the solution.

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To successfully neutralize a solution of soluble concentrate dissolved in 11 gallons (42 liters) of water to a pH level below 11:

1. Check local codes. Refer to the MSDS sheets for proper safety precautions and possible hazards for malic acid.
2. Slowly add 14 ounces (397 grams) of malic acid to the tank solution (this amount is based on starting pH level); pH will reduce from 11 to 8. Please note that the tank will foam.

2.5.11 Tank Cleaning

To clean the tank:

1. Drain, dilute, and/or neutralize the tank solution. See “Disposing of Soluble Concentrate” (Section 2.5.8) for instructions.
2. Re-fill the tank with clean tap water and operate a few minutes to circulate clean tap water throughout the system.
3. Drain the tank and wipe down all surfaces to remove traces of the soluble concentrate.

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