Acetal and Formaldehyde

Background

All Acetal materials produce formaldehyde during processing. Some more than others and all more when processed outside optimum processing conditions. The current described optimum conditions are for other processes, not 3D Printing. Formaldehyde is pungent gas and a constituent part of Tear Gas. It is quite apparent when produced. Acetal is widely used throughout industry due to its material properties. When processing Acetal using Injection Moulding there are some processing/machine conditions that are not available during processing with a 3D Printer. Some of these conditions will help with the processing of Acetal, some of these conditions will hinder. We need to find a good methodology that can be deployed widely to aide the processing of Acetal with 3D Printing techniques. However this needs to be done in conjunction with good understanding of Acetal and Formaldehyde production. This document represents a start point for that process. You should always conform to the best Health and Safety practices available.

Process

It is our aim to make public the findings of our research into 3D Printing and Formaldehyde production using Stratum3D's Acetal 613 by demonstrating them in action, using photos taken while producing a simple component. This component is a Simple Cylinder with one closed end. It is being produced using the Stratum3D Acetal 613 processing guide. (i.e. solid raft 1 or 2 layers, build bed140C, medium processing speed of 90mm/s and 3 different material processing temperatures) Each build is 30 minutes long.

We will be using a Makerbot Replicator 2X. This machine is standard as purchased except we have used a Stratum3D prototype drive/extruder gear as a replacement to the original. We have used this as we find the standard Makerbot drive gear produces a lot of debris in processing due to the high crystalinity and hardness of Stratum3D Acetal 613.

To measure the Formaldehyde produced during processing we will be using a MultiRAE Lite Meter with a Formaldehyde (HCHO) sensor fitted. (See Appendix A). We will process the component with the same conditions in each test except we will increase the material temperature with each test to induce and demonstrate the production of Formaldehyde and measure the results.

Formaldehyde exposure limits are detailed in the Material Safety Data Sheet (MSDS) supplied with Stratum3D Acetal 613. This is also available from our web site www.stratum3d.com).

Stratum3Ds Acetal 613 MSDS Limits

OSHA TWA 0.75ppm

STEL 2.00ppm

ACGIH TWA 0.30ppm

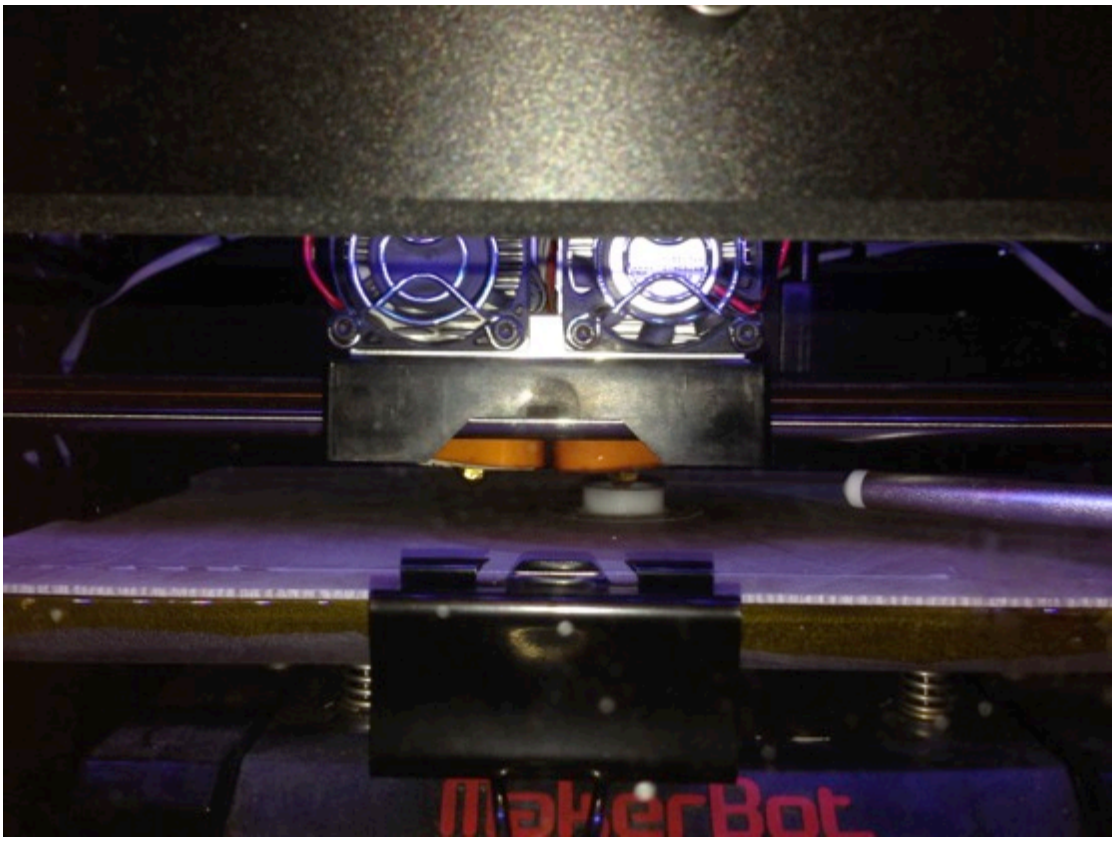
Test 1

Conditions: Material Temperature 220c. Build Bed 140c. Medium processing speed 90mm/s

10% into build 0.38 ppm Formaldehyde being produced

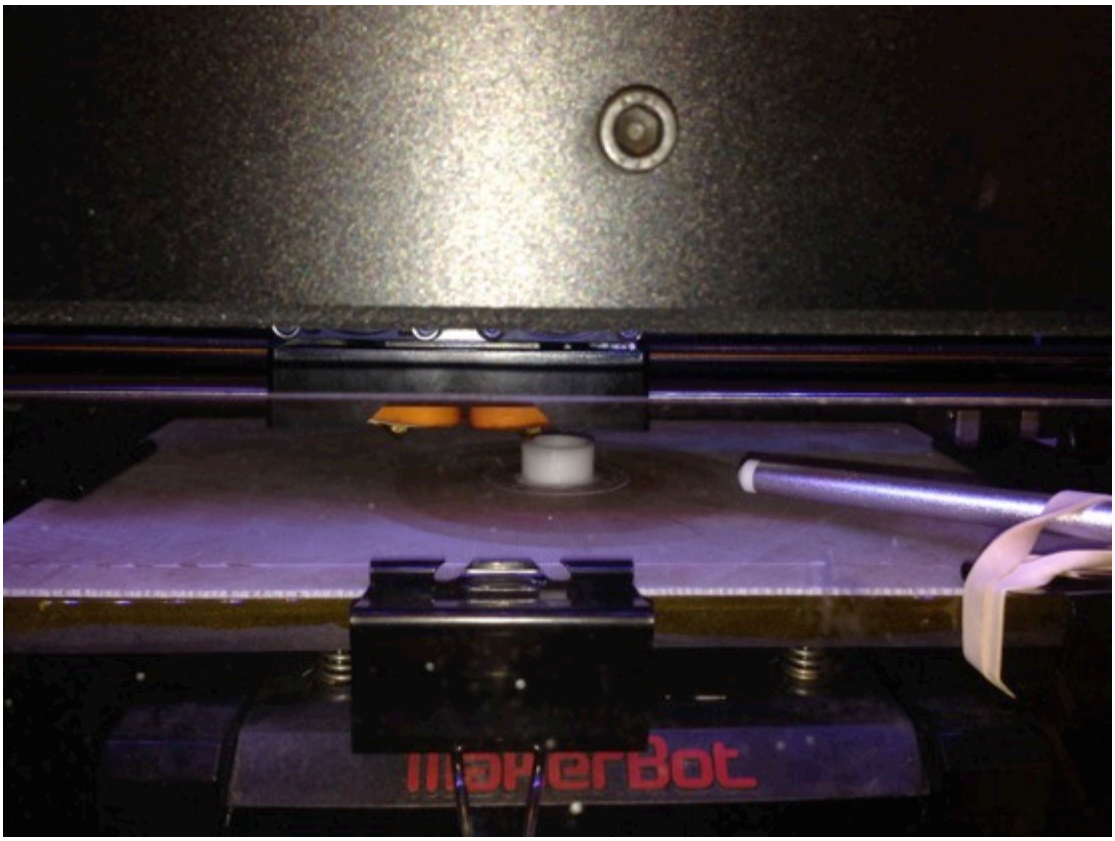
39% into build 0.20 ppm Formaldehyde being produced

39% Part build working well



48% into build 0.20 ppm Formaldehyde being produced

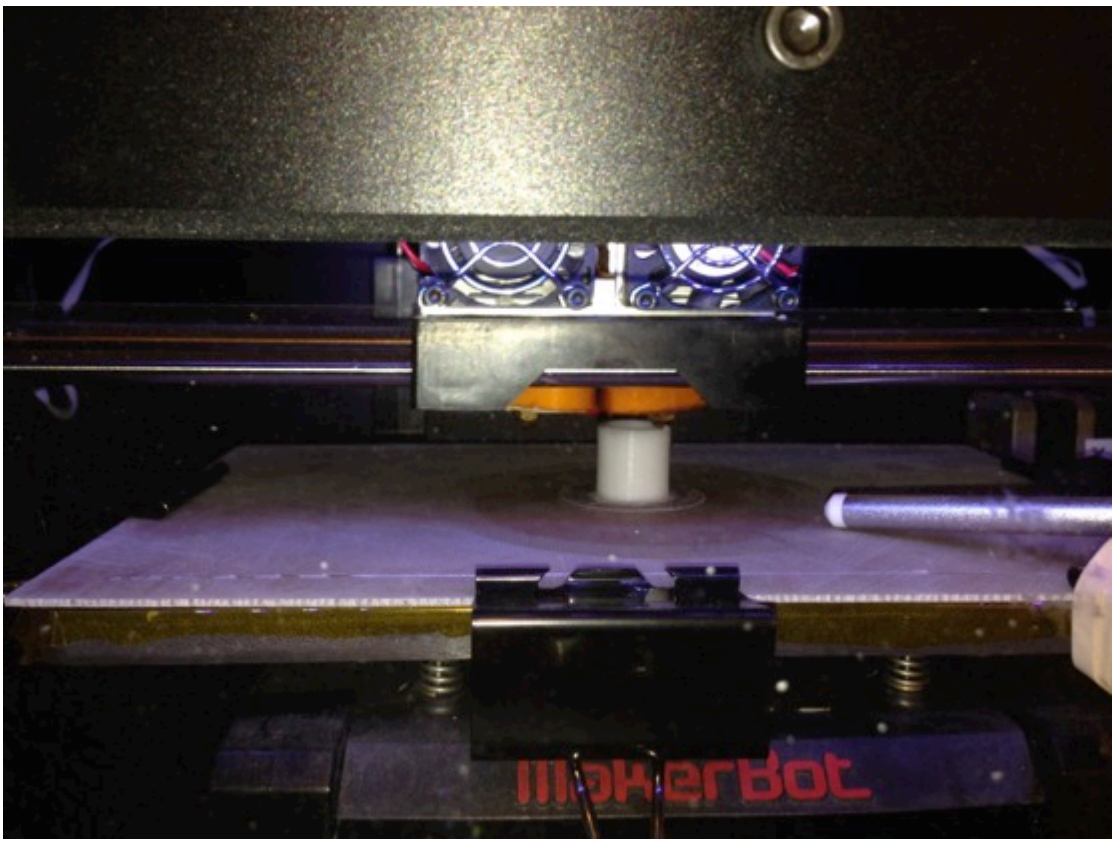
48% Part build going fine



76% in and 0.29 ppm Formaldehyde being produced.

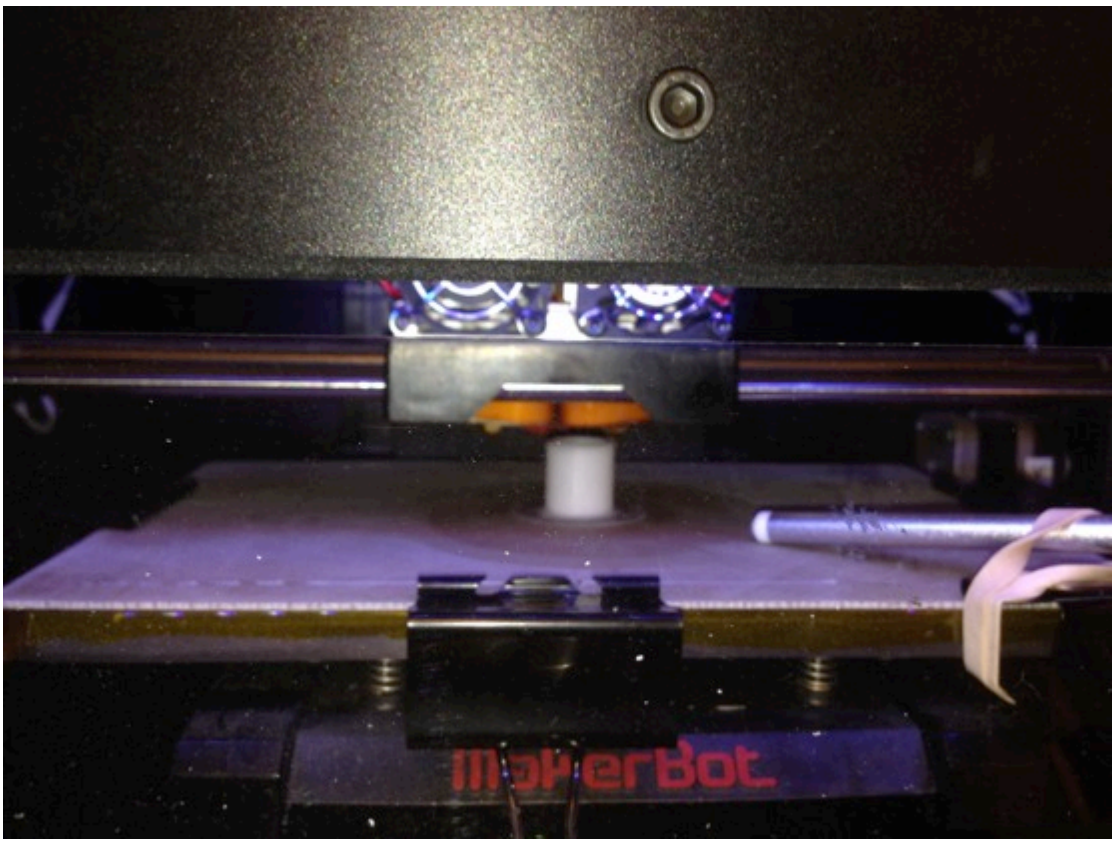
95% in and 0.25 ppm Formaldehyde being produced

95% in and part build is nearly complete, part looks good.

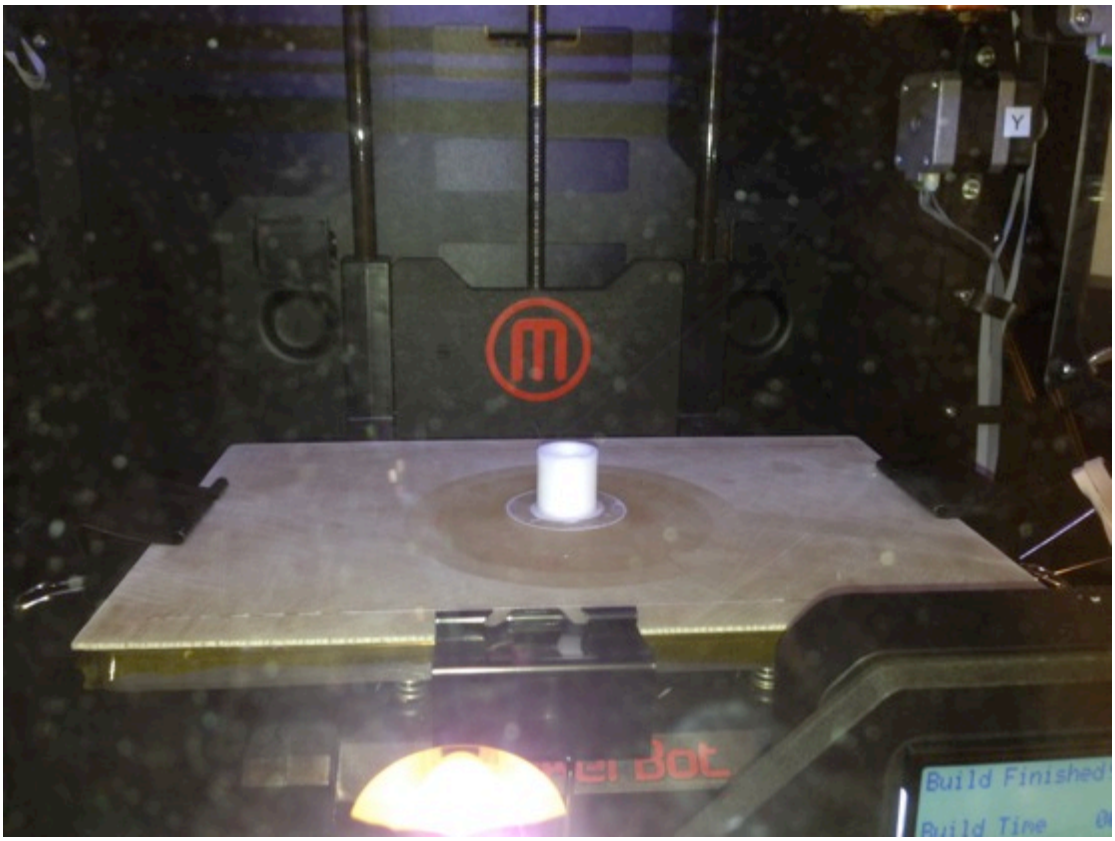


99% in and 0.22 ppm Formaldehyde being produced.

Build Complete, nice part.



Build Complete, let build plate cool down, and remove part.



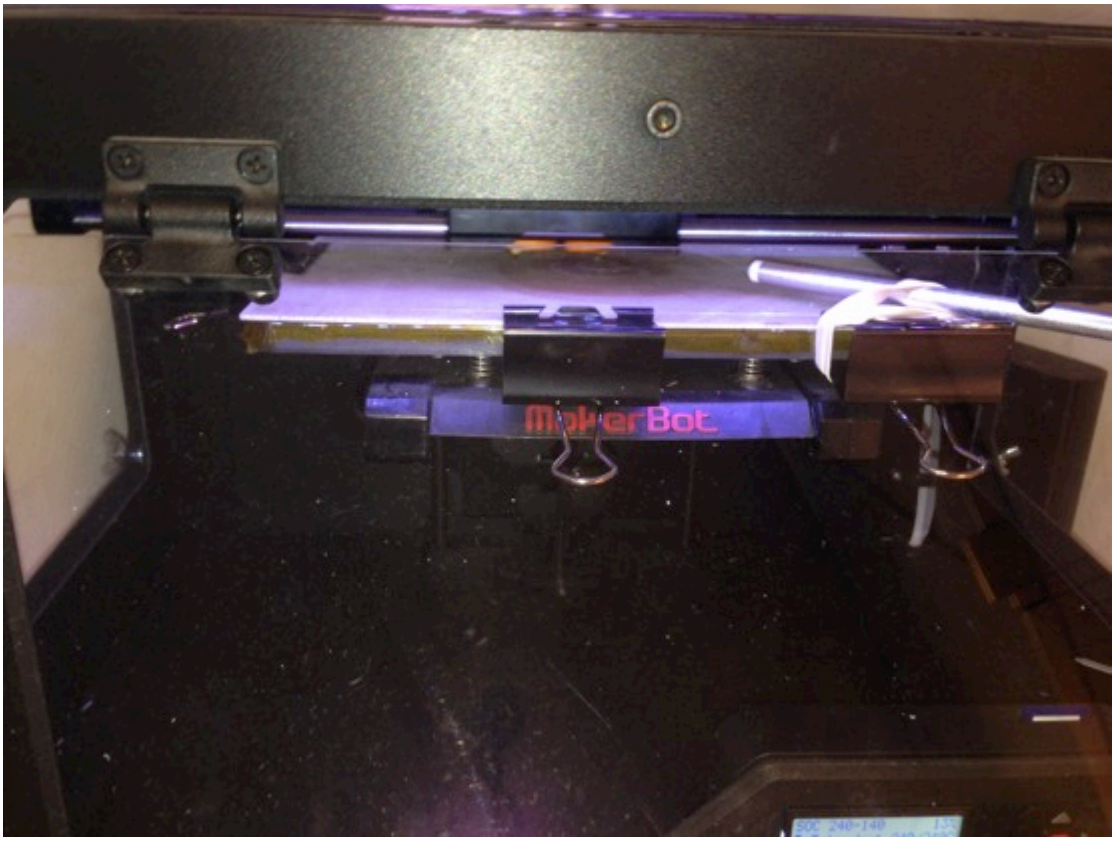
Opinion on Test 1.

Good finished part.
Formaldehyde production within TWA limits for 8 hour time period.

End of Test 1.

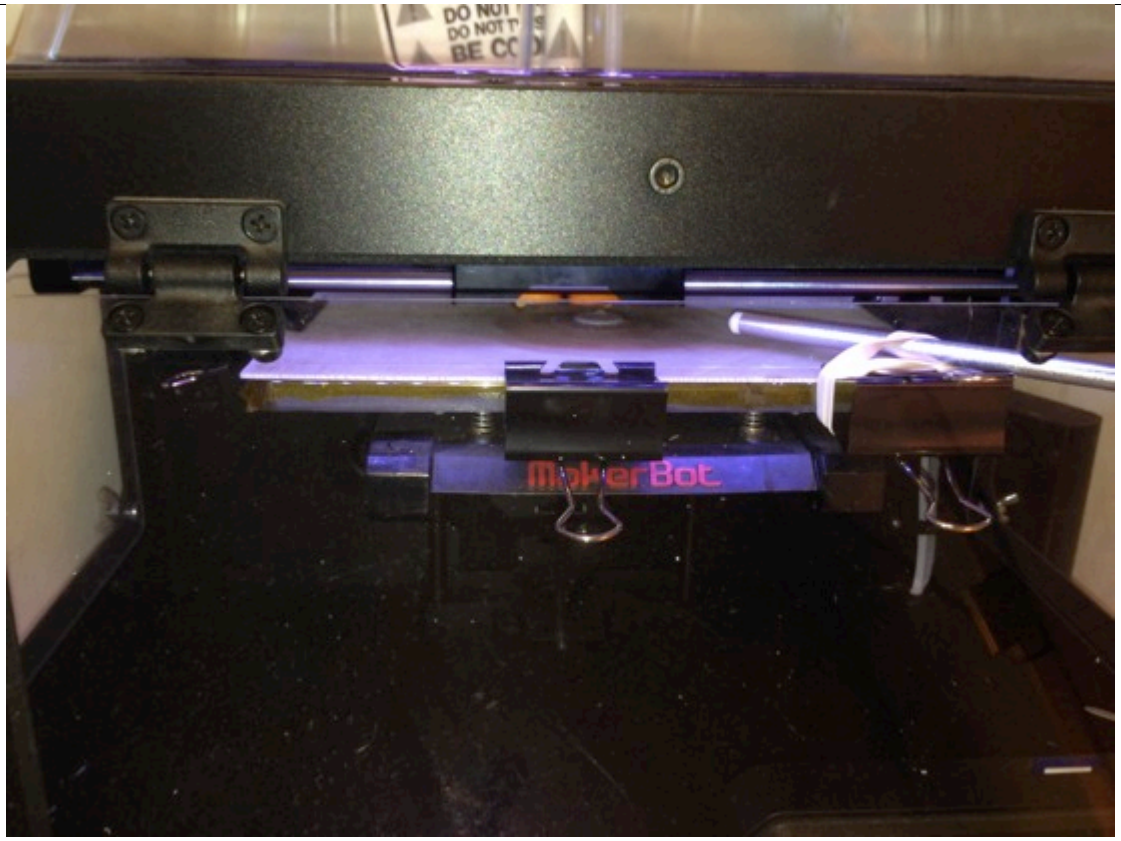
Test 2

Conditions: Material Temperature 240c. Build Bed 140c. Medium processing speed 90mm/s



4 minutes in and 0.33 ppm Formaldehyde being produced.

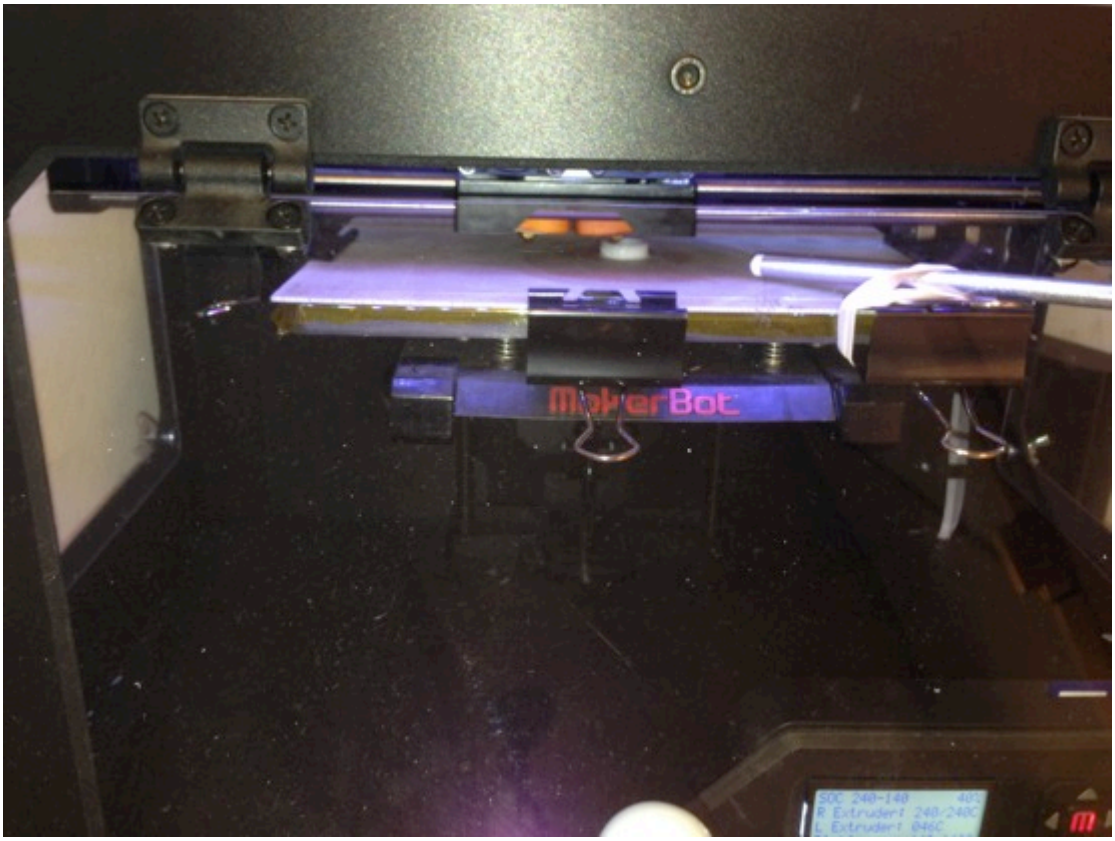
Initial build layers going down well.



26% in and Formaldehyde increasing to 0.50 ppm

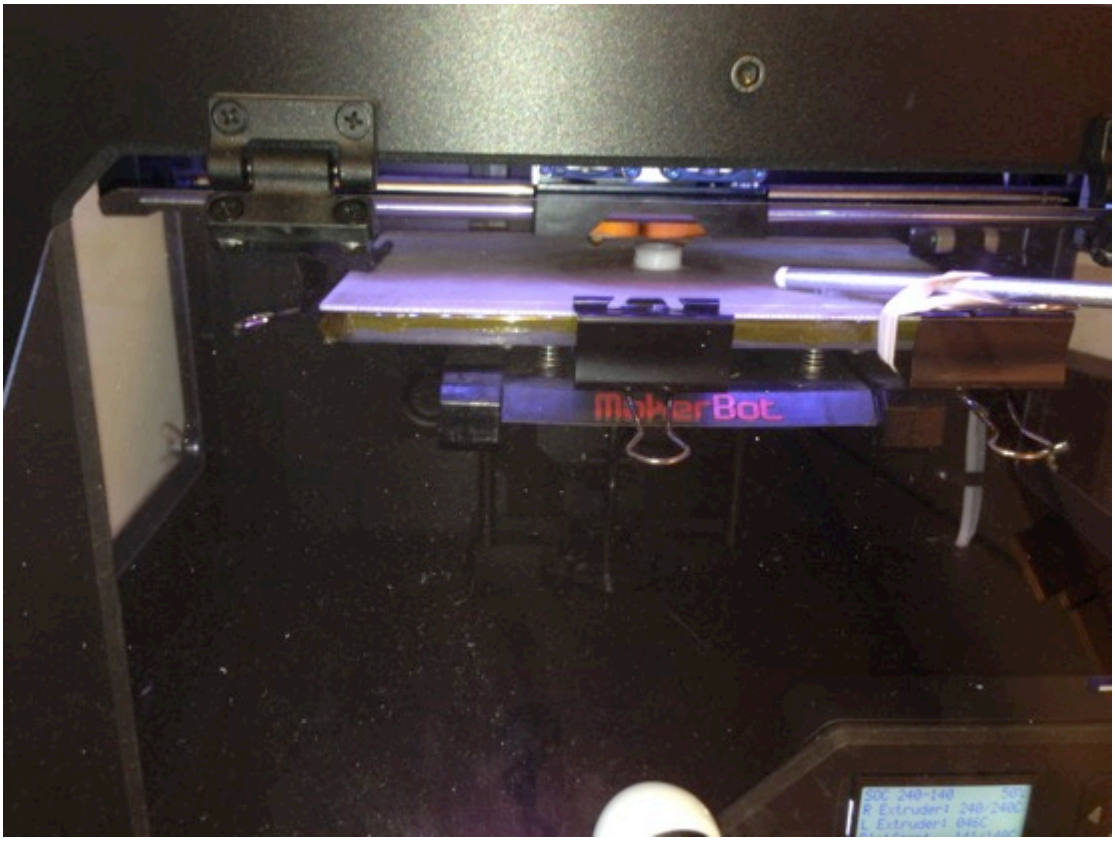
40% in and down to 0.24 ppm Formaldehyde

Build progressing well

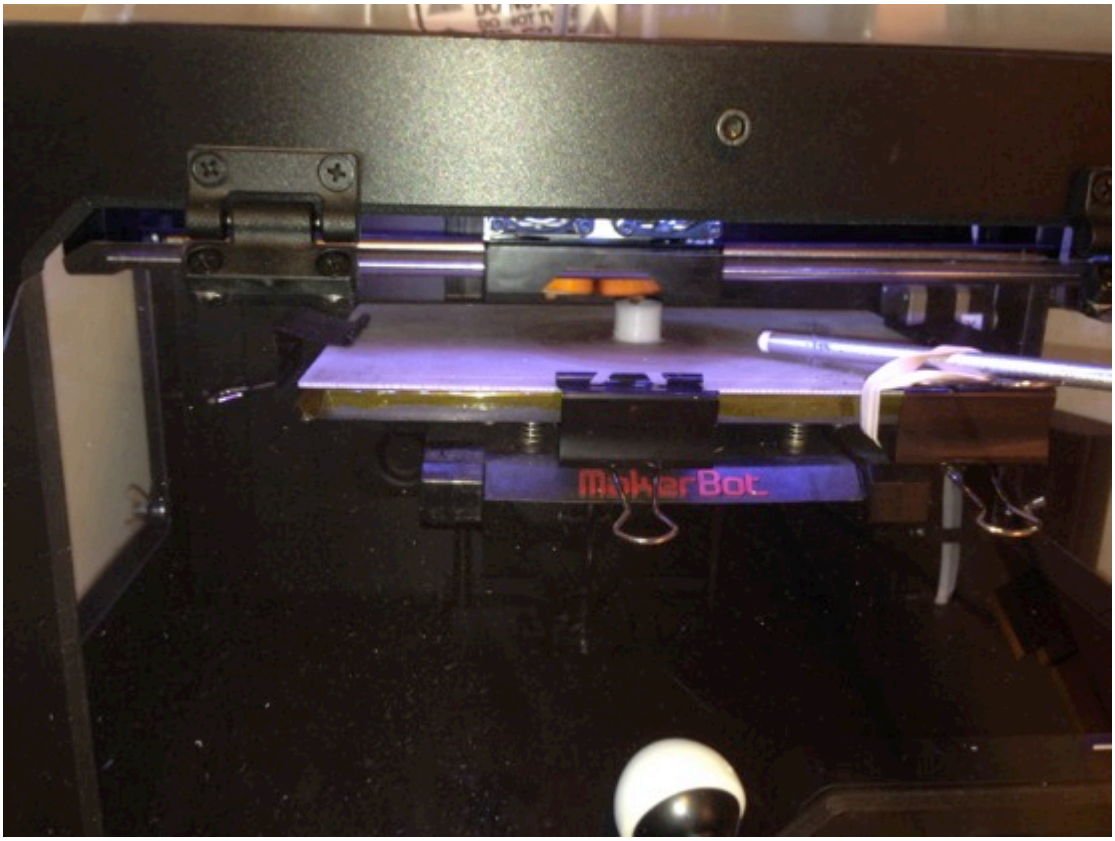


50% in and back up to 0.50 ppm Formaldehyde being produced.

Build still looks good.

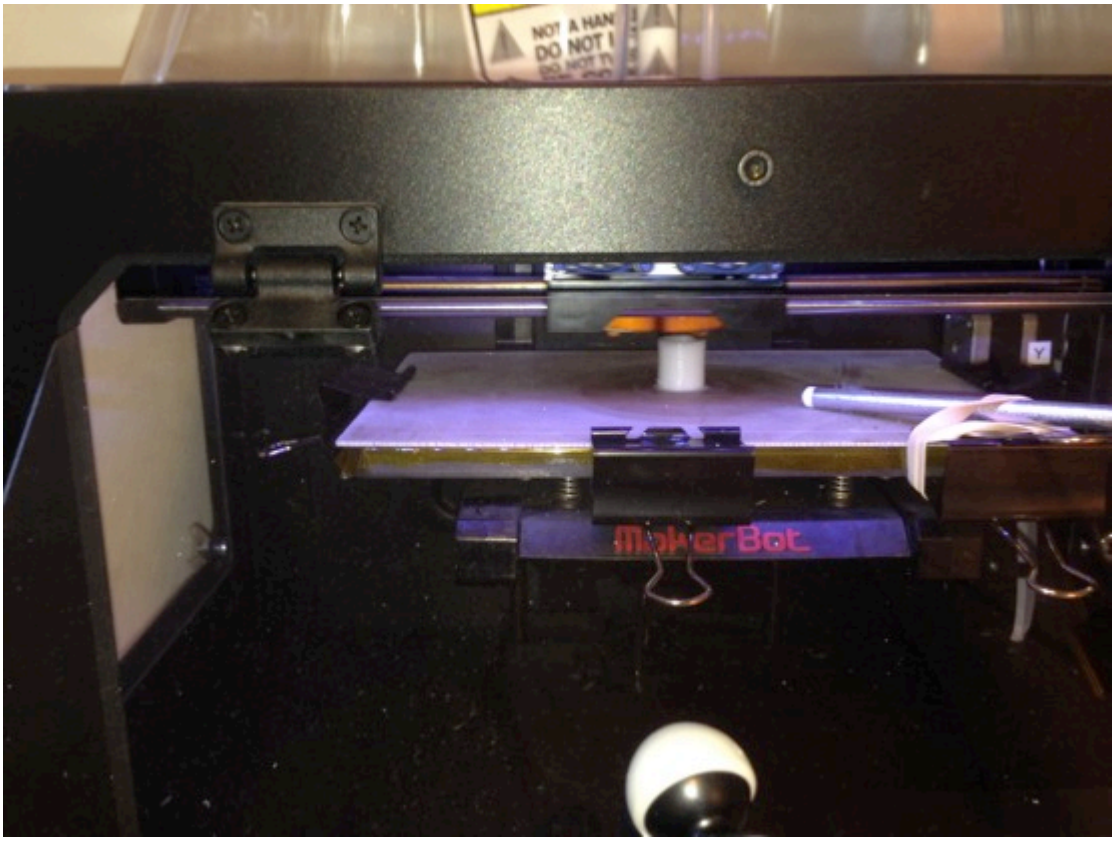


79% and we are at 0.45 ppm Formaldehyde being produced.

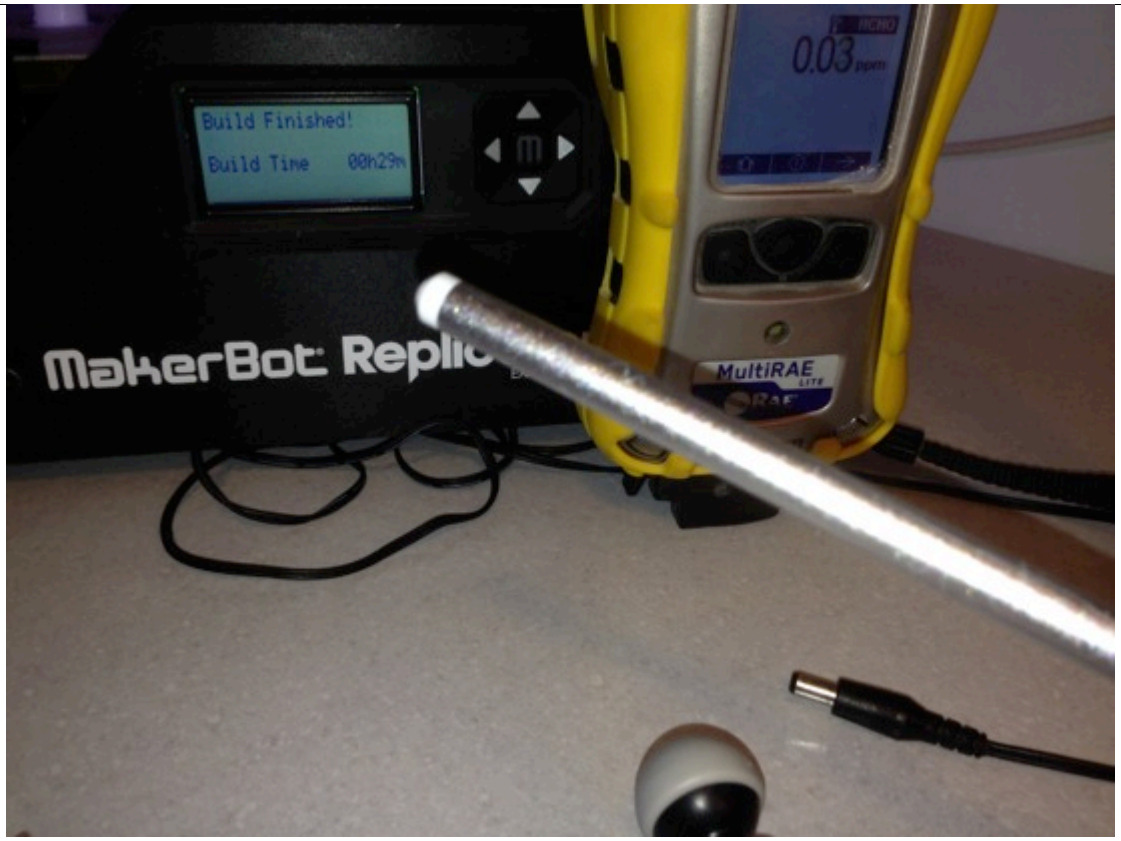


Nearly complete and 0.27 ppm Formaldehyde being produced.

Part complete.



Immediately after part complete we only had 0.03 ppm outside the build chamber



Opinion on Test 2.

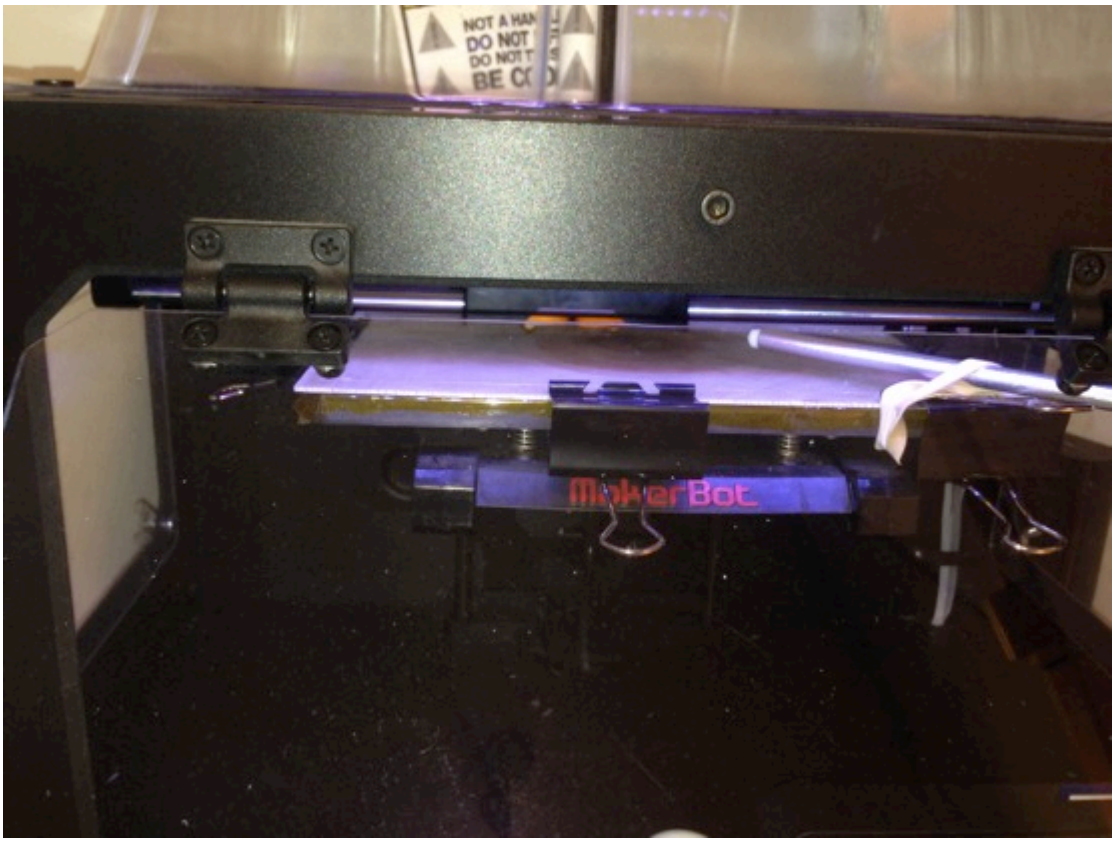
Good finished part, better surface finish that Test 1 component. No issues in build.

Formaldehyde production TWA potentially borderline for 8 hour time period.

End of Test 2

Test 3

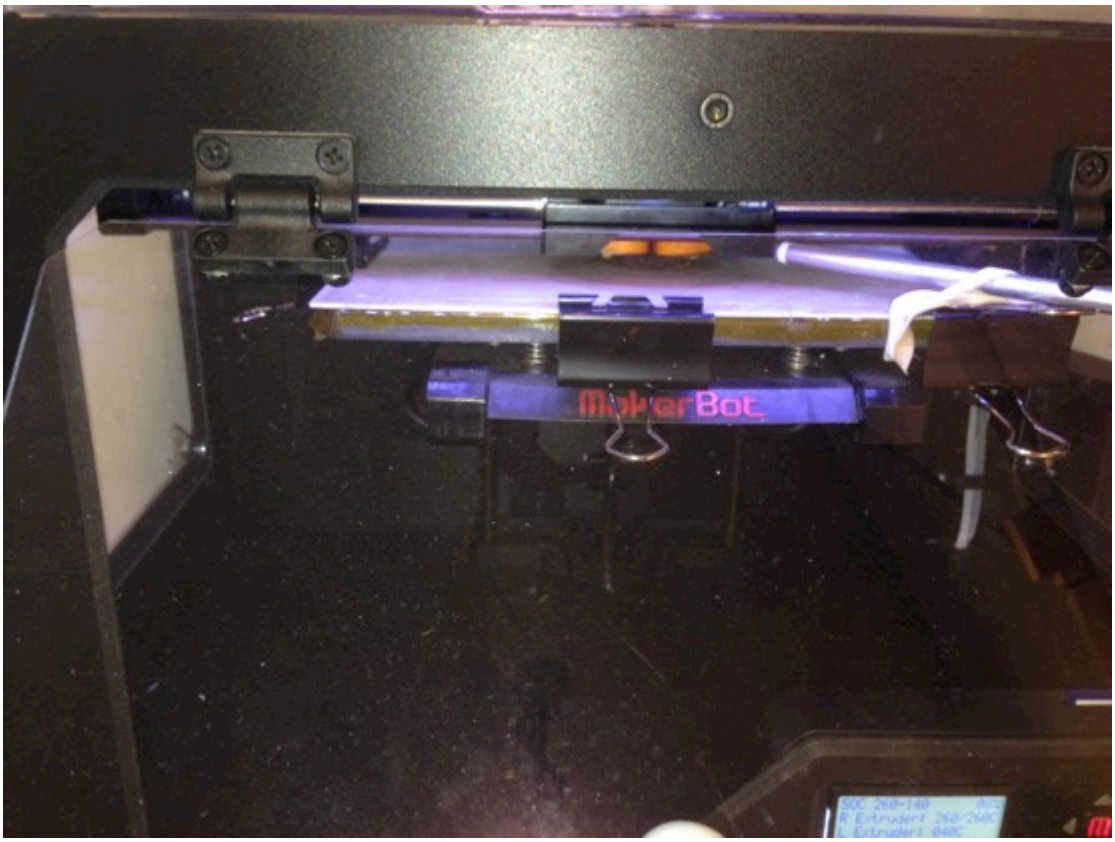
Conditions: Material Temperature 260c. Build Bed 140c. Medium processing speed 90mm/s



Almost immediately Formaldehyde spikes to 1.18ppm alarms going on tester, low limit reached

And up to 2.08 ppm Formaldehyde. Alarms going on tester, high limit reached. No Formaldehyde smell outside

build chamber.

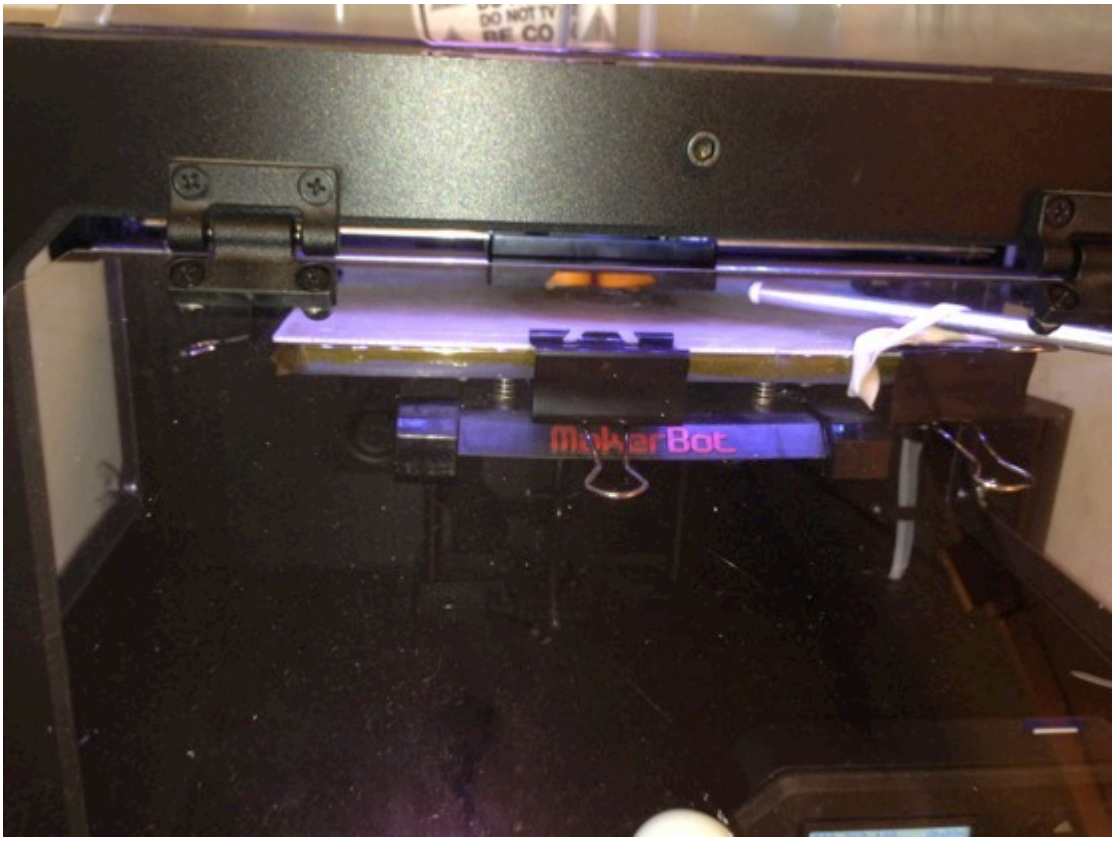


And up again, tester alarms are still sounding High Limit reached

Down to 1.27 ppm formaldehyde being produced, alarms still going as this is above the low level limit

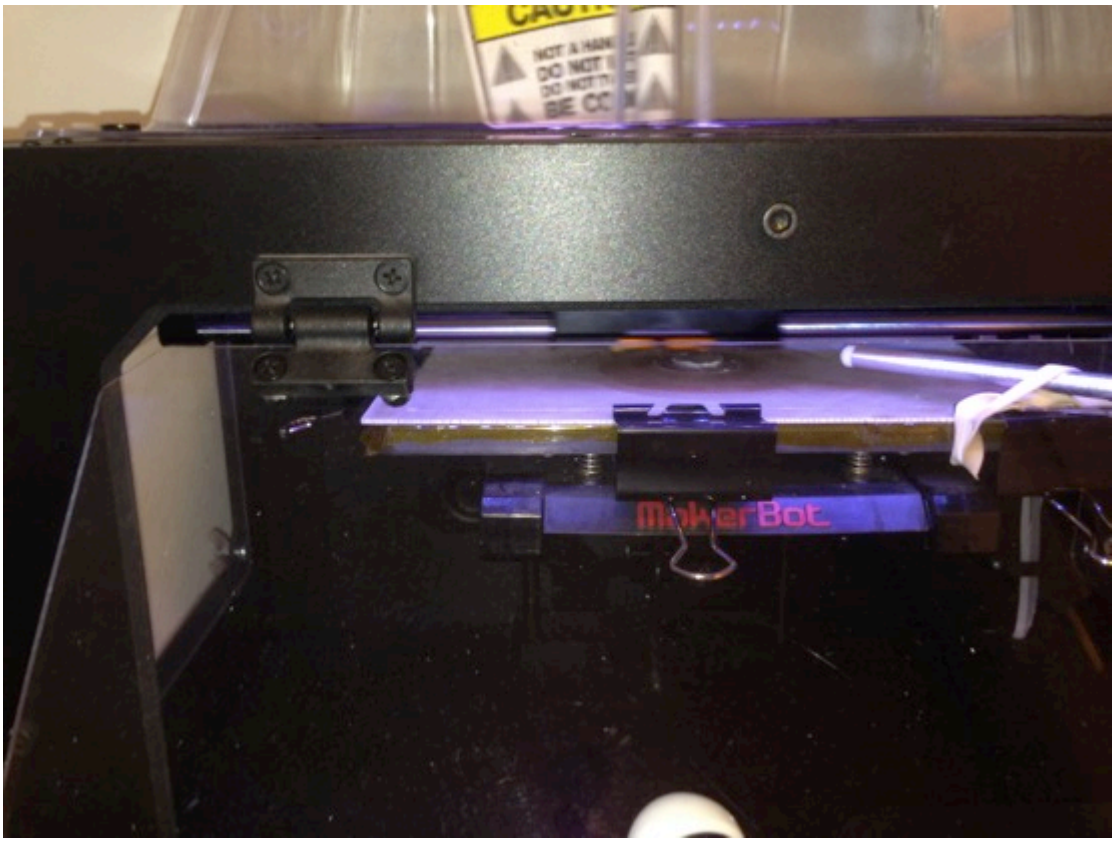
Machine now well settled and formaldehyde production is down to 0.82 ppm. Meter limit Alarms have stopped.

Part build not going well. Material at this temperature is too viscous, has a tendency to form globs and not process as desired.



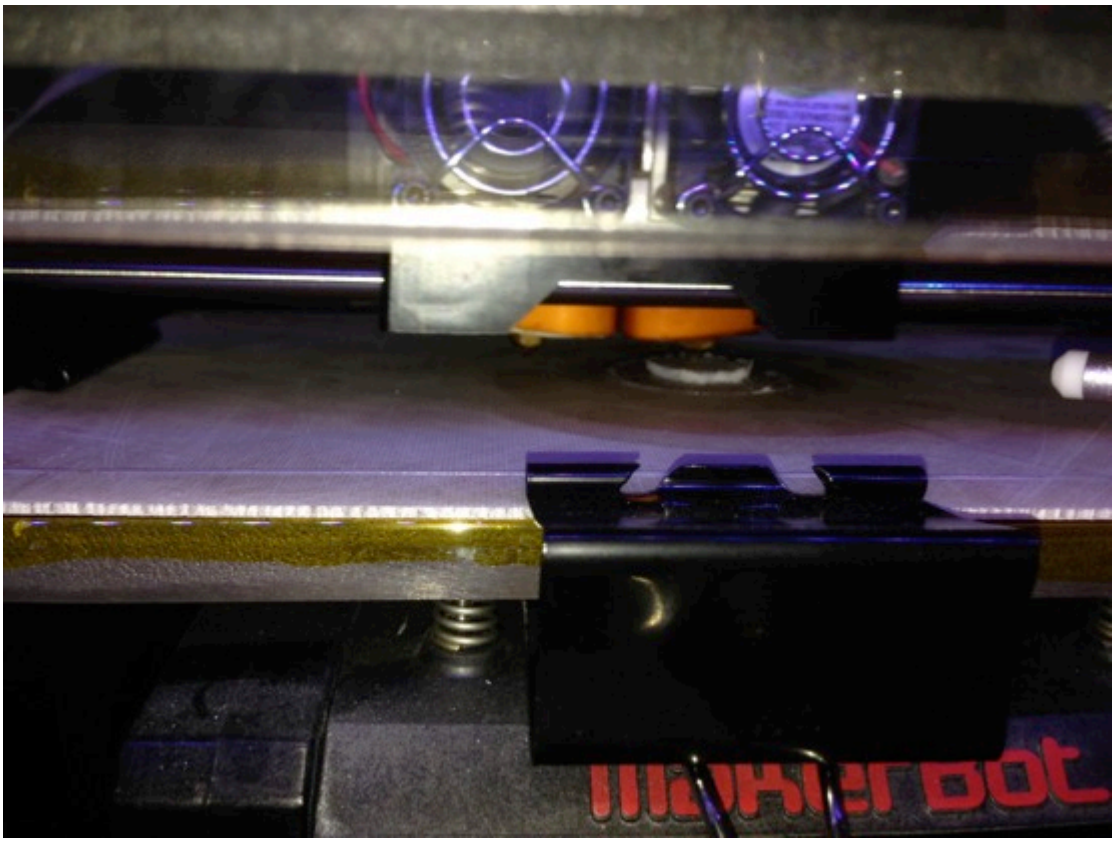
21% in and Formaldehyde production down to 0.62 ppm.

Picture does not show well, but part layer definition is not good. I will be surprised if this part completed the process



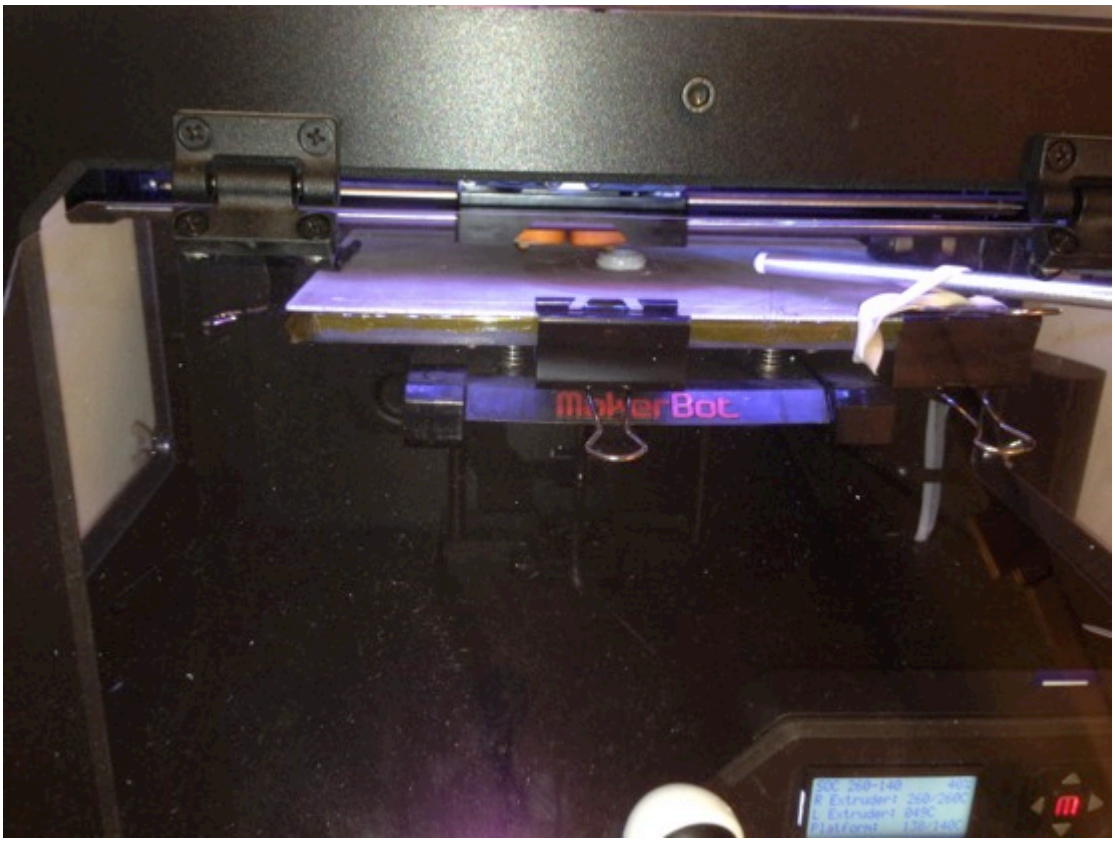
25% in and 0.40ppm.

Part layer definition is poor. Edge definition is poor.



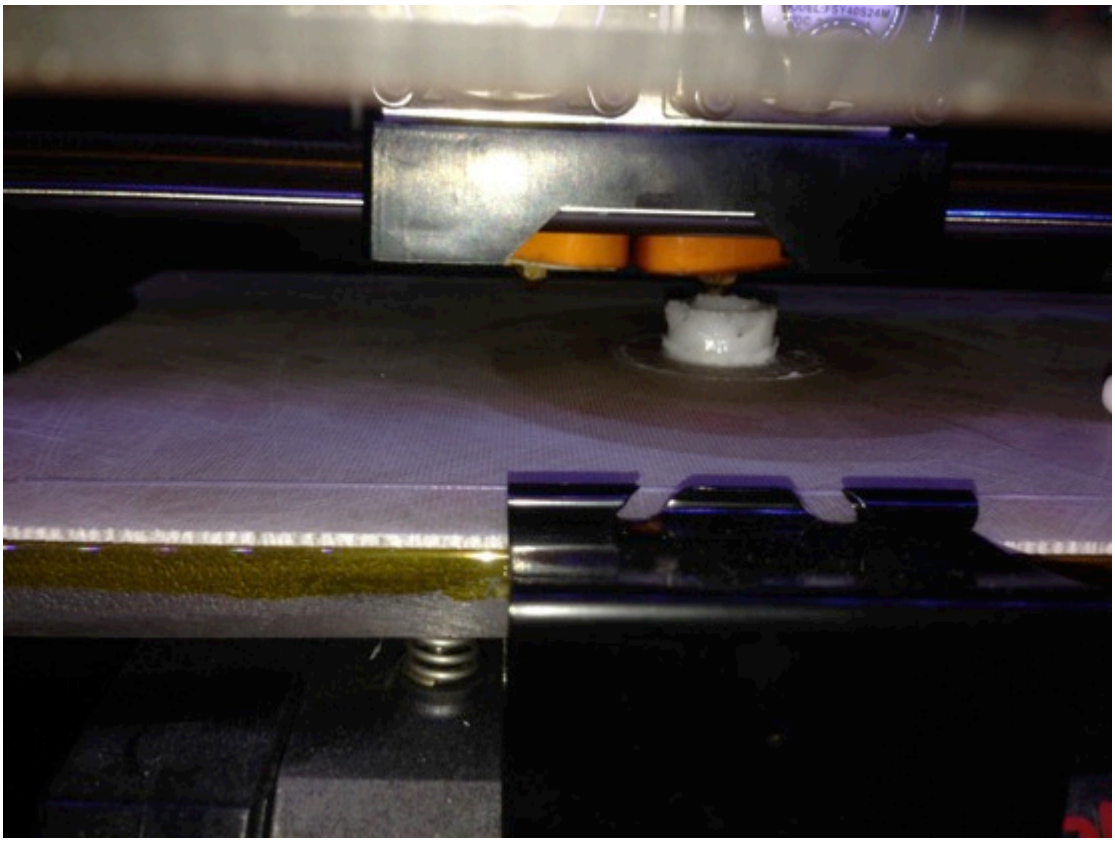
39% in and 0.44 ppm. This has settled down now.

Part is not good though.



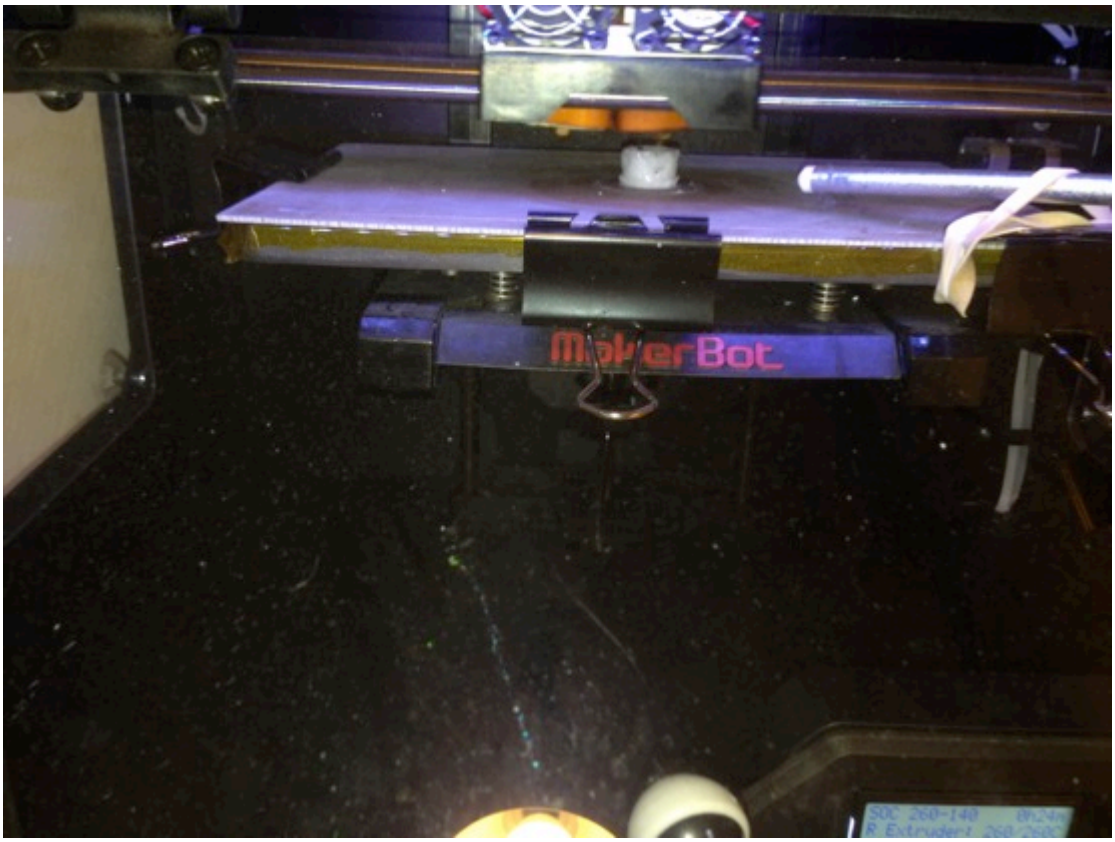
55% and Formaldehyde down to 0.22ppm

Part is not good.



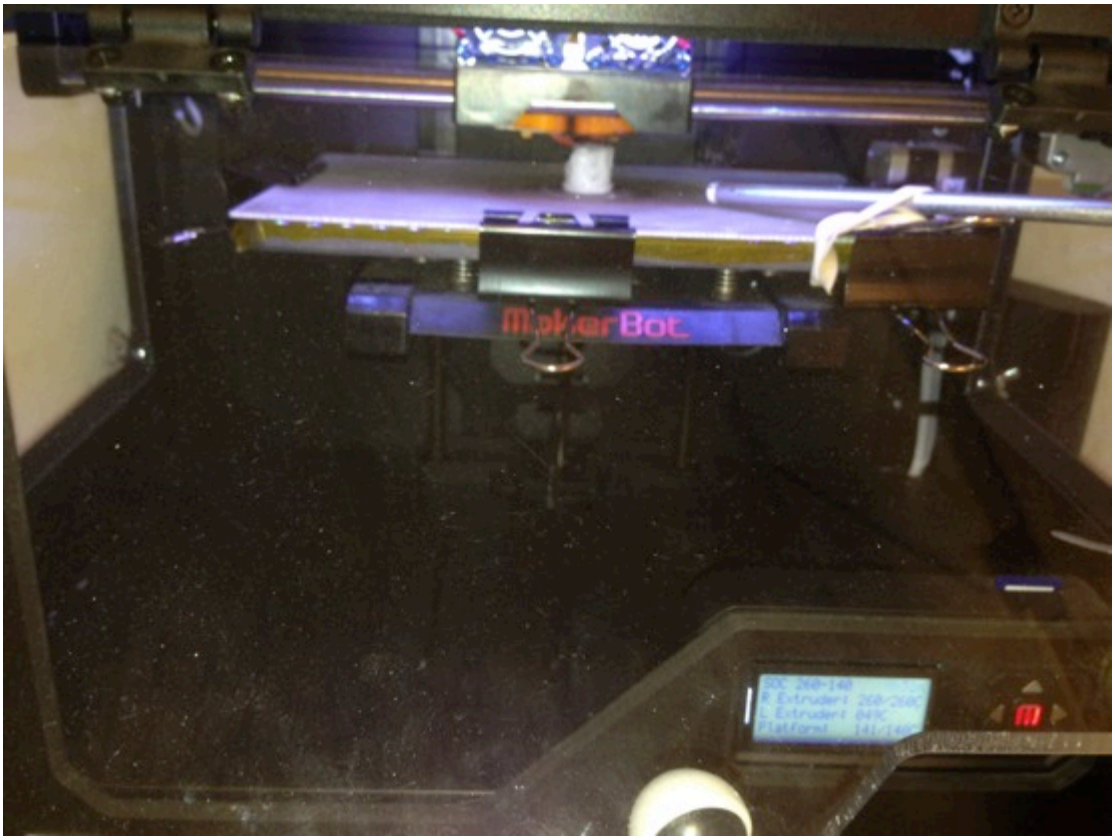
Formaldehyde production has now settled down well.

Surprisingly the part continues to build



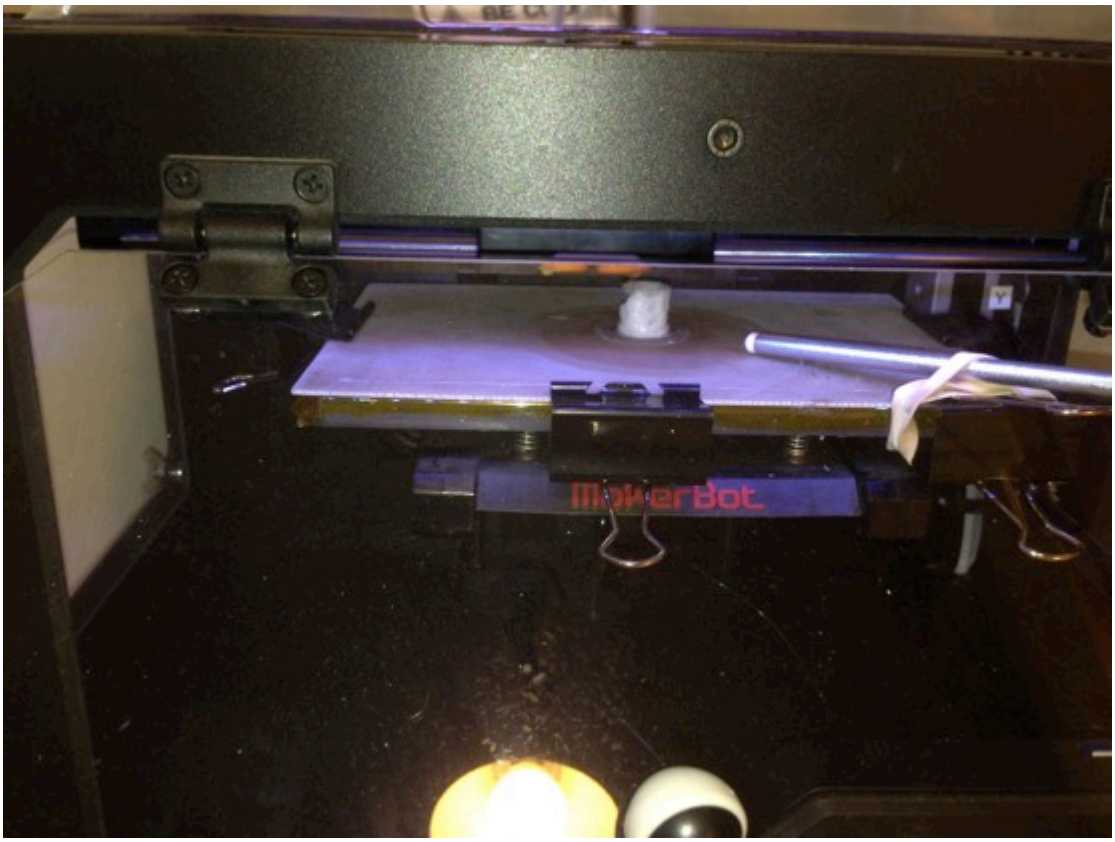
81% in and Formaldehyde production remains stable at 0.22 ppm


SOC 260-140 81%
R Extruder: 260/260C
L Extruder: 049C
Platform: 140/140C
MakerBot Replicator
MultiRAE
LITE
RAE
0.22 ppm


MakerBot

Part nearly finished and currently at 0.57ppm.

Part Fail



Opinion on Test 3.

Initially the high ppm was a function of the material “cooking” in the extruder waiting for the machine to reach its preset operational temperatures. However the part was a failure as we were processing outside the optimum conditions. 260c too hot.

Formaldehyde production TWA higher than required limits for full 8 hour time period.

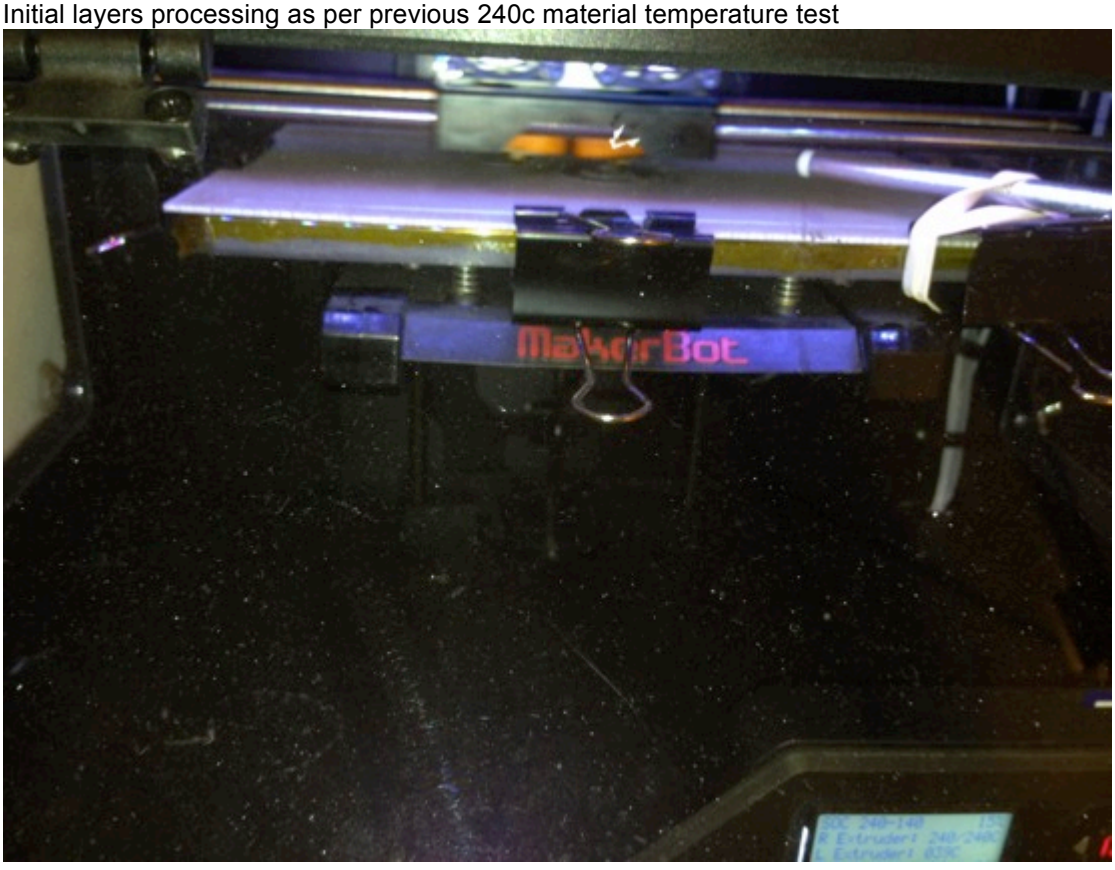
End of Test 3

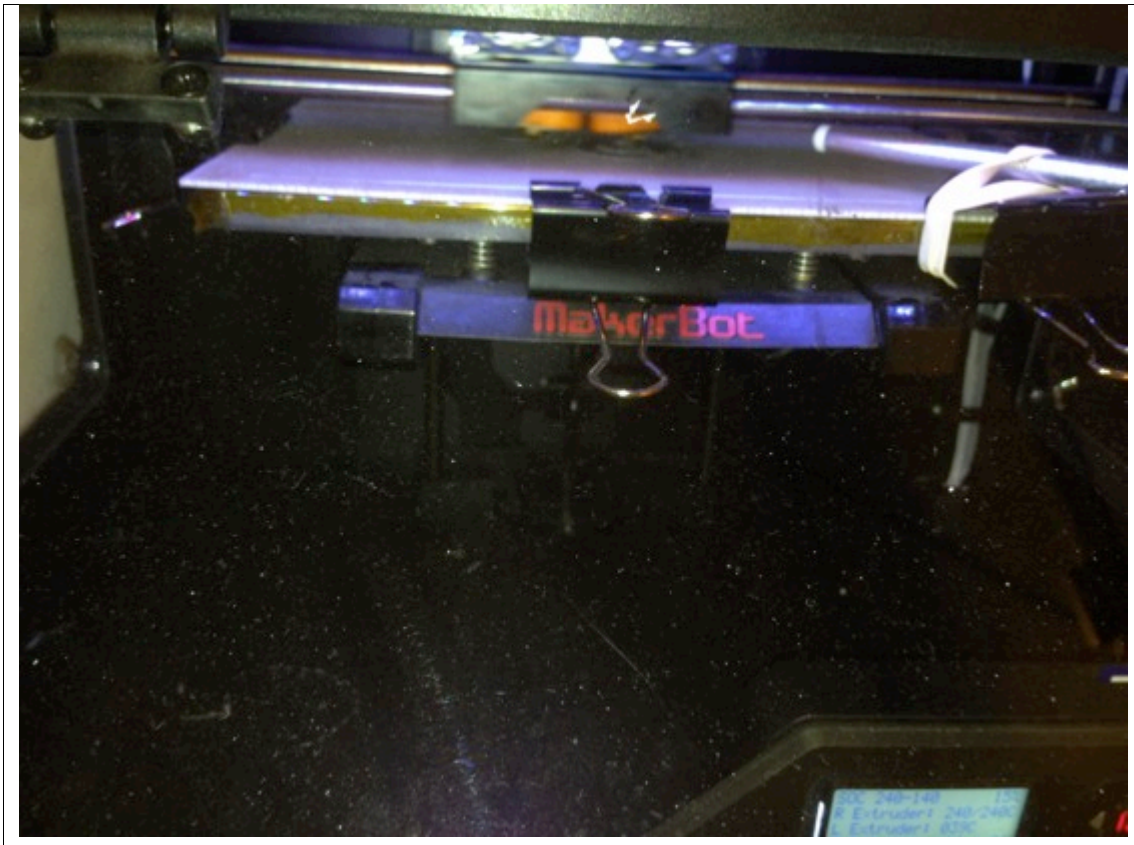
Test 4
On this test we produced an Extraction Unit and tested the results based on material temperature of 240c and Build Bed

temperature 140c.

Starting at 0.31 ppm Formaldehyde production not yet started the extractor.

Initial layers processing as per previous 240c material temperature test



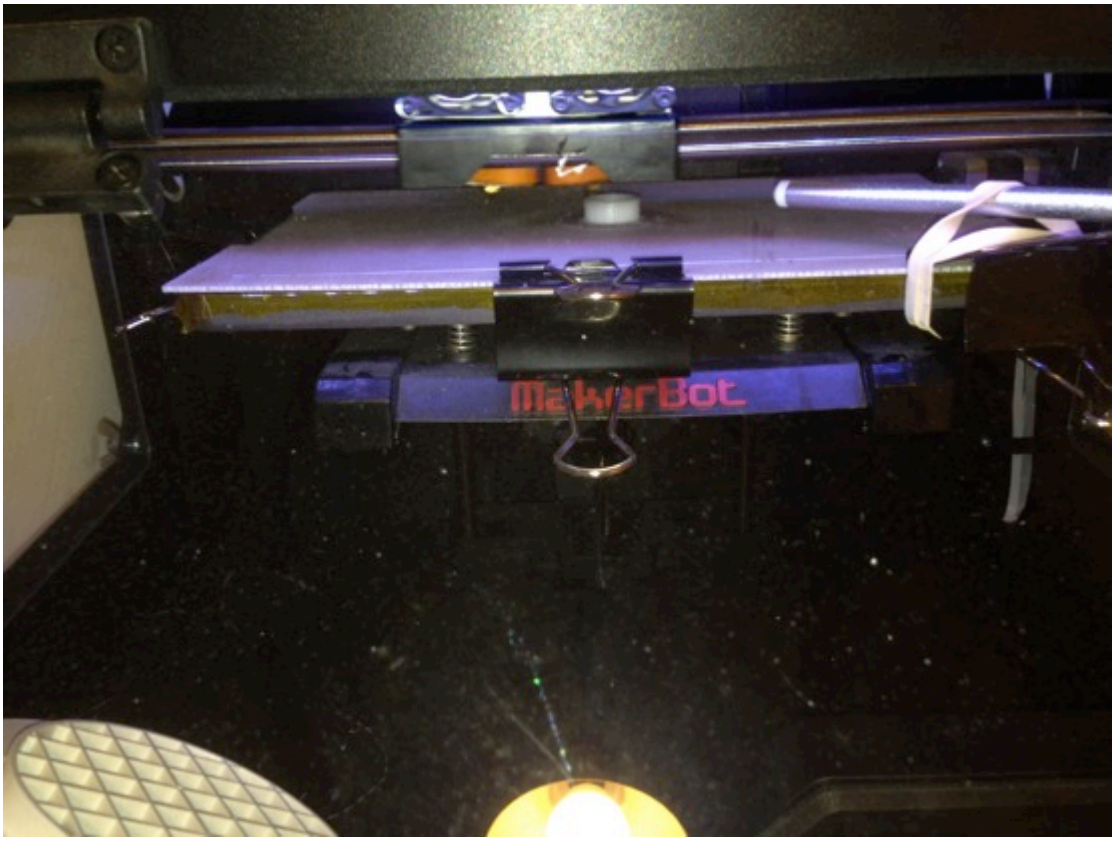


Extraction unit operational.

Formaldehyde production reducing.

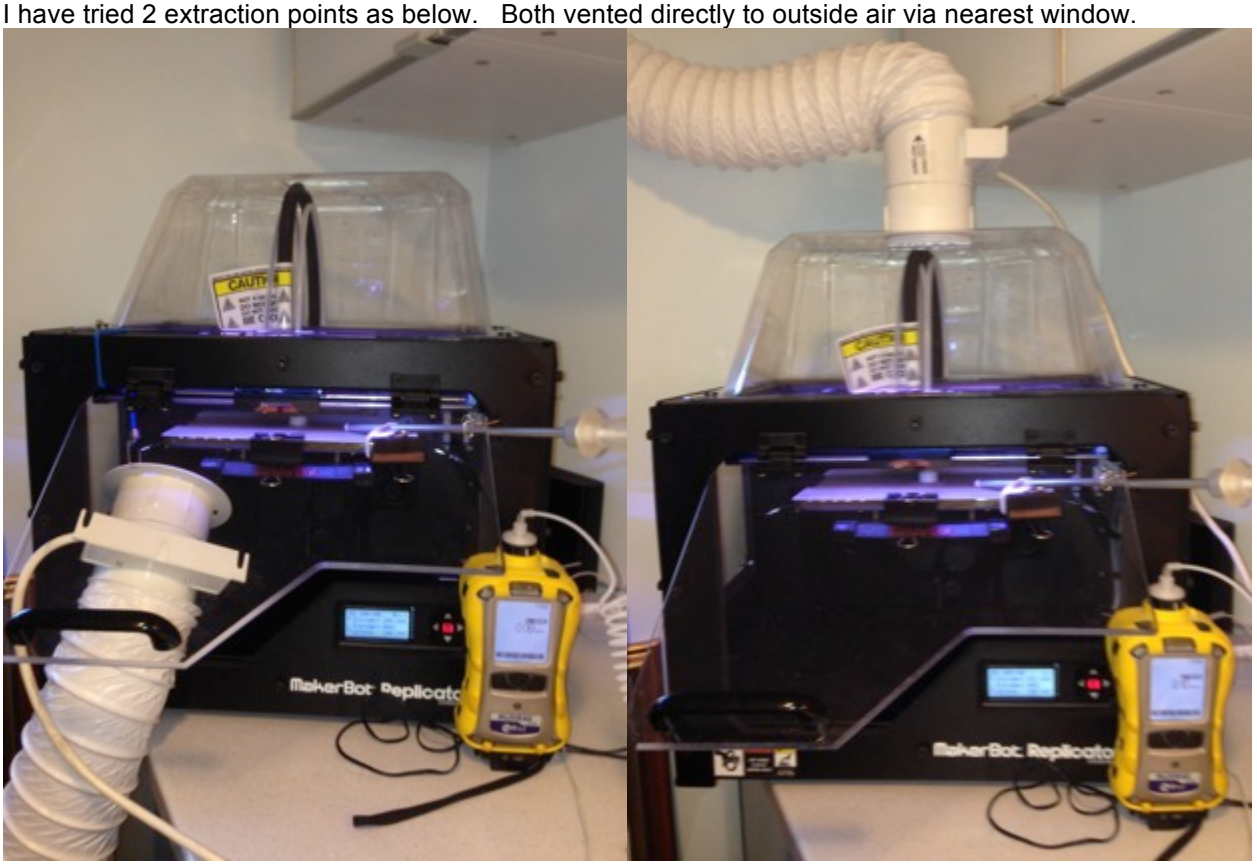
Extraction now well in control.

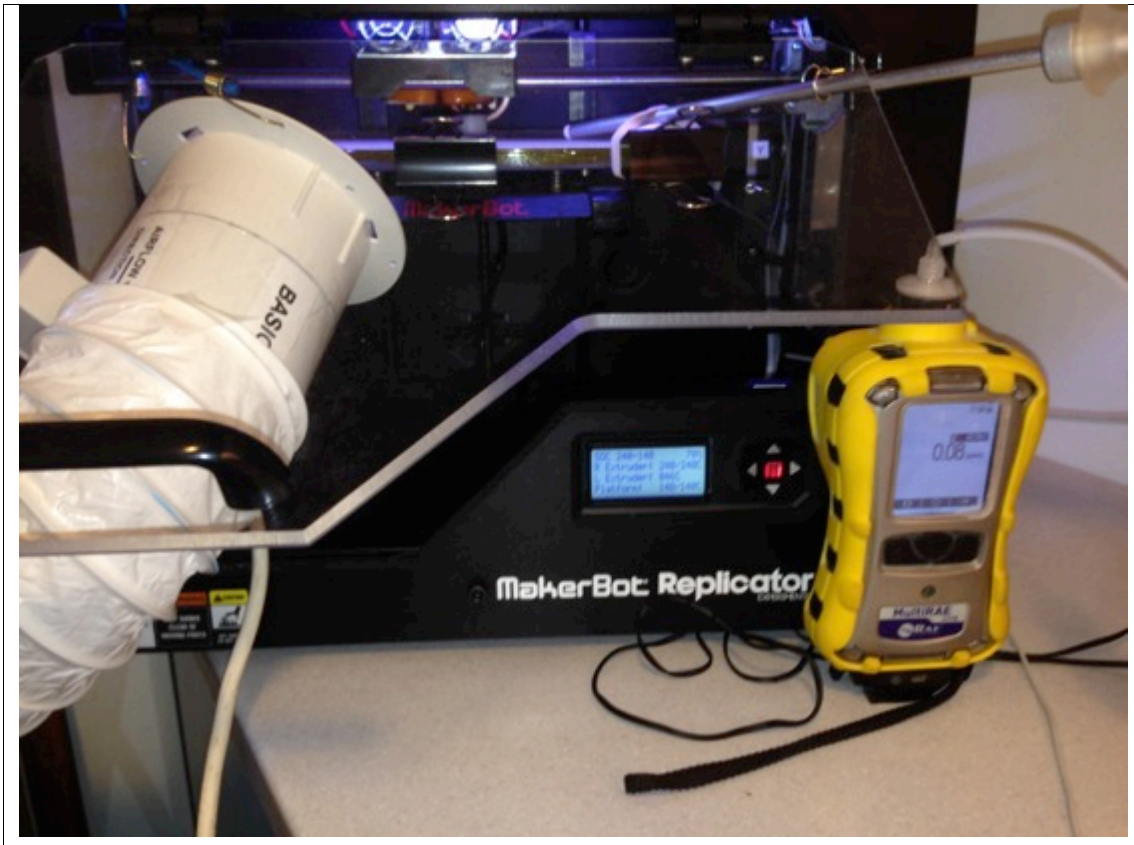
No issue with build process



53% Formaldehyde at 0.11ppm.

I have tried 2 extraction points as below. Both vented directly to outside air via nearest window.

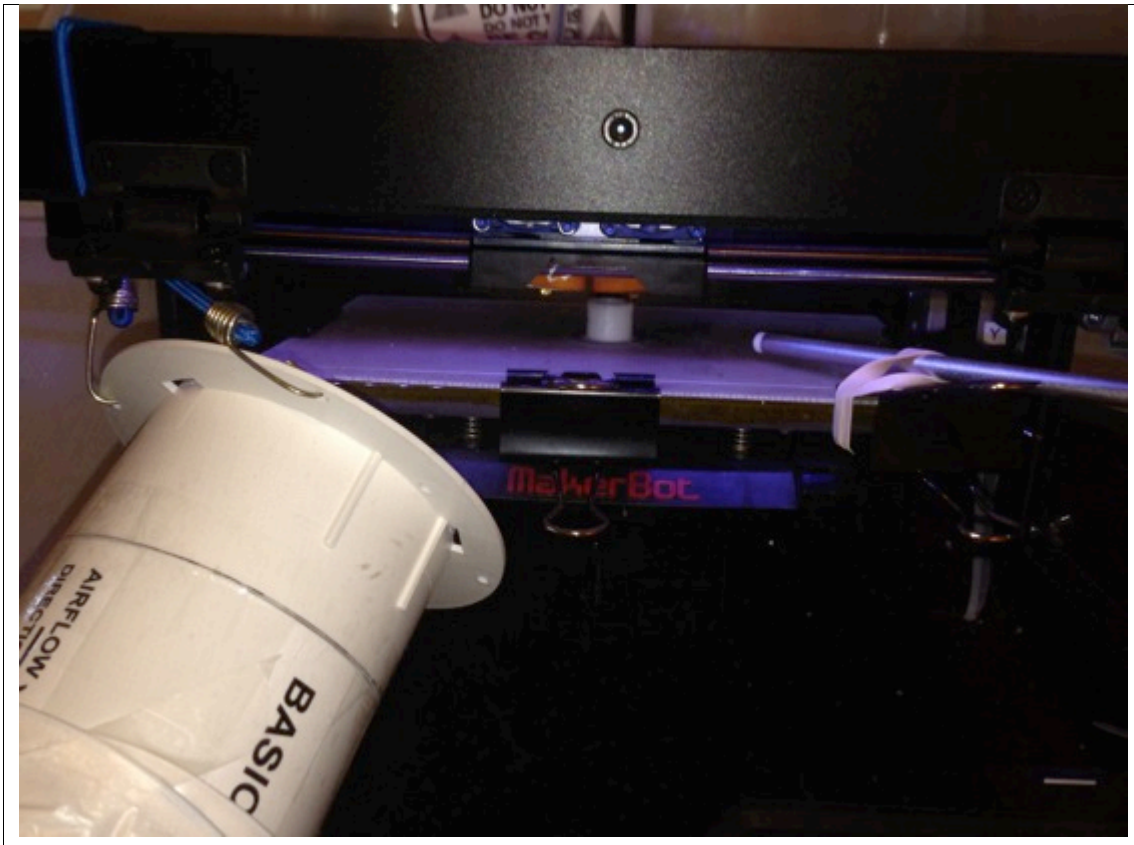




Extraction from below the build bed seems to be preferable for this build as I found extraction from the top can create a conflict with the extrusion temperature control.

Formaldehyde controlled well at 0.07 ppm.

Build proceeding well

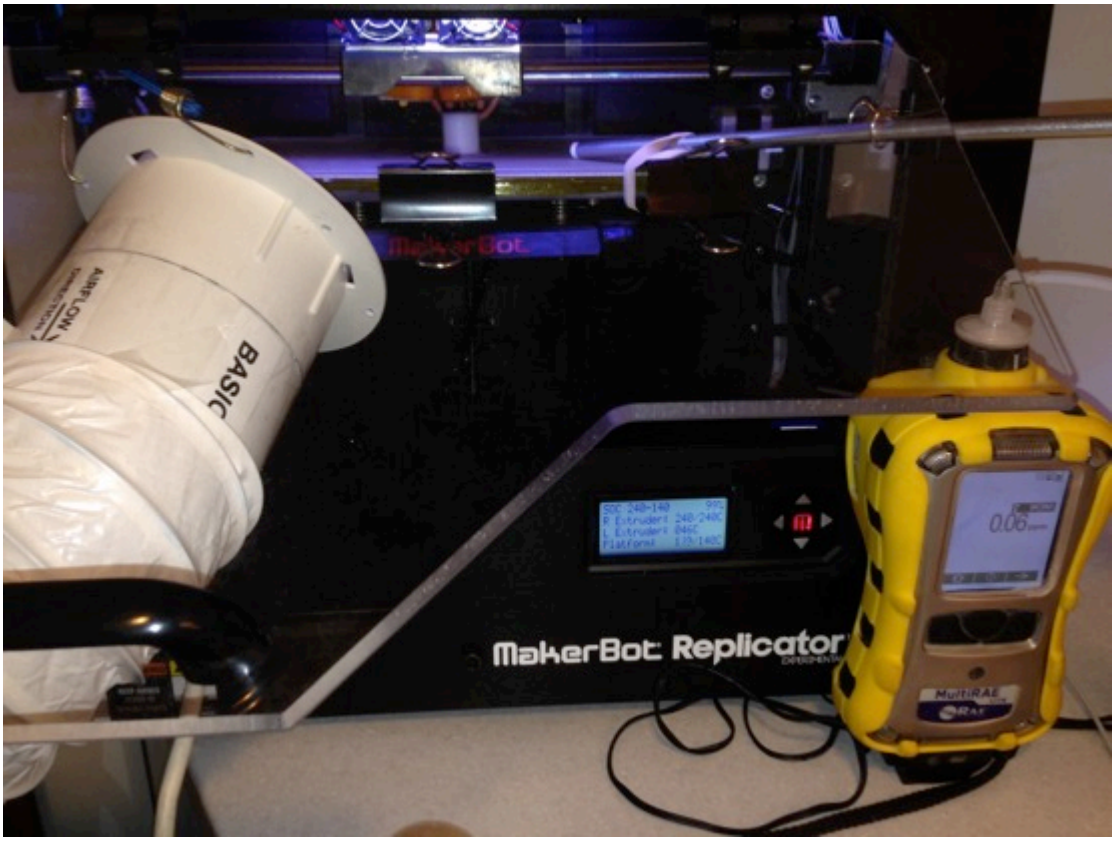


83% and still 0.07 ppm Formaldehyde.

Nearly complete, appears to have no issue with extraction from beneath the build bed. Need to consider more

permanent fixing method.

Extraction unit in-situe.



Conclusion

Acetal 613 is a new material to use with a 3D Printer and the material properties are very useful as an engineering material unlike any currently available.

Nearly all of our testing was done very close to the hot end of the printer, inside the build chamber. This is the most concentrated point of Formaldehyde production. At no point during the testing did I notice Formaldehyde or Tear Gas smell outside the chamber and the only process control photo taken outside the chamber (end of Test 2) showed very low concentrations.

As show above Acetal 613 can be processed within the safe processing ranges as described in the Material Safety Data Sheet (MSDS)

Processing conditions will vary due to machine, environment, processing parameters and part geometry.

We would recommend using an extraction unit, venting to the outside air. Even though as shown above this material can be processed on a 3D printer an extraction unit is cheap, easily constructed and easily fitted.

End