**High temperature printing**

There are three ways to make a high temperature printer:

1. The Stratasys way by insulating the movement system from the heated chamber
2. The NASA way by using infrared heaters
3. By simply upgrading all exposed components to high temperature.

This document deals with method 3. And will be using a Railcore as an example. How to modify the Railcore II to be able to print high quality PEEK with a chamber temperature of 150°C.

**Components needing upgrade**

The following components needs to be changed on a standard Railcore.

* Door
* High temperature resistant chamber
* Top cover
* Chamber heater
* High temperature pressurerized air cooled hotend
* All metal extruder
* Pressurerized air cooling of extruder motor
* High temperature rails
* High temperature belts
* High temperature couplers or protected couplers
* High temperature cables
* Printed parts must be upgraded to aluminum
* Printed parts that do not exist in aluminum must be printed in high temperature plastics

**Door, top cover and chamber**

The first thought most people will have is that to handle 150°C chamber temperature the materials must be able to handle 150°C. This is also true for the materials inside the chamber but for the door, top cover and side panels less will do. This is because the panels are being cooled from the outside and heated from the inside causing the panels to be less than the air temperature inside the printer. Here is the calculation:

Q=K\*A\*DT

K=1/(1/hi+1/ho+s/lamda)

Q is the heat flow

A is the area

DT is the temperature difference between inside and outside

hi is the heat transfer coefficient inside

ho is the heat transfer coefficient outside

s is the thickness of the panel

lamda is the conductivity of the panel

hi and ho will be around 5 if the air is not moving too much

lamda is 0.2 for most plastic materials

A we will set to 1 m2 because the area does not influence the temperature distribution.

DT is 150-20 or 130°C

So first we calculate K

K = 1/(1/5+1/5+0.006/0.2)=2.32

Then we calculate Q

Q=2.32\*1\*130=302

Then we calculate the temperature difference from the air to the surface of the plastic:

302=5\*DT so DT is 60

This means that the inside surface of the plastic is 60°C lower than the air temperature in the chamber.

150-60=90°C

If the air is moving faster inside than outside the temperature on the plastic will increase. You can repeat the calculations with hi =10 and ho=5. I would recommend that Polycarbonate is used for side panels. Polycarbonate can handle 120°C continuous temperatures. Other high temperature materials can also be used. It is a good idea to insulate because the heat loss is 300 watts per m2 but remember, do not insulate from the outside because that will increase the panel temperatures, if you insulate from the inside the insulation needs to be able to handle the full 150°C chamber temperature but then the panels will be much colder.

**Chamber heater**

To heat the chamber I recommend a PTC heater for safety reasons. PTC heaters are self limiting to a specific surface temperature. Use a PTC heater capable of reaching 180 to 220 °C depending on the insulation you are using. Use an oven fan to blow air through the PTC and to circulate the air inside the chamber.

**Hot end and stepper**

Fans don’t handle high temperatures well. It might be possible to find high temperature DC fans but so far I had no luck. Another solution is to use and pump for aquariums or garden ponds. 60 l/min should be enough to cool the extruder stepper and hotend.

**Extruder**

On Aliexpress it is possible to buy all metal BMG extruders. Unfortunately, Bondtech is not selling all metal extruders so in this case you are forced to use a clone. Other extruders can be adapted to the Railcore.

**Rails**

The standard rails can only handle 80°C but Misumi and HIWIN sell high temperature MGN12H rails capable of handling 150°C

**Couplers**

The couplers will need to be protected from the heat, as they are located at the bottom one solution is to make a cover and have vent holes in the bottom

**Cables**

The cables need to be upgraded, standard cables can not handle 150°C. You can buy silicon belts on ebay

**Printed parts**

All printed parts should be upgraded to aluminum if possible. For all the parts that can not be made in aluminum the first step is to make them in ABS, then you print them in PC and then you print them in PEI or PEEK. Possibly Nylon can also be used for some parts.

**Belts**

Standard belts can handle up to 80°C and with a reduced lifetime possibly 100°C but if you go higher standard belts will no longer be enough. I have searched high and low for high temperature belts without success. I am therefore making a kickstarter campaign for making silicon Kevlar high temperature belts. They should be good for 200°C, but this is experimental and I don’t know yet if the kickstarter will succeed.