Here is why temperature cycling can cause Catastrophic failures (Catos). The nozzle, propellant and the casing all expand and contract at different rates. Since the motors are so small, this is only a problem if the temperature that the motor "sees" swings between wide extremes. When this happens, we see several effects:

1) The propellant and the clay nozzle develop a crack at their interface. This actually results in *Lower* peak pressure and peak thrust because the motor can begin the end-burning earlier than it should (never forming the "big dome" of burning surface area that we should get at normal peak thrust).

2) The casing and the propellant can de-bond. They aren't really bonded in a "glue" sense, but the mechanical bond is weakened from the stretching and contraction. (For wet rammed motors, there may be a tiny glue-like "bonding", but the cycling will break that bond). The flame can propagate along the entire inside of the casing and propellant interface and result in a huge overpressure. This leads to a casing split (if the delay is still "grabbing" the casing tightly) or a "blow through" which is like a Roman Candle.

The two of these can combine to form different Cato scenarios:

a) Blow through at ignition or just after ignition (on the pad/rod). Clearly a sign of a nozzle/propellant interface crack allowing the flame front to reach the debonded casing to propellant interface at or just after ignition.

b) Cato above the pad (like 50 feet up). Clearly there was no crack along the propellant/nozzle interface and the flame front had to wait until it naturally reached the casing wall and then propagate up the de-bonded propellant/casing interface.

A final scenario is the cracked propellant grain. These can go BLAM (or KA-PLOW) quite spectacularly since they really overpressurize the casing big-time and can happen with a perfect casing to propellant bond. A defective tool used to form the centerbore of the propellant can cause these. The C5-3 had such a problem when a tool was mis-manufactured. I believe the root cause was a lack of radius on the tip, which formed a sharp edge, which led to cracking. Motors also could be cracked if any contaminant got on the tool or in the propellant during ramming, but dropping or rattling will not cause a crack!

As for the temperature cycling - avoid firing a motor at a temperature 75 degrees F lower than the highest temperature it has ever seen. If fired while too cold, the propellant will be contracted away from the casing and it will probably fail. Folks launching in cold weather can do so if they store their motors in their warm car or in their toasty parka inside pockets. (Is that an F100 in your pocket or are you just happy to see me?)

Why would a normally stable rocket fly unstable when using a motor that it flew stable with before?
Did you look at the nozzle? We have had several VERY scary "flights" where the rocket had little thrust and/or veered into cruise missile mode. After crashing and putting out the brush fire, we examine the nozzle and find that it is either too wide (wider than normal at the throat) or it is eroded asymmetrically. The asymmetric erosion is bad and you can clearly see the exhaust residue all over the missing area of the nozzle indicating that it disappeared at ignition or shortly thereafter.

All unstable flights with Estes motors from years "A" and "B" and maybe "C" need to be inspected and if the motor/nozzle is the cause, a M.E.S.S. form filled out and the manufacturer notified. The least that will happen is a package of replacement motors and a kit. The most that will happen is an improvement in materials used in manufacturing and a product that performs like we remember for decades and decades.

I hope this info helps folks.

-Fred Shecter NAR 20117