ReDeTec™

ProtoCycler+

User Manual

Rev 2.0

Table of Contents

1.0 Introduction to the ProtoCycler+

Welcome to the ProtoCycler+ community! The team here at ReDeTec is excited that you have chosen to walk the path of sustainable 3D printing! We're here to ensure your success with your device. Operating the device requires a knowledge base and it is **strongly recommended** that you read this entire manual before use.

Upon completion, you will know your way around the device, understand its key limitations, and be able to operate in both automatic and manual extrusion modes. Most importantly, you will be able to operate it safely.

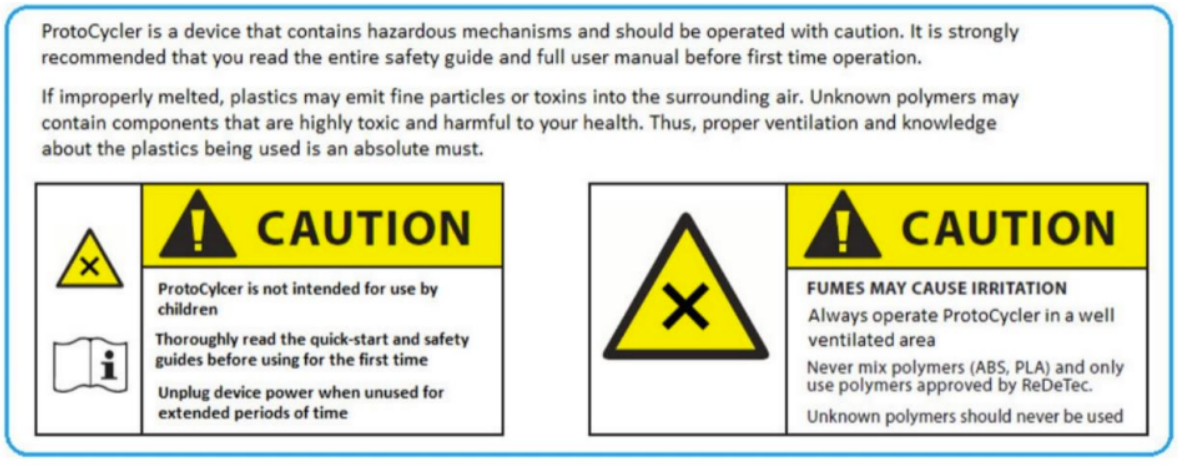
If the manual doesn't cover what you're looking to understand, or raises further questions, please visit: *www.redetec.com/support*

Please consider the environment before printing any copies of this manual.

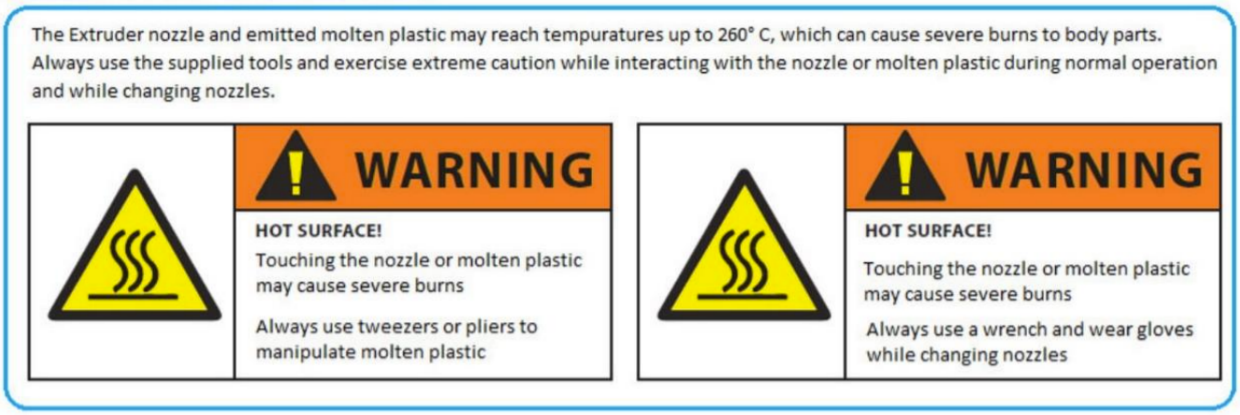
1.1 Safety

Please do not compromise safety for anything. ProtoCycler+ brings industrial grade technology to the desktop, and should be fully understood before operation. **Please thoroughly review the safety precautions before operating your device. Failure to do so may result in damage to your device or may cause bodily harm.**

1.1.1 General Safety



1.1.2 Extrusion Safety



Note: If you have a High Temperature model, temperatures may reach as high as 500°C!

Never extrude PVC or any unknown plastic. The fumes could be lethal! ProtoCycler+ currently supports PLA, ABS, HDPE*, LDPE*, PA12, PETG, HIPS (*special printing hardware is required to print HDPE/LDPE).

The device provides the ability to experiment with new materials and colors via the manual extrusion mode. Please do not attempt to extrude any unknown materials unless you understand the chemical reaction that occurs when the material is thermally broken down. For example, PVC releases chlorine gas and under no circumstances should you try to extrude it with the ProtoCycler+.

Always ensure proper ventilation when extruding any plastic, from the supported list or otherwise.

1.2 ProtoCycler+ Layout

Before we dive in any further, let's learn the basic anatomy and terminology used for the device. The following images label the key features.

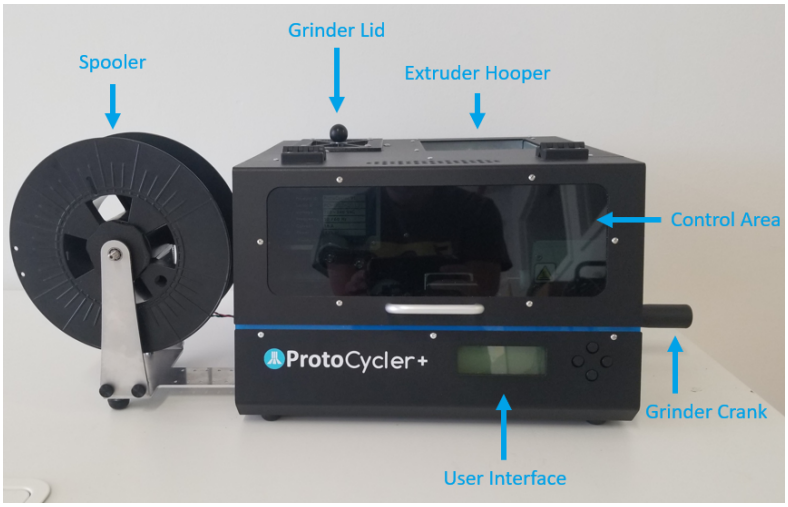


***Figure 1**: ProtoCycler+ Front View (labeled)*

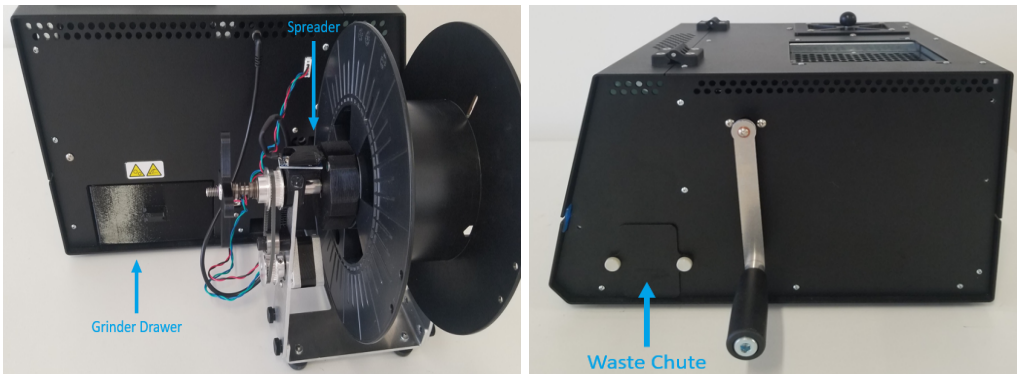


***Figure 2**: ProtoCycler+ Side Views (labeled)*

***Figure 3**: ProtoCycler+ Inside View (labeled)*

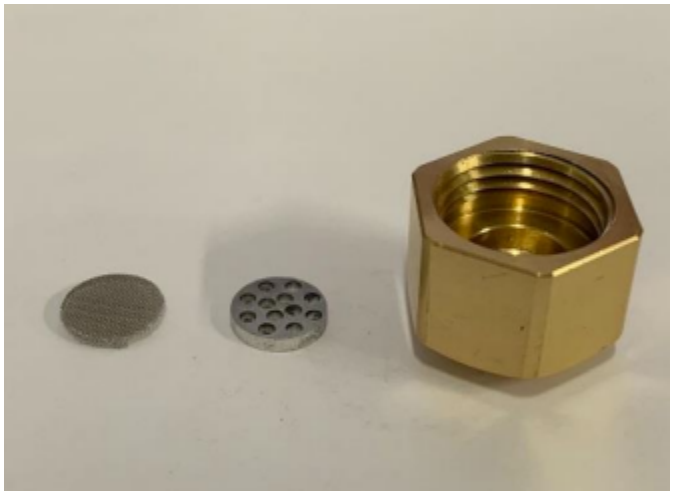


***Figure 4**: From left to right - Nozzle Screen, Nozzle Breaker Plate, Nozzle Cap*

2.0 Grinding

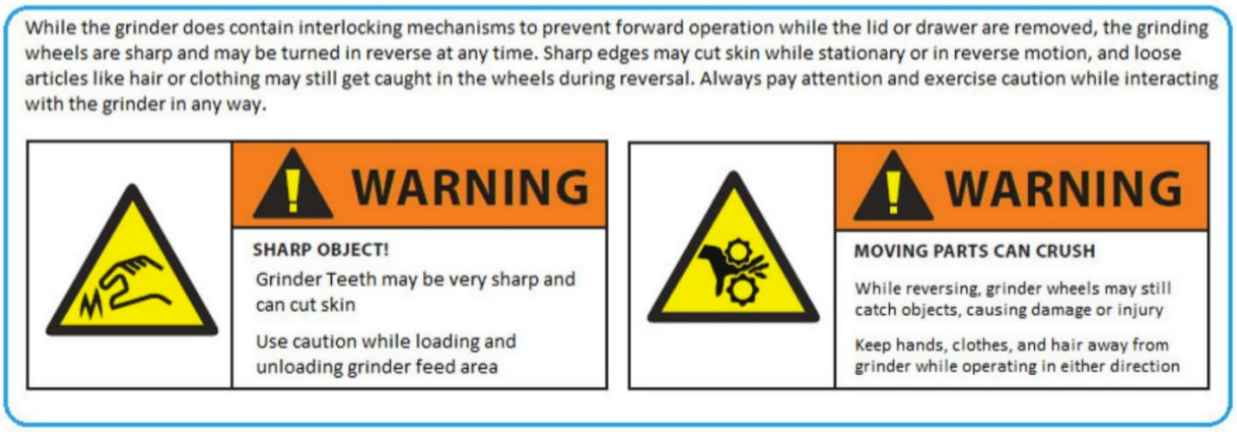
(*skip over this section if you have a Grinderless Unit*)

2.1 Grinder Operation

The ProtoCycler+ must be powered on at all times to operate the grinder. The grinder relies on an electromagnet interlock that engages the grinder drive train only when supplied with power. The electromagnet is calibrated to disengage the interlock at set torque limit value to prevent damage to the gear train. The grinder will only work if the two interlock switches are engaged while the unit is powered on. One switch is engaged by the grinder lid, and the other by the grinder drawer.

2.1.1 Grinder Safety

Please thoroughly review the safety precautions before operating the grinder. Failure to do so may result in serious injury or irreparable damage to your device.



2.1.2 Grinder First Time Setup

Installing the Grinder Handle:

1. Remove the Grinder Crank Arm and Allen Key from the Accessories Box.
2. Use the Allen Key to remove the screw and washer from the Grinder Crank.
3. Place the support washer onto the crankshaft.
4. Install the Crank Arm over the hex on the Grinder Crank with the handle facing outwards
   Note: the hex size is 5/16”.
5. Replace the screw with the washer under it, and tighten until snug.

Grinder Drawer Preparation:

1. Remove the Grinder Drawer from the side of the ProtoCycler+

2. Uninstall the Grinder Sorter from the drawer in preparation for use.
3. Insert the now empty Grinder Drawer back into your ProtoCycler+ in preparation for use. **Note: the Grinder Sorter should never be installed in the Grinder Drawer when operating the Grinder as this could cause plastic build-up and jamming. The Grinder Sorter should only be installed in the Grinder Drawer for sorting ground material**

2.1.3 Operation

Note: It is not advised to operate the Grinder while the Extruder is running. Grinder operation may shift or vibrate the unit which may affect filament quality.

1. Power on your ProtoCycler+
2. Remove the Grinder Lid and place the part you wish to grind into the grinder hopper. Place the lid back in the hopper. The lid and drawer must be correctly installed in order to operate the Grinder. **While the lid only needs to be partially in, the drawer must be fully seated against the back wall. Particulates may block this, and so it is necessary to make sure the drawer slot is clean of debris before reinserting the drawer**.
3. To grind, first rotate the Grinder Handle counter-clockwise to ensure the interlock is engaged. Then press down on the Grinder Lid Plunger and rotate the Grinder Handle clockwise. Viewing through the clear area of the Grinder Lid, you will see the Grinder Teeth spin inwards.
4. During operation, if at any time the load on the grinder teeth exceeds the maximum, the Grinder Interlock will disengage. Reverse the grinder all the way until the part is pulled off of the teeth by the clearers, and then attempt grinding again. If unsuccessful, you may need to fully remove the part and reduce its size by other means, or otherwise reduce the number of parts you are grinding at one time.
5. When you are done grinding, remove the Grinder Drawer to retrieve the ground material. Sort the particulates and re-grind the oversized bits. See the following section on sorting ground material for extrusion.

2.2 Sorting Ground Material

Depending on the material type, density and shape, it may be necessary to sort the ground material using the provided sorting mechanism. The Grinder Sorter is a liner comprising two levels of offset holes which are used to sift through the ground material and only allows ground material of appropriate extrusion size through.

1. Read section 2.3 on desired ground material size.
2. Install the Grinder Sorter into the Grinder Drawer
3. Lift the sorting mechanism most of the way out of the drawer, and hold it so they are still overlapping.

4. Shake the two side to side, up and down, until it seems the only particles left in the sorter are too large to fall through.
5. You may also wish to shake the sorter over a large pan or bucket to allow a little more freedom of motion. Make sure whatever you choose for your “catch container” is clean of contaminants. Rubbing alcohol is an excellent choice for cleaning your container as it dissolves and cleans surface contaminants while evaporating quickly. Using soap and water is fine, but make sure your grinder drawer/container is fully dry before using it with your ProtoCycler+ system.
6. Remove the sorting mechanism and pour the large particles that remain in the sorter back into a container for re-grind or back into the Grinder Hopper. Pour the small particles that made it into the drawer (or catch container of your choice) into a container or plastic bag to save for extrusion.
7. You will want to collect ground material and **dry** it as a large batch before packaging or using it for extrusion. See section 3.3 on wet/dry plastic .

2.3 Ground Material Size & Extruding Recycled Plastic

The size of pellets/ground material particles entering your extruder is very important. If the plastic media is too large in any dimension, it can jam your extruder. Using 100% regrind can also lead to jamming. De-jamming is a difficult process which may require partial disassembly of your unit.

1. The appropriate pellet size that can be used in your ProtoCycler+’s Extruder is 0.125" to 0.2" in diameter. Pellets that do not fit in this size range will not pass through the Extruder Hopper Filter. Particles over 0.2" in any dimension may jam your extruder. While having some portion of pellets be undersized is fine, the extruder hasn't been tested with high concentration of small particles yet.

   WARNING: The Extruder Hopper Filter does not replace the act of proper pre-sorting. **The Extruder Hopper Filter is a final protection for the Extruder to reduce the chances of issues. It is your responsibility to ensure proper sorting before using ground recycled plastic. Use the sorting mechanism to ensure all of your ground particles are small enough**.

2. **Ground material must be mixed with virgin pellets**. 50% recycled plastic is the recommended ratio, though tests with higher percentages of recycled materials have been successful (important factors are size, dryness, and quality of the ground material). Extruding 100% regrind may jam your extruder! High consistency in size of your ground material will improve filament quality.

3.0 Important Things to Know Before Extruding

3.1 Puller Wheel Storage

The plastic is pulled from the extruder nozzle using two wheels. These two wheels have soft silicone tires, and use a spring to hold force between them for gripping the filament. **If left stationary in one position for an extended period of time, the tires can develop a flat! Therefore, it is important to disengage the spring and rotate the puller idler wheel out of position when not in use to avoid developing a flat**. The following images depict Puller operation and Puller storage positions.

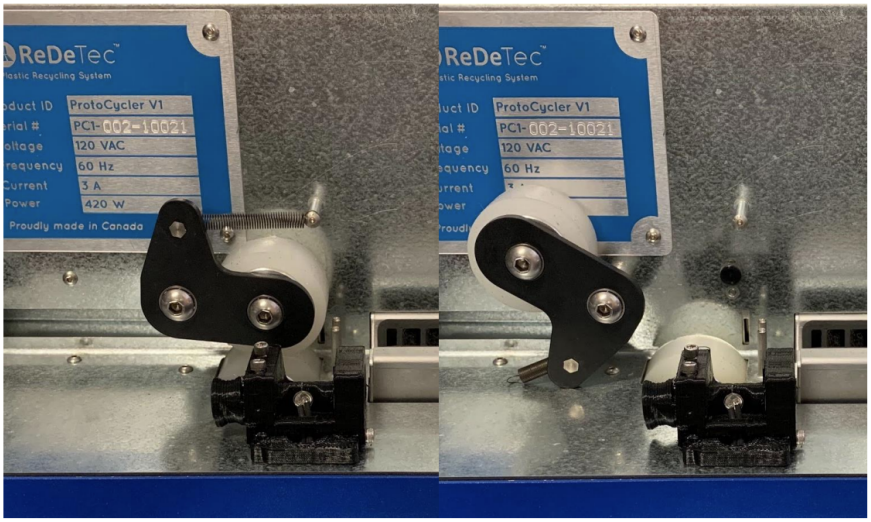


***Figure 5**: Puller idler wheel spring engaged (left image), and disengaged (right image).*

3.2 Cleanliness

It is important to make sure your device is clean before use. We thoroughly clean each unit before shipping, but dust accumulation occurs over time. Before extruding, inspect your extruder hopper for dust and other contaminants. **If material other than the plastic you wish to process makes it through the system, you risk defects in the output filament**.

ProtoCycler+ also uses two light sensors to read filament diameter output. We recommend using a canister of dry compressed air (“computer duster”) to blow-out any dust or particles that may obstruct the light sensor. We will show you how to know if there is dust getting in the way of the LED or photoresistor in the “Light Guide Alignment” section 3.6 of this manual. If compressed air doesn’t do the trick then we also recommend using a softer material (a skinny piece of PLA filament works very well) to clean the photoresistor “slot” on the UI panel where the LED shines light into. **Never use metal or anything sharp to clean the diameter sensors, as permanent damage can occur**.

Lastly, if other un-meltable materials or dissimilar materials with higher melting temperature than your plastic of choice enter your system, you may find over time that your nozzle becomes clogged. Referring to Figure 4 (Nozzle parts), inside of the Nozzle Cap there is a breaker plate and screen whose purposes are to aid in building stable pressure, and to act as a last line of defense against contaminants entering your filament. In the event that your screen becomes clogged, please contact ReDeTec support for assistance in how to clean your screen! This process requires special care and safety when executing and a trained specialist will be happy to advise.

3.3 Plastic Care: Dry vs Wet - Clean vs Dirty

Similar to filament, you want to make sure your plastic is dry and kept clean prior to use. All plastic is inherently “hygroscopic”, meaning it readily absorbs moisture from the air into its molecular structure. This moisture is your enemy when it comes to extrusion! Extruding with wet plastic will cause the moisture to be vaporized during extrusion, causing bubbles in the output and vastly changing the extrusion properties. In most cases this will prevent you from achieving high quality consistent filament.

It is very important to follow a strict regimen of properly drying, and managing your dried plastic before extrusion.

The drying process is simple and may be done using an oven, toaster oven, or food dehydrator. If using an oven or toaster oven the moist air must be removed for proper drying. Plastic manufacturers will give specific recommendations on drying temperatures and times. Temperatures and times used for ABS and PLA are shown in Table 1.

***Table 1**: Drying Guide for PLA and ABS.*

Plastic (grade)	Temperature	Time (hours)
PLA (4043D)	80°C (175°F)	4
ABS (250-X10)	80-90°C (175-194°F)	4

Make sure your drying system is already preheated before starting the timer for the drying times stated in Table 1.

After drying, the plastic must be immediately stored in an air-tight container or bag with desiccants until use for extrusion, otherwise it will quickly reabsorb moisture from the air again.

Ground plastic will have had plenty of time exposed to the environment, and must always be dried for best results.

Just as your extruder should be kept clean of contaminants prior to and during operation, the same applies to the plastic itself. We take special care to avoid contaminants entering the plastic supply. If dirt or a higher melting temperature plastic makes its way into the plastic you are extruding, you may encounter inconsistencies in the melt output and/or irregularities in the consistency of your filament diameter. Clean and dry plastic will yield a smooth and consistent output if all other conditions are correct as well.

3.4 Opaque vs Transparent Plastic

The diameter sensors work best with opaque plastics. For a naturally transparent plastic such as PLA, colorants must be added to make the filament opaque. Your order comes with colorants that are to be used with the pellets for extrusion. You can purchase more from our website, or your local shop.

3.5 Spooler Set Up

Gather the materials required to set up your Spooler. You will need the Spooler Kit, which can be found in the ProtoCycler+ accessories box, and the Spooler Base which slides out from the side of the ProtoCycler+

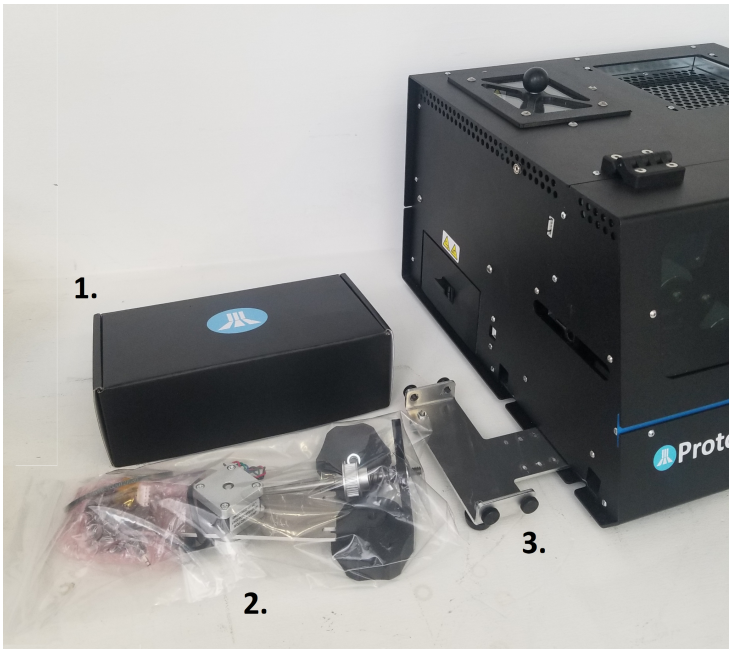


Figure 6: *1. ProtoCycler+ accessories box 2. Spooler Kit which can be found within the ProtoCycler+ accessories box and 3. Spooler Base shown pulled out from its recess.*

Before setting up your Spooler, please check to ensure all of the parts in the image below are included as part of the Spooler Kit.

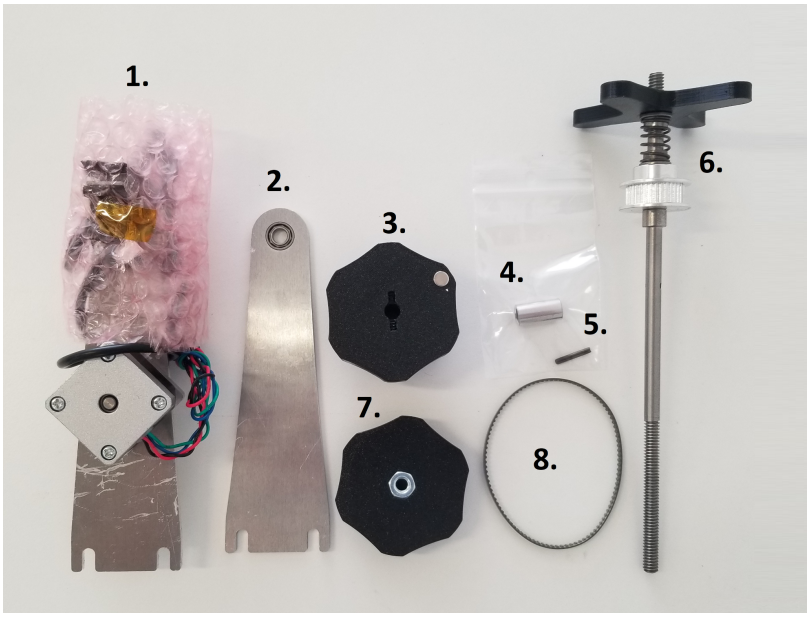
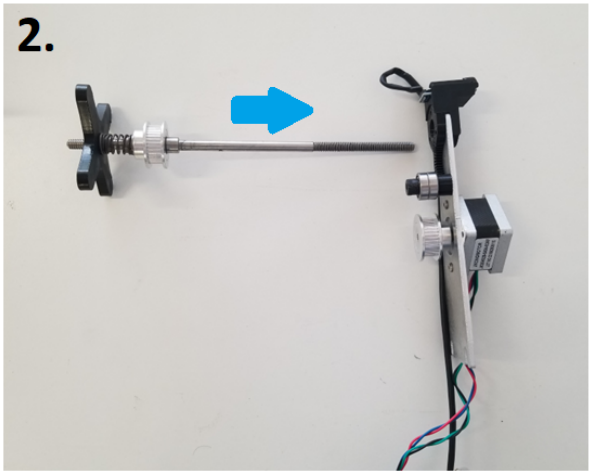
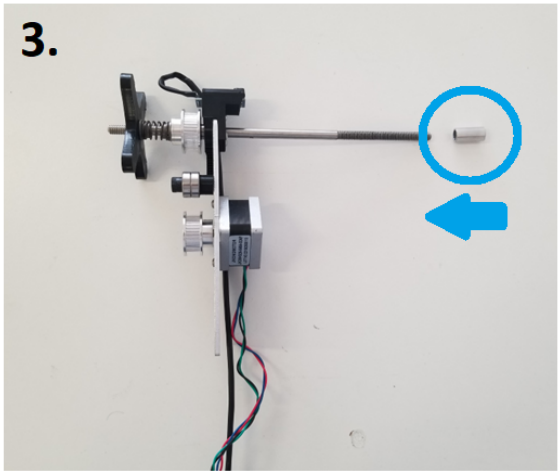
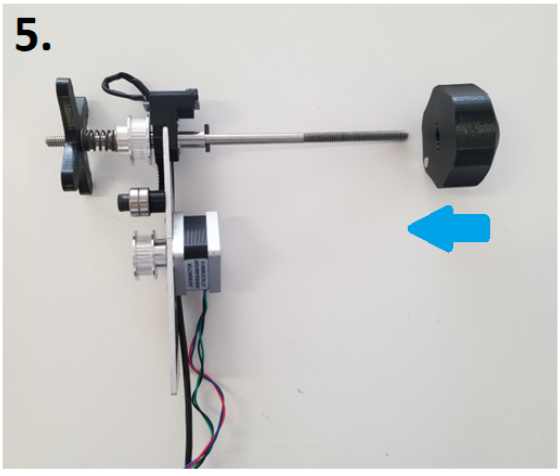


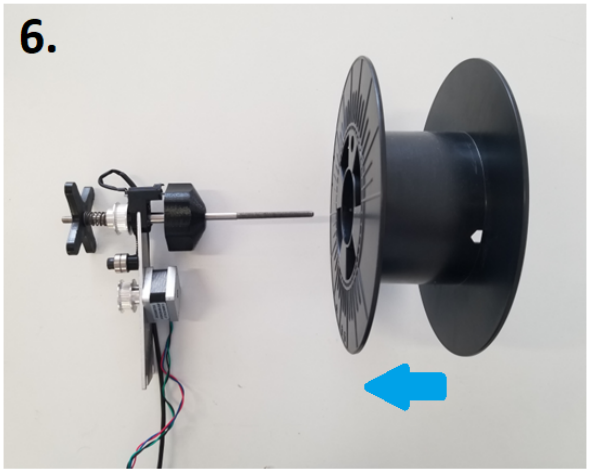
Figure 7: *Spooler Kit Parts; 1. Spooler Motor Bracket 2. Spooler Support Bracket 3. Spooler Hub with Magnet 4. Spooler Spacer 5. Spooler Pin 6. Spooler Shaft and Clutch Assembly 7. Spooler Hub with Nut 8. Timing Belt*

The following illustrations outline how to assemble the spooler and correspond to the set of written instructions that follow.

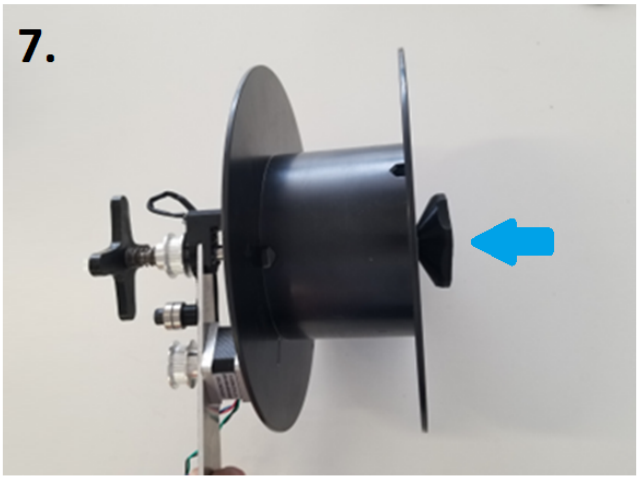






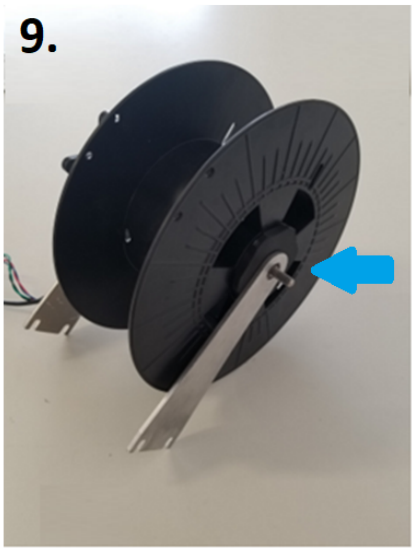


7.



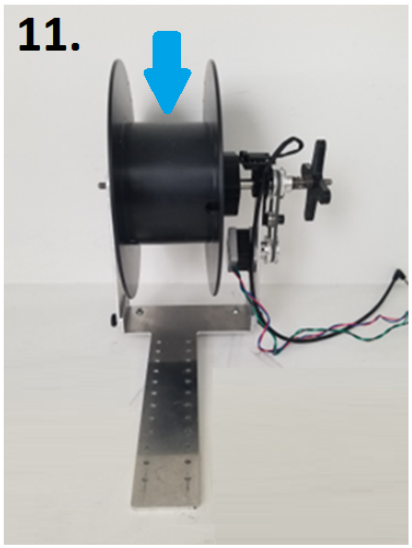
8.

9.

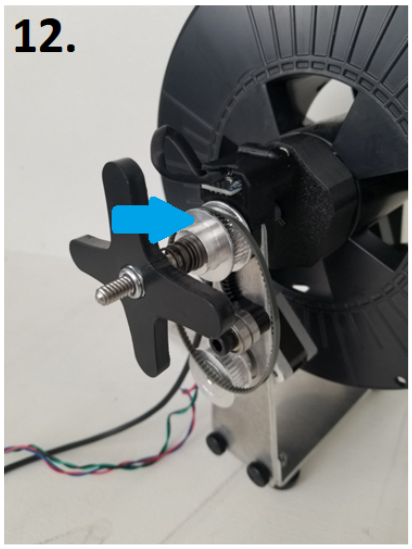


10.

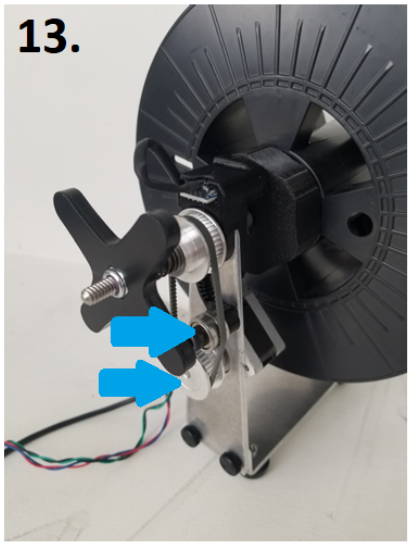
11.



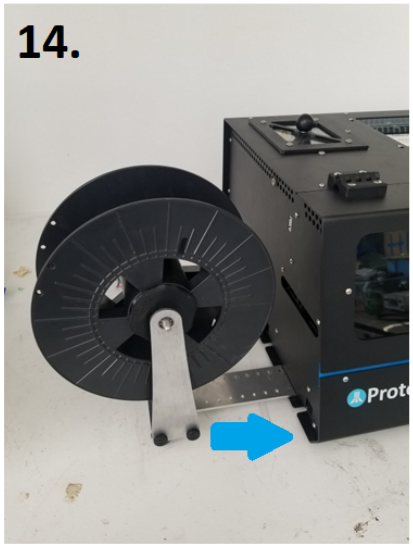
12.



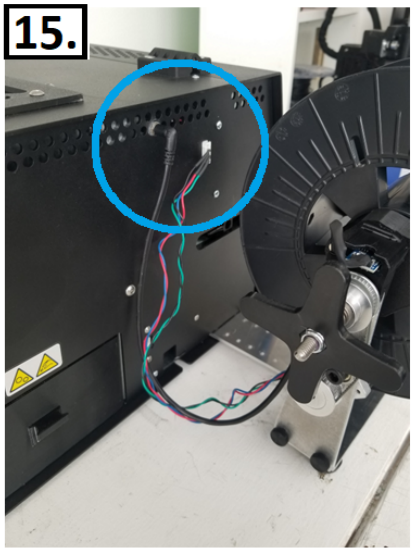
13.



14.



15.



3.5.1 Spooler Assembly Instructions

Warning: The ProtoCycler+ must be powered-off when installing and plugging in the spooler. Unplugging or plugging in the spooler while ProtoCycler+ is powered on can permanently damage the main circuit board.

1. Remove the bubble wrap from the Spooler Motor Bracket.
2. Slide the Spooler Shaft and Clutch Assembly through the bearing in the Spooler Motor Bracket in the direction shown.
3. Slide the Spooler Spacer onto the shaft so it rests against the bearing and is clear of the pin hole in the shaft.
4. Slide the Spooler Pin into the hole in the shaft. Hold the pin in place.
5. Slide the Spooler Hub with Magnet onto the shaft as shown, ensure the Spooler Pin seats properly into the groove in the spooler hub.
6. Place a spool over the shaft so it rests against the tapered face of the spooler hub.
7. Thread the Spooler Hub with Nut onto the shaft.
8. Tighten the spooler hub until it is contacting the spool. The spool should now be firmly held in place by the two spooler hubs.
9. Slide the Spooler Support Bracket onto the shaft.
10. Ensure the thumb screws on the Spooler Base are as loose as possible.
11. Place the spooler assembly into the spooler base as shown, ensuring that the Spooler Motor Bracket is above the longer arm of the spooler base. Tighten the screws so the Spooler Motor Bracket and Spooler Support Bracket are secure.
12. Slide the Timing Belt over the clutch handle and onto the spooler shaft so that it is sitting on the upper pulley wheel
13. Gently slide the timing belt over the lower pulley wheel, ensuring that the Timing Belt is on the outside of the bearings on the tensioning arm.
14. Insert the Spooler Base back into the side of the ProtoCycler+
15. Plug the spooler stepper motor and the spooler sensor cables into the receptacles located on the left side of the ProtoCycler+
16. Now it is time to turn on your ProtoCycler+ and set the spool geometry settings in ProtoCycler+'s User Interface. First, measure the inside width of your spool with a pair of calipers. Enter this measurement as “spool width” in ProtoCycler+ Settings.
17. Then, align the spreader guide so that the inside edge of the guide (away from the user) is exactly aligned with the inside edge of the spool (away from the user)

The spooler is now set up and ready for extrusion! However, the clutch system may still need adjustment. When extruding for the first time, loosen the clutch off until the spool just stops spinning. Then, tighten the clutch one full turn. Check to ensure that the spool is still permitted to slip against the pulley - this is required for the diameter control system to function properly.

3.6 Light Guide Alignment

Light guide alignment is key to your ProtoCycler+'s vision system to verify and maintain filament diameter. Every unit is aligned and tested for performance before shipping, but sometimes things are bumped and moved between when the unit ships to the next time it is turned on again by you, the owner. Ensure your light guides are properly aligned.
Depending on when your unit was built, you may have one of two variants. One is not better than the other in terms of function. They both work to align the LED beam of light, but an iteration was made to improve fabrication and assembly time. The following image details the two types of light guides:

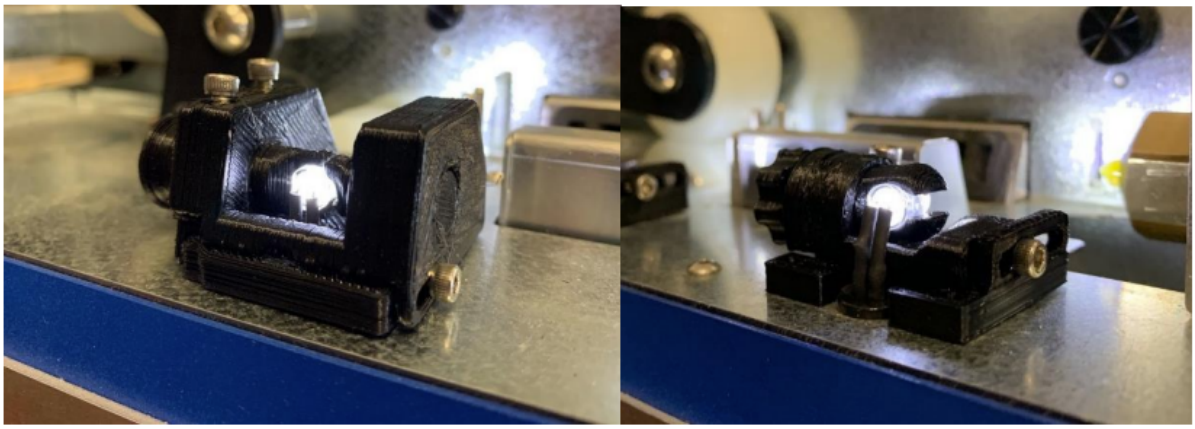


***Figure 9**: Light Guide V1.0 (left). Light Guide V1.1 (right).*

3.6.1 What you need to check Light Guide Alignment:

- You'll need two sizes of dowels. Drill bit shafts are an excellent option (use the smooth shank, not the cutting flutes side). **It's very important that the dowels are a consistent, known size - DO NOT use extruded filament!**
- ReDeTec uses a 1.83mm and a 2.56mm dowel to align the light guides, but you can use anything close within +/- 0.1mm. The larger dowel size is used for the sensor closest to the nozzle, and the smaller dowel size is used for the sensor closest to the puller wheel. For reference we will call these the Puller Sensor and the Nozzle Sensor.
- You will also need to be connected to a computer, to use ProtoCycler+ Command Center ("PCC").

3.6.2 Light Guide Alignment Overview:

With ProtoCycler+ connected to PCC, start manual mode extrusion via the ProtoCycler+ User Interface (For guidance, refer to the ProtoCycler+ Command Center Overview). You will see a screen that looks like this upon manual mode startup:

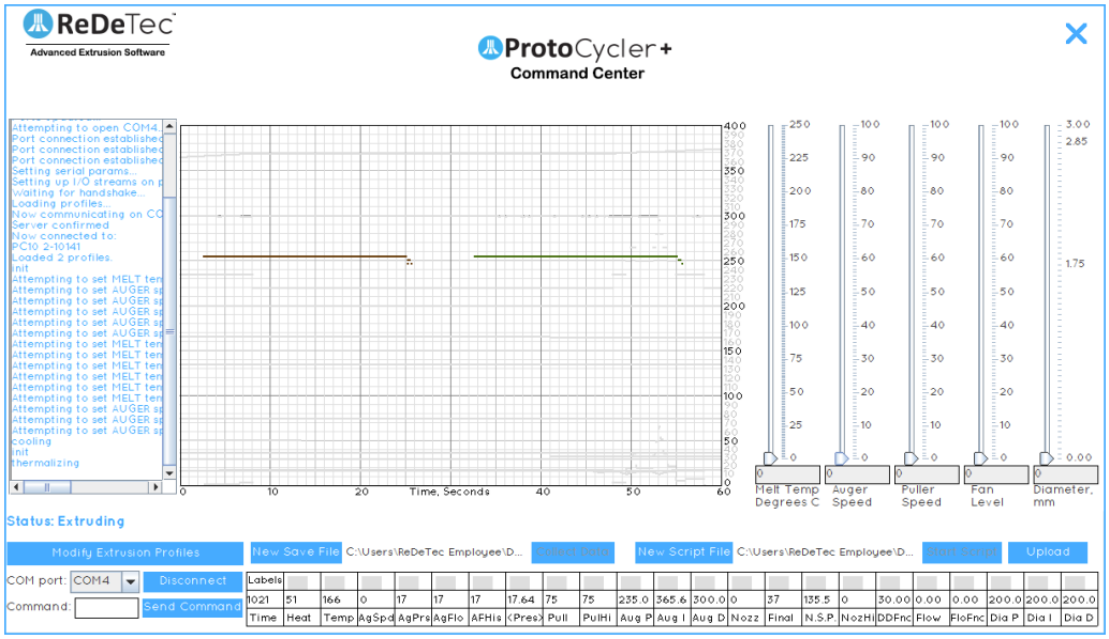


***Figure 10a**: Startup screen of manual extrusion with all readings toggled off (by clicking the "Labels" button above the "Time" readout).*

The two flat lines seen in Figure 10a represent the raw data read by the light sensor photoresistor array for the diameter of filament at the nozzle (left - brown line) and the final diameter of the filament at the puller wheel (right - dark green line). These lines being flat at a value of 255 (with a small amount of "drop-off" on the right) is a good sign that your light guides are well aligned. If the light guides are lower than 255 or have severe angles to them, such as Figure 10b below, then alignment is required.

Note that "alignment" refers to two separate tasks. The first is to ensure the light is evenly lighting the sensor. The second is to ensure that the readings are accurate.

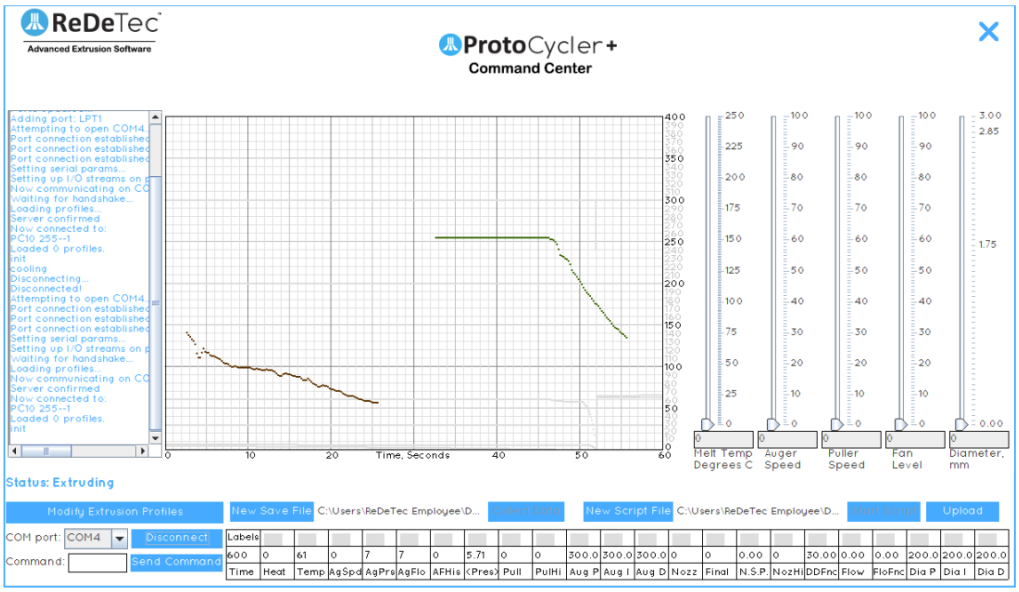


***Figure 10b**: Two examples of incorrectly aligned light guides – the nozzle sensor is very bad and the puller sensor has too much drop off on the right side to work.*

3.6.3 Step 1 - Adjusting the sensor height

1. The first step is to ensure the sensors themselves are aligned. Each sensor has a thumbscrew that, if loosened, permits the sensor to move up and down, as shown below in Figure 11. **The sensors are adjusted from the factory and neither sensor should be adjusted unless the filament is seen to be frequently "falling off the edge" of the sensor.**

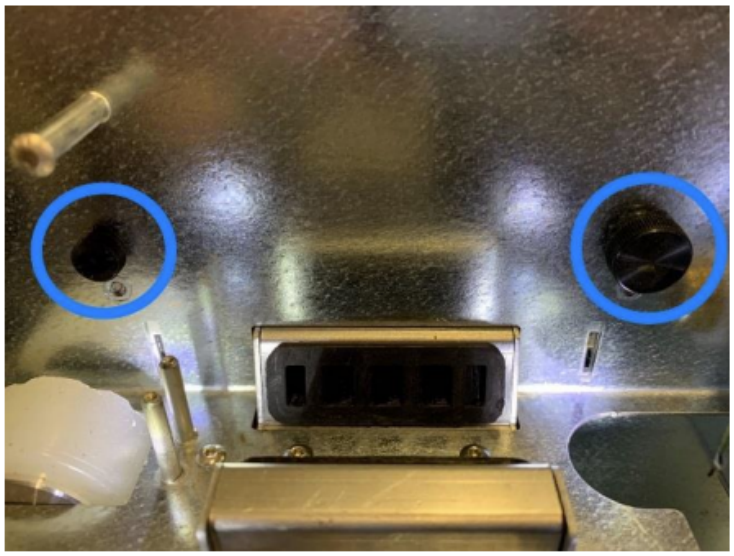


***Figure 11**: UI Thumbscrews for adjusting the height position of the photoresistors.*

2. Typically the puller sensor's photoresistor will be positioned all the way at the bottom range of its movement for best results. It has been adjusted this way from the factory, and should not need adjustment!
3. The nozzle sensor is a little more tricky depending on what material is being extruded and at what diameter; both of which will affect how the filament passes the first diameter sensor at the nozzle. Typically, the nozzle diameter sensor's photoresistor will be positioned ~1mm (~0.04") above the midpoint of its range of motion. The nozzle sensor's photoresistor height can also be fine tuned during operation; this will be addressed in the extrusion instructions of this manual.
4. If adjustment is required, loosen the thumbscrew holding that sensor, and move the sensor up and down. **Take extreme care to ensure the sensor remains correctly oriented in its slot - it cannot be angled or offset sideways, or it will be impossible to align the LED lights**.

3.6.4 Step 2 - Evenly lighting the sensor

1. If the sensor is not evenly lit (Figure 10b), the LED needs to be re-aimed to ensure that the response curve shown in Figure 10a is obtained. The process is the same for both the Nozzle and Puller sensors.
2. Both light guide versions 1.0 and 1.1 allow the LED to be angled up or down, to ensure the light guide is evenly lit. Their operation differs however - see step 3 for version 1.0 and step 4 for version 1.1.
3. Version 1.0 has two screws facing "up", which push on opposite sides of a lever to angle the LED shaft. To aim the LED up, first loosen the front screw (farther from the user), then tighten the back screw (closer to the user). To aim the LED down, first loosen the rear screw, then tighten the front screw. Adjust the LED incrementally, monitoring the response pattern shown on the screen until it is an even response as shown in Figure 10a. Finally, ensure both screws are tightened to prevent further movement. **Always loosen one screw before tightening the other. Also, be sure to not overtighten the screws - they should just be snug.**
4. Version 1.1 has only one screw facing "up", that clamps the LED shaft in position. To adjust the LED, first loosen the screw. Then use the shaft knob on the left side of the light guide to adjust the angle of the LED. You may want to support the other end of the shaft with your thumb for more control - see Figure 12 below for reference. When the desired response pattern as shown in Figure 10a is obtained, simply re-tighten the screw.

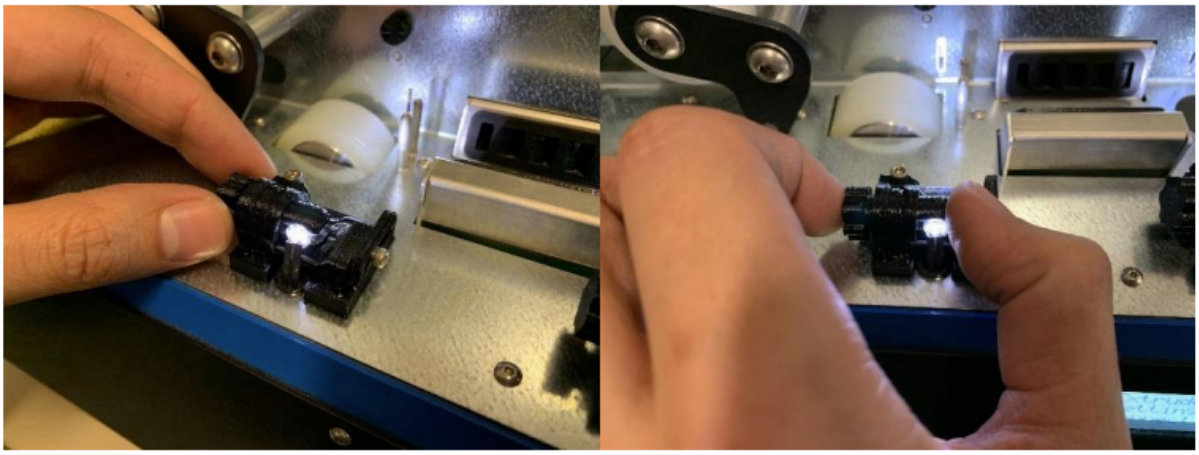


***Figure 12**: How to grip the light guide shaft to adjust LED angle.*

3.6.5 Step 3 - Calibrating the readings

1. Finally, we need to ensure the light guide readings are accurate. This is where we'll use the dowels. The procedure is the same for both the puller and nozzle sensor, with minor differences that will be noted as required.
2. Place the ~1.83mm "dowel" in between the puller wheels as shown in Figure 13. Similarly, check the nozzle sensor using your ~2.56mm dowel of choice. Do your best to align the dowel with the nozzle output as seen in Figure 13. **Make sure the puller idler wheel's spring is attached! This will effectively position the dowel at the right height as it squishes the puller wheel into position.**

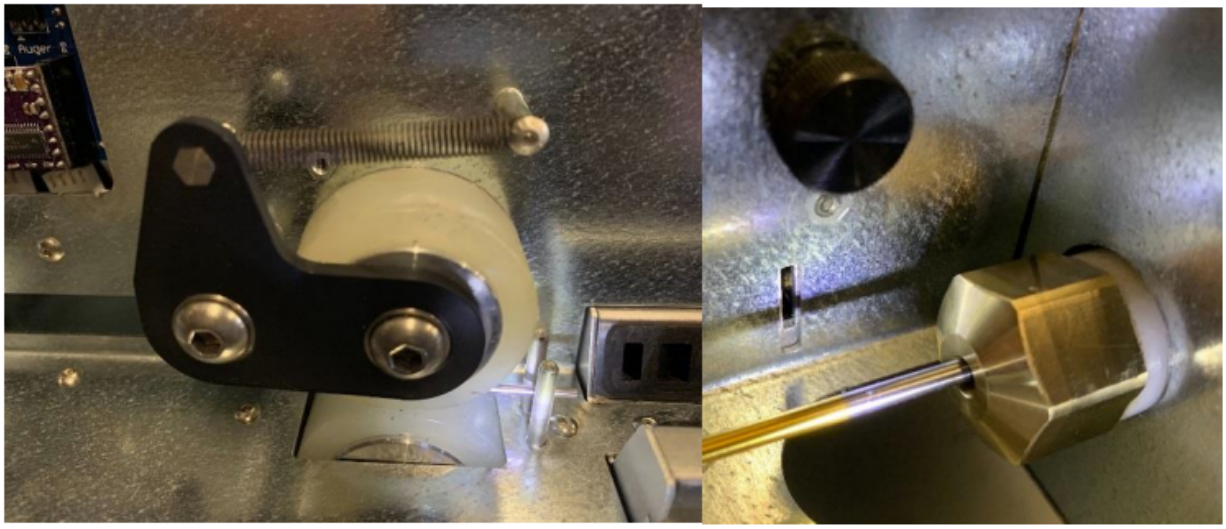


***Figure 13**: The light guide alignment dowel positioned in between the puller wheels on the left, and aligned with the nozzle on the right, in preparation for light guide alignment.*

3. Looking at the GUI (graphical user interface) of your PCC, you should notice that the flat raw data line (representing light being read by the photoresistor) is now a “U-shaped” trough. This is representative of the shadow cast by the LED shining on the dowel, and is shown below in Figure 14.

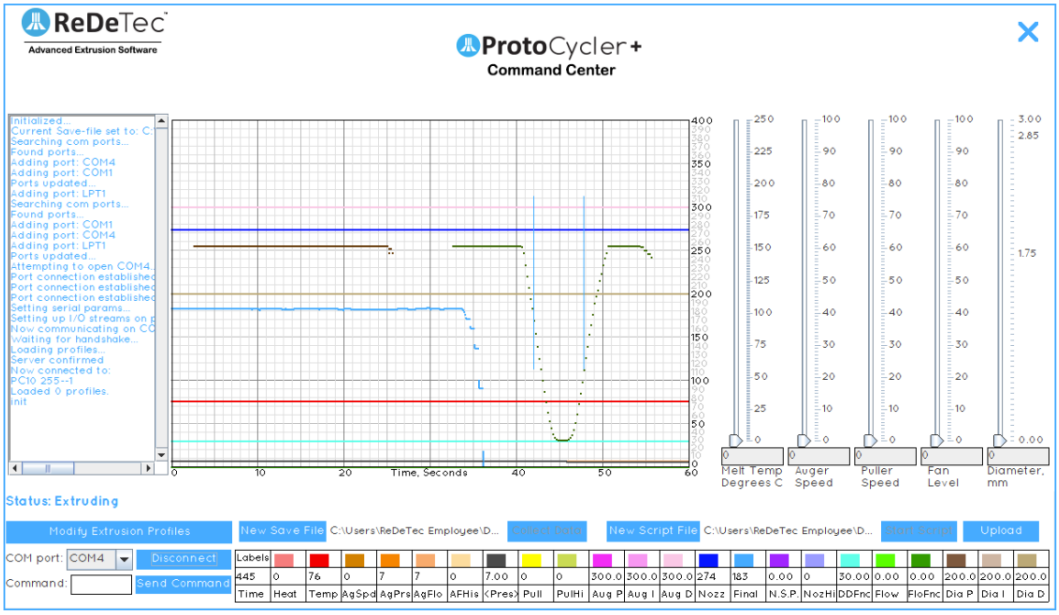


***Figure 14**: Puller sensor raw data reading with 1.83mm dowel.*

4. If either light sensor is not reading the correct value in the Raw Data Stream (“Nozz” and “Final” diameter readings) then the light guides require adjustment by sliding them forward and backward.
5. Both light guides V1.0 and V1.1 have a screw on their side, facing to the user's right. In both cases, loosening this screw allows the light guide to be slid forward and backward, which in turn decreases or increases the reading respectively. To be clear, sliding the LED mount back towards the user increases the diameter reading. Conversely, the diameter reading will decrease as you move the slider carriage closer to the sensor. This is how you achieve nominal reading based on your dowel’s true diameter. This is only effective if the angle of the LED is correctly aligned.

In all likelihood you will only have to adjust the LED’s angle. This is more subject to movement if accidentally bumped when compared to the slider position.

Note that the nozzle sensor’s reading can be a little “off” from nominal - up to 0.1mm - and still operate just fine. The software will adjust the puller speed accordingly. What is critical is that the final diameter sensor’s reading be as accurate and precise as possible.

Diameter sensor alignment can sometimes be an iterative process. Sliding the LED mount forward or backwards may necessitate repeating Step 2, evenly lighting the sensor. Similarly, If the sensor itself is moved up or down, and adjustments are required to evenly light the sensor,

the sensor should be re calibrated (Step 3) to ensure a correct reading. **Ultimately, you want to achieve Figure 14's response for both sensors -the key points are that the shadow is right in the middle of the sensor response pattern, that the pattern is a flat line at 255 where it's not blocked by the filament, and that the diameter reading is exactly accurate as reported.**

4.0 Extrusion Operational Instructions

4.1 Overview

Now that we are all tuned up and have assured our ProtoCycler+ is clean and diameter sensors are aligned, we can extrude filament! We will guide you through Automatic Mode Extrusion and Manual Mode.

Before starting either automatic or manual extrusion, please make sure you've set up your Spooler correctly, including Step 16 and 17 of Spooler Set Up (setting spool dimensions on the ProtoCycler+). If this step is not completed the filament will not spool properly.

Please be sure to operate your ProtoCycler+ in a clean, dry environment, at ambient air temperature (~23C is ideal temperature for your room to be). All ProtoCycler+ units have been primed with PLA and calibrated before leaving ReDeTec. This means there is plastic already in your melt section! Depending on how much time has passed since the ProtoCycler+ was calibrated, the plastic in the melt section may have absorbed moisture from the air. If too much moisture has been absorbed into the melt section plastic, purging may be required - simply run the unit for ~10 minutes to flush out the old plastic with new, dried plastic.

4.2 Initial Extrusion Steps for both Manual and Automatic:

1. Fill your hopper with dry plastic and colorant. Remember colorant is critical if the plastic you are processing is naturally clear when melted (PLA is clear). Mix 11g of colorant for every 500g of plastic.
2. After powering on ProtoCycler+, choose whether you would like to connect to your computer or not.

Automatic extrusion does not require a computer, but it is useful for experimentation and/or troubleshooting with new materials or different ambient conditions. To connect to a computer, follow the procedure in the ProtoCycler+ Command Center guide. **For manual extrusion, you must be connected** to the ProtoCycler+ Command Center.

3. Navigate to the "Extrude" screen using the buttons on the front panel. Press the right button to select Extrude and then either "Automatic" or "Manual. Finally, select "Begin Extrusion" – and proceed to the corresponding section below.

4.3 Automatic Extrusion

One of the best features of ProtoCycler+ are the automatic profiles, which allow your unit to extrude filament completely automatically. ProtoCycler+ comes with some preloaded extrusion profiles, and more can be added depending on your firmware version. It is important that you have the most recent firmware and EEPROM loaded onto your ProtoCycler+ for these profiles to work optimally. Starting with firmware 1.05 and greater, ProtoCycler+ also allows you to upload and run your own custom profiles via the PCC. Please refer to the ProtoCycler+ Command Center Overview manual for guidance on what all the different variables are. Custom profiles must be created and uploaded via the PCC. We suggest creating, testing, and uploading in manual mode extrusion before proceeding with custom automatic profile extrusion.

4.3.1 Automatic Extrusion Steps

1. After completing steps 1-3 in “Initial Steps for Extrusion”, above, your ProtoCycler+ will begin preheating to thermalization temperature. Once up to temperature, the extruder will hold here for 100 seconds to thermalize the melt section. This allows the hot (melt) section of your device to reach a uniform temperature throughout before initiating the rest of the extrusion start-up sequence. This may take a few minutes depending on ambient conditions and the type of plastic you are using. Following thermalization, the extruder will preheat to the extrusion temperature of your selected plastic.
2. Once up to extrusion temperature, you will hear a chime and a prompt on your ProtoCycler+’s UI screen saying “Filament Ready”. At this time, you can now use tweezers or needle nose pliers to feed the plastic from the nozzle in between and through the puller wheels. Be careful! - The nozzle is extremely hot at this point in the startup sequence; follow safety guidelines to avoid personal injury or harm. Make sure you have engaged the puller wheel idler spring! See Figure 15 for reference.

3. Once the filament is being correctly pulled through the puller wheels, select “Filament Ready” on the button pad to confirm to ProtoCycler+ that it may begin stabilization. Note that for safety concerns, there is a 2 minute timeout feature, and if you fail to select “Filament Ready” within this time, ProtoCycler+ will automatically begin to cool down.

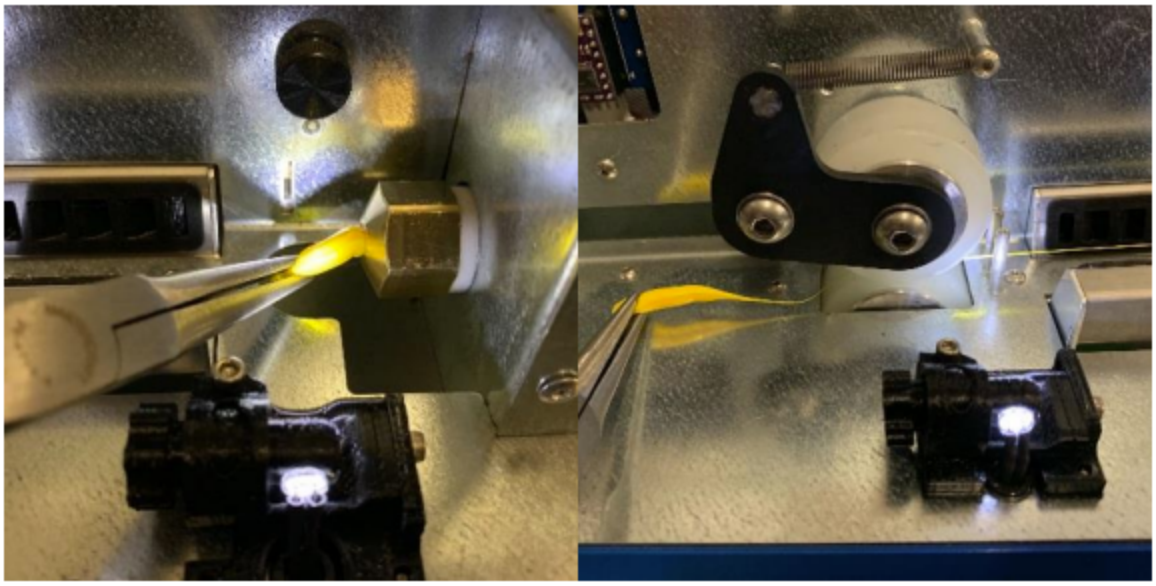


***Figure 15**: Using tweezers or pliers to feed the filament from the nozzle to the puller wheels*

4. ProtoCycler+ will now enter the “Stabilization” phase. Your ProtoCycler+ control system will wait for the filament diameter to become consistent enough to proceed to the spooling phase. In the meantime, just let the filament “dump” off the front-side of the UI. Stabilization may take a few minutes (3-5) depending on material and ambient condition influences. **Ensure that the filament does not begin to wrap around the puller wheel during this time!**
5. Once the output filament has stabilized you will hear another chime and a prompt on the UI screen saying “Spooler Ready”. The fan speed will reduce to allow the filament to soften to a point that it is able to start spooling. Using the yellow handle snips that come with every ProtoCycler+, snip the excess filament that has been extruding off the front side of your UI. Now feed the filament through the spreader guide. See Figure 16 for reference.

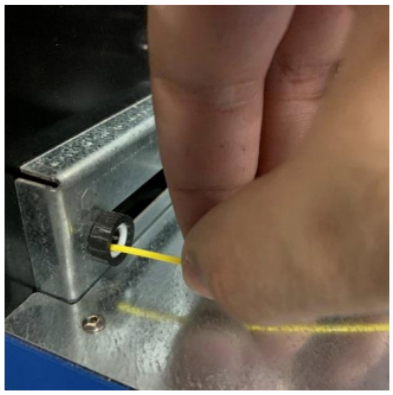


***Figure 16**: Feeding filament through the Spreader Guide.*

6. After feeding the filament through the spreader guide, you must attach the filament to the spool. The spreading and spooling system expects the filament to start against the edge

of the spool, as close to the user as possible, and tightly wound with no slack or loops. Different spools will require different methods of attaching the filament - some have strategically placed holes that you can feed the filament through, and others may require strategic taping. **In all cases, ensure that the filament is tightly attached to the spool!**

7. Once filament is taped to the spool, select “Spooler Ready” using the button pad. If you don’t do this, the extrusion cycle will timeout after 2 minutes, and extrusion will need to be restarted.
8. Now that we’ve accomplished all of the setup work required to begin extrusion, the control system will take over fully. Before the diameter control engages, the ProtoCycler+ waits 60 seconds to allow filament to reach steady state while spooling. At which point the puller wheel speed and fan speed will constantly adapt to changes in output and disturbances to the system to maintain consistent filament diameter.

   Note: For best results, close the door to the UI to avoid any cross-wind affecting your filament output - i.e. if a cross-wind cools the filament at the nozzle too quickly, the puller wheel won’t be able to draw-down the filament to its desired final diameter.

9. And there we have it! You are now off to the races and creating your very own filament!

Note: If connected to a computer, now is a good time to check how your diameter sensors are doing. In particular, your nozzle sensor alignment may need tweaking. Refer to the section below.

4.3.2 Diameter Sensor Check

Depending on the rate of output, you may find that your filament is a little high or low relative to the diameter sensor. From the alignment process, the nozzle sensor is positioned approximately half way in its range of motion. Figure 17 shows ideal light sensor positioning. Notice the two troughs (representing the shadow of the filament) are relatively centered without falling off to either side. Whereas in Figure 18 we see the filament is too far off one side of the sensor for the nozzle sensor. If you find that your filament shadow is too far off one side that the sensor can no longer see the full “width” (diameter) of the filament’s shadow, we can fix this by adjusting the height of the light sensor. Using the thumb screw in the UI (Figure 11 for reference), loosen and adjust the height of the photoresistor so the shadow is centered within the range of measurement similar to Figure 18. When you have achieved this positioning, tighten the thumbscrew to fix position.

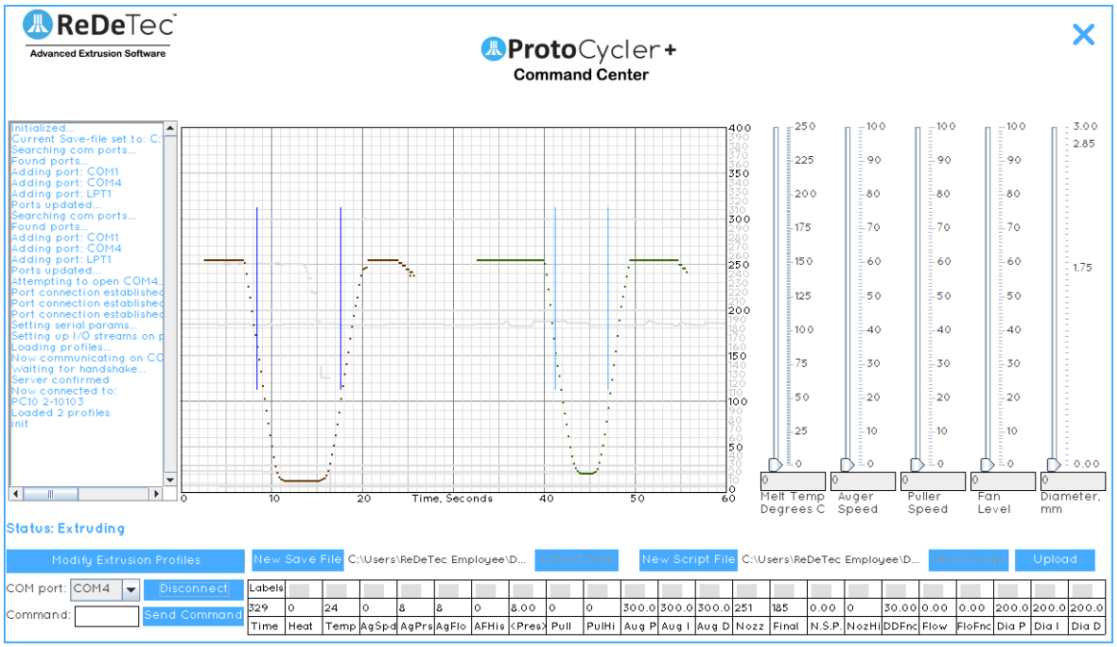


***Figure 17**: Nozzle Diameter Sensor raw data ideal reading example.*

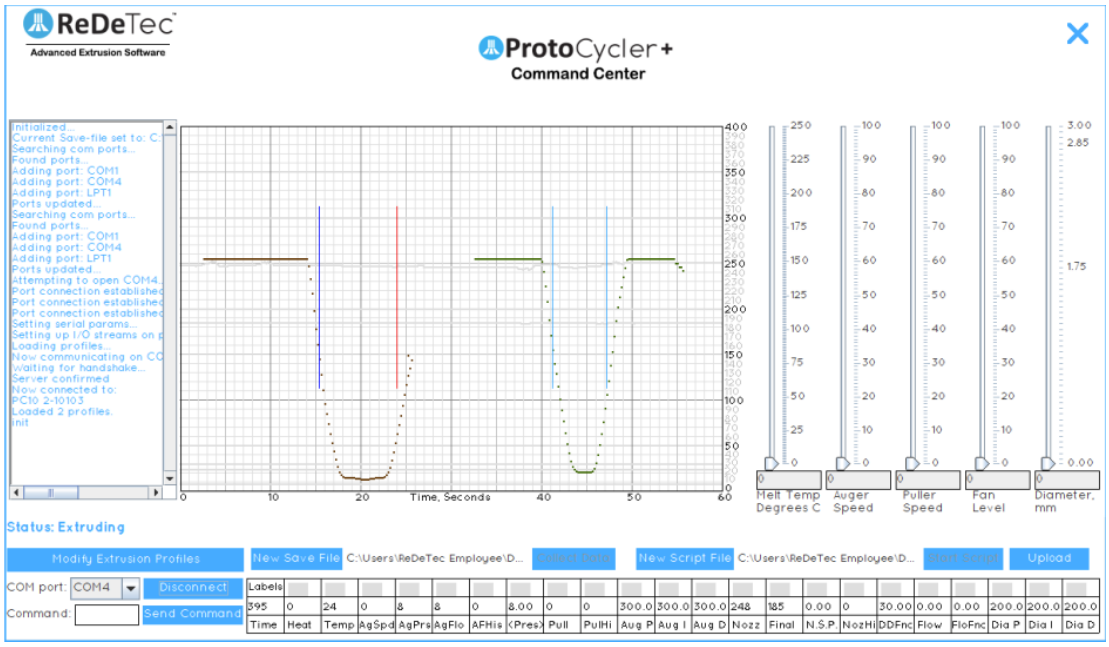


***Figure 18**: Nozzle Diameter Sensor raw data misaligned reading. Notice the rid vertical line indicating the shadow of the filament has completely fallen outside the bounds of the sensor reading range.*

4.4 Manual Extrusion

For greater control and the ability to experiment with extrusion settings and materials, we have enabled a manual mode control. This is excellent for discovering new materials or adjusting existing plastics processing settings based on your ambient conditions. A lot of these instructions are going to be similar if not identical to the Automatic Mode instructions. We copied a few of them here for ease of reference.

4.4.1 Manual Extrusion Steps

1. Once you've clicked "Begin Extrusion" (see "Initial Extrusion Steps", above)...nothing will happen. ProtoCycler+ is now awaiting your commands to do pretty much anything. You'll have to heat up and begin the extrusion process, well, manually!
2. Note that there are a lot of different things happening in automatic extrusion, and you have to set and control all of them in manual mode. It is not easy! Please ensure you have fully read and understood the ProtoCycler+ Command Center Overview - particularly the sections and appendices on how to extrude manually, and what all the commands do - before attempting manual extrusion on your own. Note as well that this guide is very brief, but should at least get you up and running.
3. Begin the thermalization process by sliding the temperature sensor to the desired setting. A safe starting point is whatever the data sheet for your plastic says, minus ~30 C. Do NOT use the settings that you would 3D print with! For instance, PLA usually 3D prints around 190-220 C, and the datasheet suggests 200 C for processing. However, ProtoCycler+'s patented MixFlow system requires a temperature of only ~180 C for PLA, so we would want to thermalize around 170 C.
4. Before turning on your auger feed, we need to disable the lower pressure bound by entering in the command line: "pl000000", no quotes, and clicking "send command". This will prevent stalling during the preheat and priming phase.
5. Now set your auger speed via the slider, somewhere in the lower half of the range until the system has fully preheated.
6. Allow the melt section to thermalize for 100 seconds once up to temperature (set in step 4).
7. Following thermalization, you may begin the extrusion temperature preheat. Using the slider set to the desired temperature - As in step 3, you want to set the temperature notably lower than the datasheet or 3D printing knowledge would suggest. For PLA, a temperature of 180 C is a good starting point. **Always start low and increase as needed, not the other way around!**
8. Once the plastic has reached its correct temperature and is correctly flowing out of the nozzle, we can now set the lower pressure bound back to its default. Enter "pl000025" in the command line, no quotes, and click "Send command". For more information on the PL term, consult the extrusion theory guide.
9. Turn on your fan using the slider. This may vary depending on what material you are processing. Essentially, we want the plastic to be soft enough to start spooling easily. If the plastic is too cool then it will be very stiff and difficult to begin spooling with. Similar to

3D printing, you want the fan on max for plastics like PLA. However, unlike 3D printing, you ALWAYS want the fan on at least a little bit - even for plastics like ABS. **Never run the unit without the cooling fan enabled.**

10. Attach your puller wheel idler arm spring if you haven't already. Set your pull speed slider to ~30% of its range depending on material throughput. This will set the puller wheel to spin at a constant speed that is easy to work with during setup.
11. Use tweezers or needle nose pliers to feed the plastic from the nozzle in between and through the puller wheels. Be careful! - The nozzle is extremely hot at this point in the startup sequence; follow safety guidelines to avoid personal injury or harm. Make sure you have engaged the puller wheel idler wheel spring! See Figure 15 for reference.
12. If spooling is desired, follow the steps below. If not (because your filament isn't usable), skip this step. To begin spooling, reduce the filament speed and cooling as much as possible (halving the auger, fan, and puller is a good starting point). Then follow steps 5 and 6 from the automatic instructions - feed the filament through the spreader, and attach tightly to the spool. As soon as the filament has made one loop, send the command "ss000000" to begin spooling, and re-increase the auger, puller, and fan speeds back to their intended values.
13. Finally, enable diameter control. To do so, slide the diameter slider to the desired filament size (measured in mm). Note that diameter control may fail irrecoverably if the filament is too far away from the desired size, if the extrusion flow is too low (or too high), or if any of the parameters are incorrectly set. It is always best to get the diameter as close as possible to nominal before enabling diameter control!

As in Automatic operation, now is a good time to check how your diameter sensors are doing. In particular, your nozzle sensor. Refer to section 4.3.2.

Note: For best results, close the door to the UI to avoid any cross-wind affecting your filament output - i.e. if a cross-wind cools the filament at the nozzle too quickly, the puller wheel won't be able to draw-down the filament to its desired final diameter.

14. And there we have it! You are now off to the races and creating your very own filament!

5.0 Intro to the ProtoCycler+ Purge Procedure (PPP)

When purging your ProtoCycler+'s extrusion system there are two types of purging depending on what you wish to achieve. They are:

1. Short Purge: Required when transitioning between wet and dry plastic or color changes. Please see section 5.1.1 for instructions on how to conduct a Short Purge.
2. Disco Purge: Required when conducting a materials change. Please refer to section 5.1.2 for instructions on how to Disco Purge.

Please be sure to abide by all safety precautions outlined in the main user manual.

For further details on different purge conditions and temperature settings please refer to the Appendix in section 7.0, Table 2 of this document.

5.1 Purging

The following steps will guide you through purging from a cold-powered-down-hopper empty ProtoCycler+ state. Be sure to have a set of pliers or tweezers and nozzle wrench (if needed) ready.

All temperature settings for purging are found in the Appendix, section 7.0 of this document.

5.1.1 Short Purge

1. Power on your ProtoCycler+ and connect to the PCC software. Pour the new plastic you wish to extrude into your Extruder Hopper. While connected to the PCC begin manual extrusion.
2. Enter the command "pl000000" in the command line and click "Enter Command". This will assure the lower auger speed limit has been disabled.
3. Manually set the temperature using the PCC slider to the preheat temperature (in accordance with Table 1).
4. Set the auger speed to ~40% of its range using the PCC slider.
5. When the preheat temperature is achieved, wait 100 seconds for the melt section to reach a uniform temperature and viscosity.
6. Once Step 5 is complete, increase the temperature slider to the appropriate purge temperature.
7. When purge temperature is achieved, increase the auger speed to ~75% of its range on the slider. Purge for ~10-15 minutes at the designated purge temperature and auger speed until fully transitioned to new plastic. Purge time may take longer depending on the material.
8. Material will start flowing and dump into the Garbage Shoot. Remove the side door to clear the material inside. Be careful, the melted plastic is quite hot if it does not have

time to cool. Take proper precaution with PPE and pliers when removing the plastic from the Garbage Shoot to avoid injury.
9. From here you may proceed into regular manual extrusion operation or choose to shutdown following manual mode shutdown procedure as outlined in the “Manual Extrusion” section of this manual.

5.1.2 Disco Purge

Disco Purging means we are going to thermal cycle the ProtoCycler+ to help transition from one material to another. It is strongly recommended to remove nozzles for the duration of a disco purge and replace it only when purging is complete with a new nozzle. Removing the nozzle will require preheating in order to soften the plastic inside to release the nozzle. Please refer to Table 2 for nozzle removal temperatures.

Steps:

1. Remove nozzle and follow steps 1-8 of section 5.1.1 (Short Purge).
2. After your first 10 minute cycle, immediately set your temperature slider to 0 C. The auger will limit its speed as the extruder cools and material melt resistance increases.
3. Once the extruder reaches the temperature of the “Lower Temperature” material’s nozzle removal temperature (see Table 2 for reference), increase temperature back up to the Purge Temperature.
4. Purge for 10 minutes.
5. Repeat steps 2-5 until completely transitioned to the new material.

5.2 Purge Tips

1. Purging plastic – especially from a warmer temperature plastic to a cooler temperature plastic – can take a long time. It is recommended that you avoid or mitigate the need for switching plastics as much as possible.
2. Use different colorants as an indicator when purging to distinguish between old and new plastic.
3. When purging dissimilar materials, the general rule is to look at the MSDS documentation to see where the extrusion (purge) temperatures overlap. Importantly, do not increase temperature so high that you burn the old or new material inside of the extruder. But what if there is no overlap in the two materials’ processing temperatures? If this is the case, please contact Technical Support immediately for assistance, stating what plastics you are transitioning from and to. ReDeTec will advise further.
4. Having an extra nozzle (with breaker plate and screen) is especially useful when switching between materials to not contaminate the new material!

6.0 Congratulations!

You are now ready to make your own filament! As with anything, there is an initial learning curve, and longer path to mastery. But following this manual should set you up on the best path forward.

If there is anything we can help with please contact our technical support email: techsupport@redetec.com

All the best and happy extruding,

Team ReDeTec

7.0 Appendix

Table 2: *Below summarizes possible purge scenarios, their respective temperature settings, and what type of purge they require.*

	Old Material to be Purged	New Material to be Primed	Purge Type	Nozzle State	Nozzle Removal Temperature [C]	Preheat Temperature [C]	Purge Temperature [C]	Notes
1	Low Temperature Material (eg. PLA)	High Temperature Material (eg. ABS)	Disco Purge	Off	Low temperature material preheat temperature minus 25C. Temperature can vary depending on material type and grade. Special exception to ABS where the removal temperature is the same as the preheat temperature.	Low temperature material extrusion temperature minus ~10C. Temperature can vary depending on material type and grade	Low temperature maximum extrusion temperature specified in manufacturer's MSDS document.	Cross reference materials extrusion temperatures when purging dissimilar materials. If the minimum extrusion temperature for the high temperature material is higher than the maximum extrusion temperature of the low temperature material then you will risk burning

								the low temperature material and clogging your extruder. If there is no overlap in material processing temperatures, you may require an intermediary purge material.
2	High Temperature Material (eg. ABS)	Low Temperature Material (eg. PLA)	Disco Purge	Off	High temperature material preheat temperature minus 25C. Temperature can vary depending on material type and grade. Special exception to ABS where the removal temperature is the same as the	High temperature material extrusion temperature minus ~10C. Temperature can vary depending on material type and grade.	High temperature minimum extrusion temperature specified in manufacturer's MSDS document.	Cross reference materials extrusion temperatures when purging dissimilar materials. If the minimum extrusion temperature for the high temperature material is higher than the maximum

					preheat temperature .			extrusion temperature of the low temperature material then you will risk burning the low temperature material and clogging your extruder. If there is no overlap in material processing temperature s, you may require an intermediary purge material.
3	Color 1	Color 2	Short Purge	On	Material Dependent.	Material Dependent.	Material Dependent.	Run extruder in manual mode until purged of previous color and fully transitioned to the new color. Color can also be

								switched at any time during regular extrusion.
4	Wet Plastic	Dry Plastic	Short Purge	On	Material Dependent.	Material Dependent.	Material Dependent.	Run extruder in manual mode until purged. Plastic may be wet if you notice necking or bubbles (or pockets) in extrusion. You can leave the nozzle on for wet to dry plastic conditions.