3devo

MATERIALS MADE **SIMPLE**.

FS92-A & FS92-A-N

Intumescent Plastic Parts

Blend of plastic with inorganic fillers

Extrusion Walkthrough

Our experiences with the extrusion of FS92-A / FS92-A-N, which is according to the Safety Datasheet a blend of Polypropylene and Chlorinated Polyethylene among other plastics, and inorganic filler components. The material will be referred to as “FS92” in this report.

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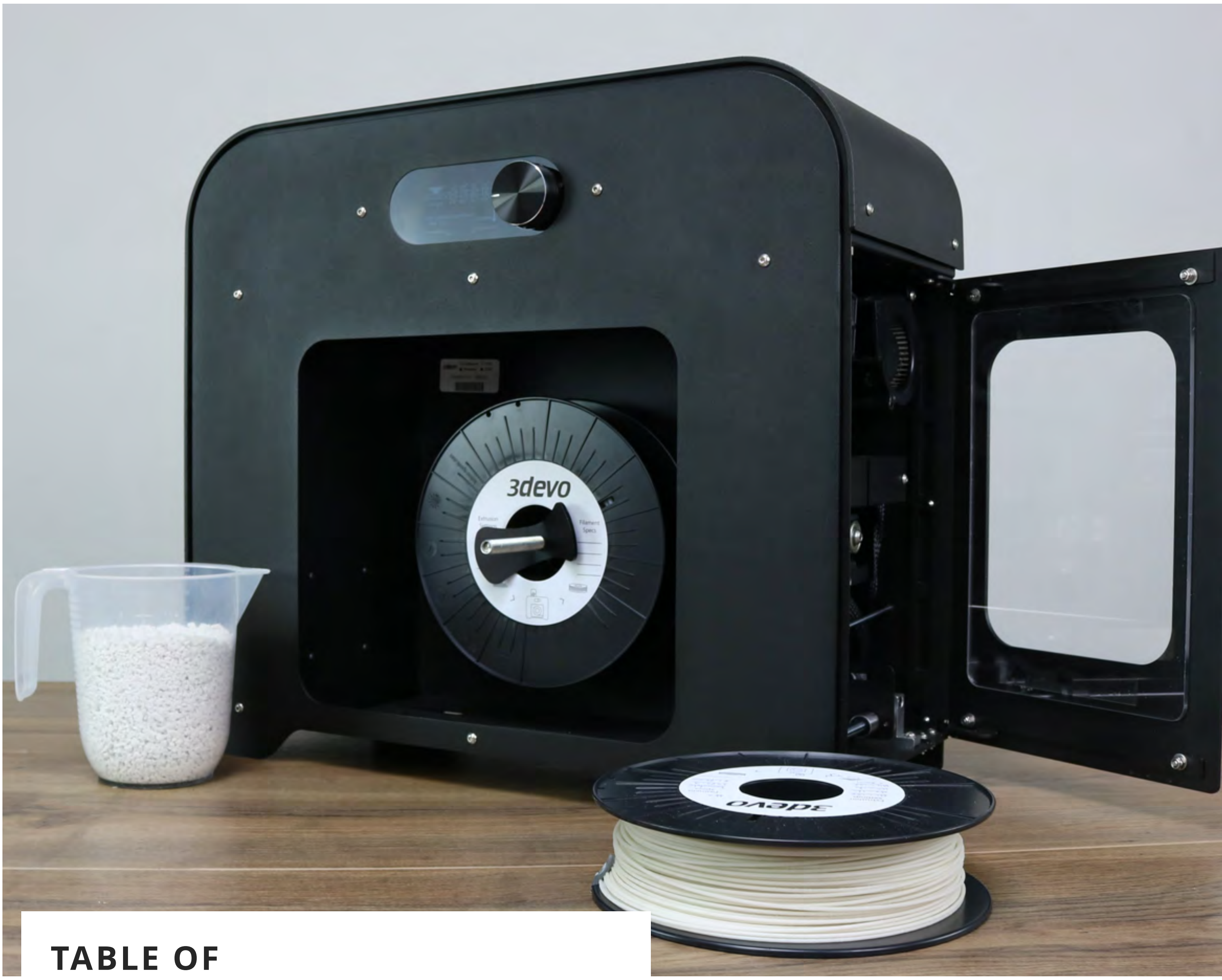
CLIENT: Lancotek



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1. INTRODUCTION AND CONTEXT OF THIS REPORT

This document is a guide through the extrusion process of FS92, performed in our test lab at 3devo. It describes the experimental process that led to the optimal settings and the best product quality. Please be aware that every material behaves differently, so this process might not be 100% applicable to all materials.

The goal of the test was to extrude the supplied regrind material into **1.75mm filament**. Figure 1 is a picture of the original batch of regrind.

Chapters 2 to 5 explain more in detail the main experimental steps of the extrusion test itself, which consisted in a series of adjustments. It is crucial to note that the final extrusion test was performed on a **Precision** machine equipped with a **2mm nozzle.** Chapter 6 gives an overall conclusion regarding the processability of FS92, and summarizes the entire report.

Figure 1 - *Batch of FS92*

Figure 2 - *Feeding FS92 regrind into the hopper of the extruder*

2. PREPARATION AND PRE-PROCESSING

Before the extrusion test, a transition material had to be determined. This is because according to the SDS the FS92 has a low processing temperature (143 ˚C – 160 ˚C), within a range that most polymers do not cover. A material has to be found which can be extruded at these temperatures, to be able to introduce the FS92 without decomposing it too much, which usually leaves contamination in the extruder. The transition material chosen here was pellets of PLA 4043D, since this has a peak melting temperature of 153 ˚C.

So before extruding FS92, PLA was extruded around 200 ˚C (all four heaters). Once pure PLA was coming out, the temperatures of all heaters were reduced to 160 ˚C which is the upper processing limit of FS92.

Once the machine cooled down to 160 ˚C, FS92 was introduced (Figure 2).

WARNING When experimenting with a new grade of plastic, it is very important to introduce the plastic at temperatures high enough to ensure sufficient melting and to avoid the clogging of the machine.

3. EXTRUSION (1): STARTING POINT AND FIRST OBSERVATIONS

The following settings were used as a starting point during the extrusion test:

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	160 °C	160 °C	160 °C	160 °C	5.0 RPM	50%

WHY 160˚C ? As mentioned earlier, it is wise to start at a temperature that is too high, to avoid clogging of the machine as a result of unmelted particles. Also, this starting temperature could not have been much lower since the melting point of the used transitioning material 'PLA' is 153 ˚C. For FS92 160°C is on the high end of the thermal window of operation, because this is the point where the Chlorinated polyethylene component starts to decompose.

WHY 5.0RPM AND 50% FAN SPEED ? These values are very often appropriate values to start experimenting with a new material. In order to extrude stable filament of 1.75mm thickness, the best rotation speed is usually found between 3.0 and 7.0 RPM, which is why the starting value of 5.0RPM is always a good start. As far as the fan speed is concerned, it is harder to define an ideal percentage that works by default, because this parameter can vary a lot; it is good to start with a medium value and be ready to make quick adjustments.

THE FIRST RESULTS : The transition from PLA was smooth and fast, Figure 3 illustr ates the transition from PLA to FS92. The transition only took a few moments, it was sudden and clearly visible as the FS92 is more opaque, white and rough than PLA. The output flow seemed to be better than with the PLA at this temperature, probably because the melt viscosity of the PLA was quite high at this point (which means that it flows less easily).

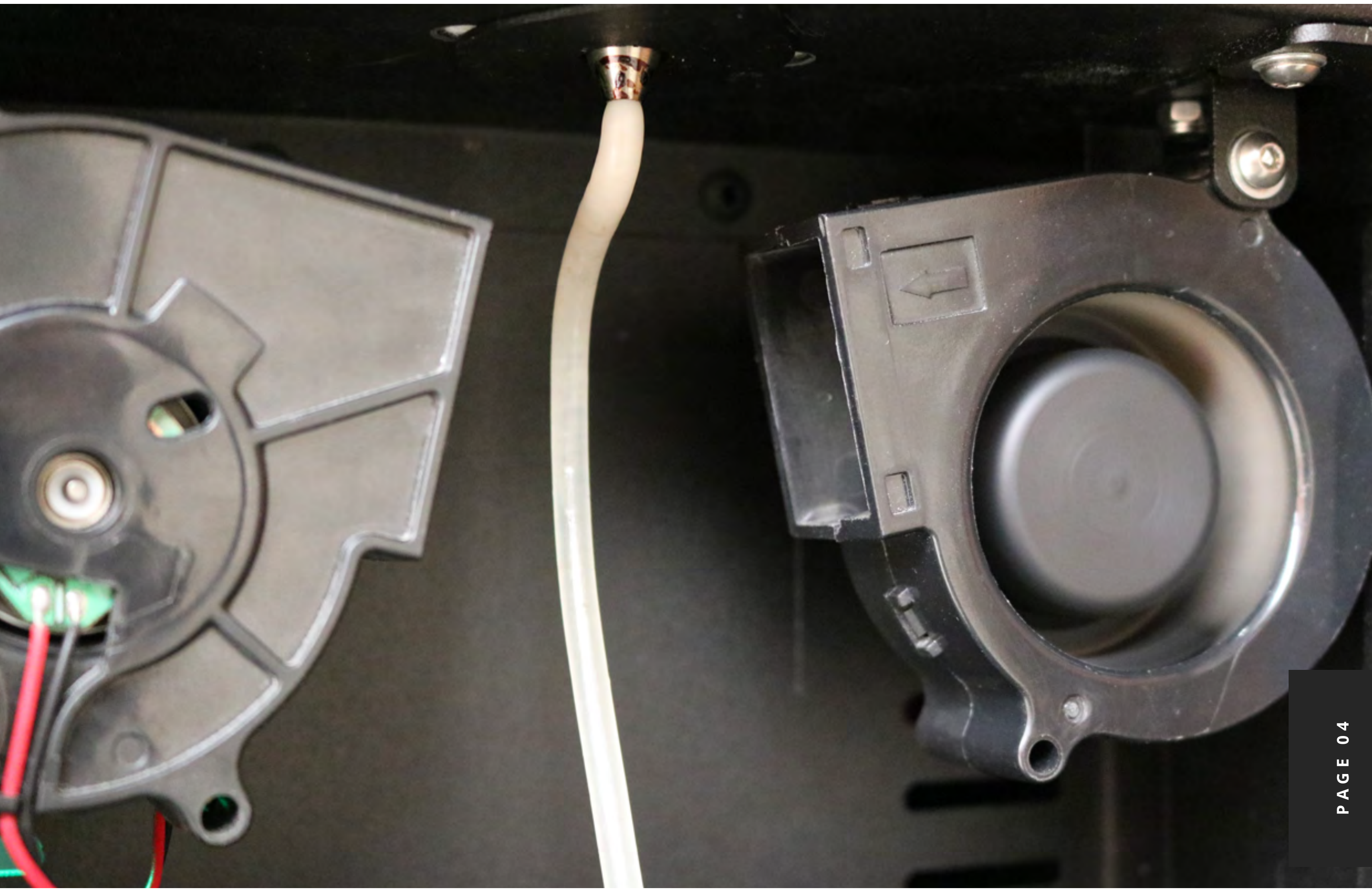

Figure 3 - *Transition from purging PLA (slightly transparent extrudate at the bottom) to FS92 (opaque extrudate at the top)*

After a couple of minutes of extrusion the PLA was completely purged out of the machine, with now pure FS92 coming out of the nozzle. The formed filament was put between the puller wheels and filament sensor, to pull it from the 4mm nozzle opening to the desired 1.75mm filament thickness. As soon as this was done, the first problem occurred. The extruded melt was not strong enough to be able to be pulled a lot. As soon as the puller mechanism accelerated to stretch the melt, it tore apart as in Figure 4.

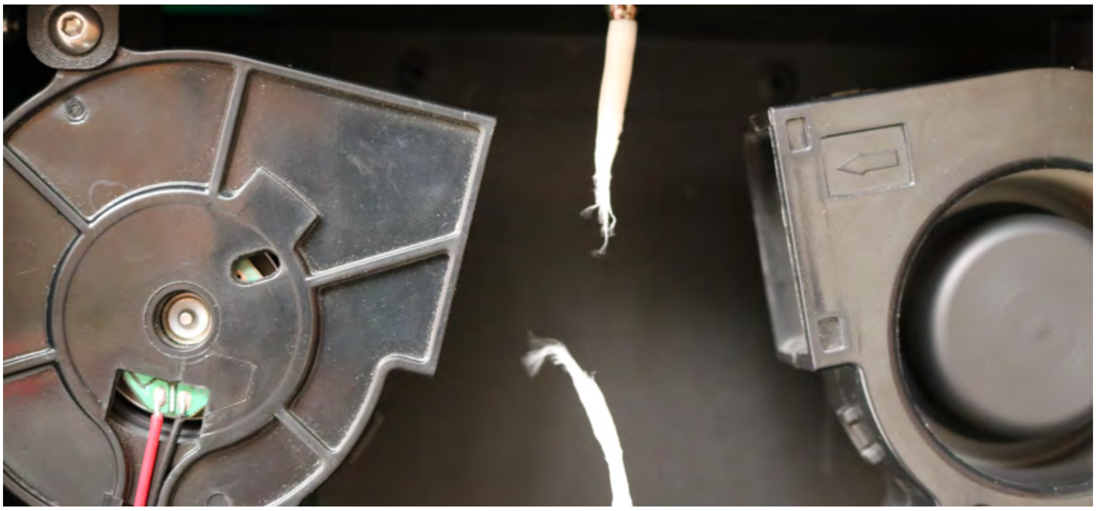

Figure 4 - *Overstretching of the filament*

This can be fixed by either increasing the melt strength of the material (by increasing the viscosity upon decreasing temperatures), or using a 2 mm nozzle instead of this nozzle with a 4 mm opening, so the material does not have to be stretched so much.

Another problem which occurred after a while of extrusion, was ratholing in the hopper of the machine. This can be seen in Figure 5, where a **"RATHOLE"** occurs in the hopper which prevents the material from feeding consistently into the machine. This usually occurs to materials that have a very irregular and rough shape such as this FS92. If the input is unstable, the output will very likely be unstable as well. As you can see in Figure 5, the hopper grid was taken off so there was full access to the hopper, and the material could be stirred every now and then to break up the rathole again. Luckily at 3devo we are working on an automated add-on for the machine to permanently fix this, so this does not have to be done manually anymore and input consistency can be improved. For this test we used the first prototype for this add-on.

Figure 5 - *Ratholing in the hopper*

4. EXTRUSION (2): AJUSTMENT STEPS

The objective was to find the optimal extrusion settings with the help of the filament sensor. Figure 5 is a picture taken during the adjustment phase, before the filament was of sufficient quality to be spooled. The challenge here was to improve surface quality, uniformity and filament thickness stability.

FILAMENT FAN SPEED: Because the extrudate solidified too soon while reaching the puller, the correct approach was to decrease the fan cooling percentage down to only 10%. When the filament becomes solid too soon, the filament is not stretchable enough to reach the desired thickness and rather breaks than stretches.

SCREW RPM: The screw rotation speed was decreased gradually down to 2 RPM. This was to give a higher residence time for the material inside the barrel, to ensure more homogeneous melting and more stable flow. Also the output of the material decreases, which makes it easier for the puller mechanism to adjust to the desired thickness consistency. By giving the material also more time to be pulled to the desired thickness, there is less chance of overstretching certain parts.

TEMPERATURES: Finding the right temperature settings was tricky to a certain extent. The safety datasheet of FS92 states that the melting point is 143 ˚C, but the Chlorinated Polyethylene component already starts decomposing around 160 ˚C. This means that the extrusion temperature should be found somewhere in between to retain a high quality. Unfortunately this was not entirely possible. If the temperatures drop below 155 ˚C, the material does not melt sufficiently, and eventually overloads the motor that powers the extrusion screw. Eventually it was found that a descending temperature profile worked out best for this material. This made sure that the material melts sufficiently in the beginning, but the temperature of the output is slightly lower. With this lower output temperature a higher melt strength was achieved, which made the formed filament stronger and less likely to overstretch or break.

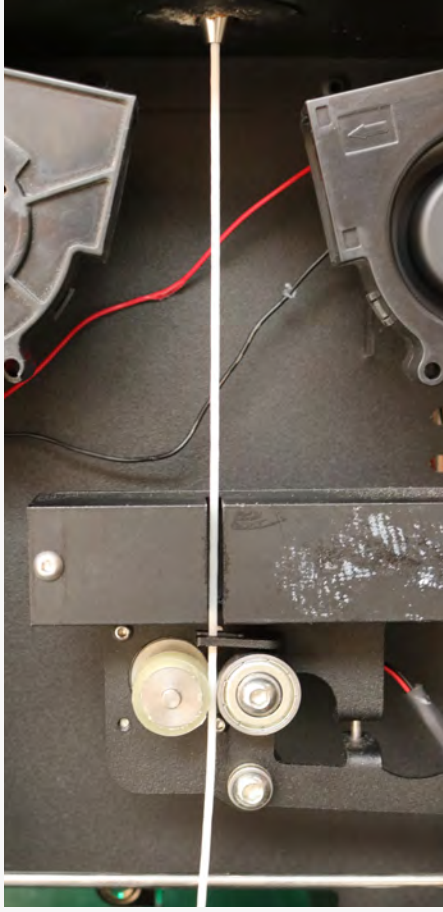

Figure 6 - *Filament flowing freely during the adjustment phase*

5. EXTRUSION (3): SPOOLING

The filament was spooled using the final settings found during the adjustment phase:

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	158 °C	160 °C	160 °C	157 °C	2 RPM	10%

A spool was successfully manufactured using these settings. Figure 7 is a microscope shot of the product.

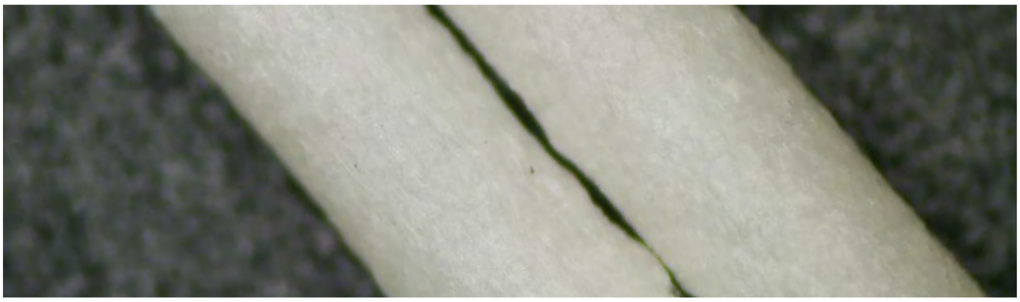

Figure 7 - *Microscope shot to show the visual aspect of the filament : smooth, homogeneous, clear, consistent*

Figure 8 is the graphical representation of the datalog which corresponds to the produced spool. It shows that the filament thickness was very stable during the entire spooling process, relatively well kept within an industrial tolerance (1.75 ± 0.05mm).

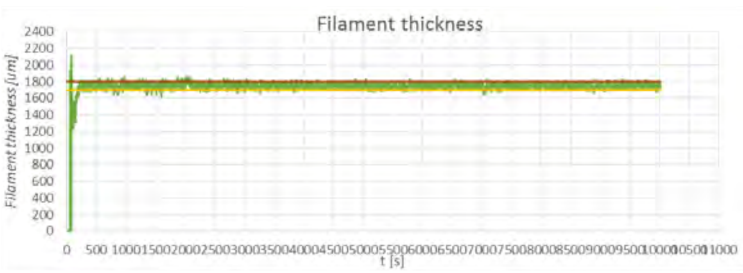

Figure 8 - *filament thickness (set value : 1.75mm, red line : 1.80mm, yellow line : 1.70mm)*

Figure 9 *- Spool of FS92*

6. CONCLUSION AND RECOMMENDATIONS

This extrusion experiment was quite positive. Indeed, 1.75mm filament of decent quality was obtained using a Precision equipped with a 2mm nozzle. Even though the 3D printing of this filament remains to be investigated in order to close the loop and print parts of good quality, it can be said that the material can be extruded quite easily when the right parameters are found, and that the resulting filament's thickness is well kept within industry tolerance standards (+/- 50 microns). Figure 9 is a picture of a spool which was obtained at 3devo in a few days of testing. After this test the machine had to be purged clean. PLA was used to purge out most of the FS92, to be able to increase the temperatures again. Then, around 200 °C the machine could be purged with Devoclean mid-temp purging compound. This procedure went without problems as well, only 300 grams of each material was needed for proper cleaning.

REPORT SUMMARY:

TO DOs:

- Use PLA or another material with such a low melting point as transitioning material.
- Use a 2mm nozzle.
- Purge thoroughly after extrusion using PLA first to be able to increase the temperatures, and then Devoclean Mid-Temp (at the processing temperatures).
- Remove the hopper grid, to be able to stir the hopper whenever a "rathole" is forming. (this is not necessarily dangerous, just be careful not to stick anything inside the screw)

WARNINGS:

- It might be necessary to adjust the fan speed depending on the room conditions.
- Do extrude the material too fast, because this increases the chance of overstretching the filament by the puller mechanism.
- Do not exceed temperatures of 160°C, otherwise the Chlorinated Polyethylene component will start to decompose.

Parameter	H4	H3	H2	H1	Screw speed	Fan speed
Set value	158°C	160 °C	160°C	157 °C	2 RPM	10%