

## Kerbal Space Program - Feedback #6336

### Heat shield ablation rate and overheating mechanics seem wrong

12/23/2015 12:24 PM - Kasuha

|                        |                     |                     |              |
|------------------------|---------------------|---------------------|--------------|
| <b>Status:</b>         | Needs Clarification |                     |              |
| <b>Severity:</b>       | Normal              |                     |              |
| <b>Assignee:</b>       |                     |                     |              |
| <b>Category:</b>       |                     |                     |              |
| <b>Target version:</b> |                     |                     |              |
| <b>Version:</b>        | 1.0.5               | <b>Language:</b>    | English (US) |
| <b>Platform:</b>       | Any                 | <b>Mod Related:</b> | No           |
| <b>Expansion:</b>      |                     |                     |              |

#### Description

I don't know how exactly heat shields are implemented but the fact that if I aim too deep into the atmosphere, the heat shield will "explode due to overheating" with over 90% ablator still on is in my opinion unphysical.

Physics of ablative shields are complex but in general, rate of ablation depends on temperature of the ablator, the higher the temperature, the more they are ablating and the higher is the rate of dissipating of heat to the atmosphere instead of inside the ship. In general the bulk of the ablator will never exceed the temperature at which its pyrolytic components change to gas while staying on the shield - it's not physically possible.

If we omit aerodynamic pressures and g-forces and concentrate on heat alone, the most dangerous approach with ablative shield is slow, gradual reentry where the ablator doesn't heat up enough and does not convert to gas, or at very low rate. Then the ablator holds a lot of heat and the slow approach allows the heat to transfer inside the ship. Fast and rough reentry should definitely burn all ablator at rate corresponding to energy being transferred first, and only then potentially overheat remnants of the shield.

Disclaimer: it's my opinion and I may be wrong, although it makes sense with my knowledge of heat shields and general physics. I am not an expert on heat shields.

#### History

##### #1 - 07/17/2016 09:41 AM - TriggerAu

- Status changed from New to Needs Clarification

##### #2 - 03/05/2017 04:28 PM - Anonymous

- File quicksave.sfs added

Attached is a small save-file to clarify: ablator does not carry away heat quickly enough, when the heat shield is near its maximum temperature, to make a noticeable game-play difference.

Conversely, ablator is noticeably consumed during mining or orbits near Moho (<https://www.google.com/search?q=site%3Aforum.kerbalspaceprogram.com%2F%20ablator>). Ablator has little or no niche of usefulness.

KSP uses an activation model for ablation rate,  
 $\text{rate} = \text{lossConstant} \cdot \exp(-\text{lossExp} / \text{Temperature})$ ,  
but with lossExp corresponding to a low activation energy for evaporation (near that of mercury). Tripling lossExp (closer to the activation energy of evaporation of lead) makes the ablation rate vary more strongly with temperature, so that its loss is negligible in normal operation, but increases strongly enough to carry away energy so to protect the heat shield so long as some ablator material remains.

Suggestion:

```
@PART[*]:HAS[@MODULE[ModuleAblator]] {
  @MODULE[ModuleAblator] {
    %lossExp = -25000 // was -7500
    // maintain previous lossConst * exp[ lossExp / T ] at T=2000K
    %lossConst = 500 // was 0.1;
  }
}
```

##### #3 - 03/12/2017 02:30 AM - Anonymous

Maintaining the current ablation rates at 2000K (which are shown in the VAB) while increasing the activation energy, can use too much ablator during early reentry at 2500K. Better to keep the current rate at 2500K so we have faster ablation between there and 3300K

```
PART[*]:HAS[@MODULE[ModuleAblator]] {
@MODULE[ModuleAblator] {
%lossExp = -25000
%lossConst = 100
}}
```

#### #4 - 03/21/2017 04:37 AM - Starwaster

IRL it is entirely possible to come in too steeply with the result that either your shield fails because it can't dissipate heat fast enough or braking forces are too extreme (crew death, craft structural failure) or both.

Nothing unusual about it. There is a very narrow corridor you need to be in and if it's too steep then you can burn up. If it's too shallow you might 'skip out' because you didn't have enough braking forces. Or you can bake away your heat shield slooowly because of shallow reentries where the shield burns itself out before you slow down enough to reenter.

Likewise there is nothing unusual about all your shield being consumed near Moho. It's a pretty hot place. Read here about AVCOAT, the heat shield material used on Apollo, second page:

[http://www2.aero.psu.edu/RGD\\_2010/PaperSubmission\\_Full\\_Uploads/Titov,%20Evgeny\\_219\\_PDF\\_revised.pdf](http://www2.aero.psu.edu/RGD_2010/PaperSubmission_Full_Uploads/Titov,%20Evgeny_219_PDF_revised.pdf)

They have the start of pyrolysis at 588.88 K. I've also seen it cited as low as 450 K. KSP shields are configured to start ablating at 500K, a nice median value. So, barring some means of protecting them from the heat, they're going to sublime away. That too is natural.

#### #5 - 05/13/2017 11:34 PM - Anonymous

The 500K threshold before ablation begins is fine, but the temperature-dependence of ablation above 500K is strangely weak. (<http://forum.kerbalspaceprogram.com/index.php?topic/157622-heat-shield-ablation-rate-seems-wrong/>) Combining a low-temperature low-ablation-rate ablator material, with a rather high 3300K limit of the heat-shield, leaves little practical use for ablator.

KSP stock  
enthalpy = 2.4 MJ/kg  
lossConst = 0.1/s  
lossExp = 7500 K

The example with 588.88K ablation-threshold linked above came from NASA publication 1289

(<https://ntrs.nasa.gov/search.jsp?R=19930009576>)

which gives the pyrolysis rate for several materials in the Arrhenius form that KSP uses:

carbon phenolic  
enthalpy = 16100 BTU/lb = 7.7 MJ/kg  
lossConst = 1.62e8 lb/ft<sup>3</sup>/hr ÷ 60 lb/ft<sup>3</sup> = 750/s  
lossExp = 10'000R = 5500K

phenolic microballoons in Novolac resin (STAB-II data)  
pyrolysis starts at 1060 R = 588.88 K  
charring at 1460 R = 811.11 K  
recession at 2235 R = 1242 K  
enthalpy 180 BTU/lb = 0.086 MJ/kg  
lossConst = 0.95e8 lb/ft<sup>3</sup>/hr ÷ 16 lb/ft<sup>3</sup> = 1650/s  
lossExp = 23'300 R = 12'900 K

silicone rubber  
enthalpy 50 BTU /lb = 0.024 MJ/kg  
lossConst = 14e8 lb/ft<sup>3</sup>/hr ÷ 17 lb/ft<sup>3</sup> = 23000/s  
lossExp = 23'905 R = 13'280 K

high density phenolic nylon  
enthalpy = 12'000 BTU/lb = 5.7 MJ/kg  
lossConst = 6.2e8 lb/ft<sup>3</sup>/hr ÷ 75 lb/ft<sup>3</sup> = 2300/s  
lossExp = 43'200 R = 24'000 K

Only the higher-lossExp materials can be useful in protecting KSP's 3300K heat-shields.

In order to give ablator a game-play use, we can increase lossExp, decrease the maximum temperature of the bare heat-shield (as Starwaster's Deadly Reentry mod does) or a mix of both.

## Files

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|               |         |            |           |
|---------------|---------|------------|-----------|
| quicksave.sfs | 32.2 KB | 03/05/2017 | Anonymous |
|---------------|---------|------------|-----------|