8D Report: Capacitor Reliability Issue (Power System)

0	**Prepare** Why does this problem require an 8D?	An early customer on our Build 7 AP3 padlocks reported unusually high failure rates. This failure mode was not seen on locks from prior production runs. The increase in failure rate and the unexpected occurrence of the failures necessitates a structured problem-solving project.
1	**Assemble Team** Team should have the knowledge, skill, and authority to solve the problem and implement corrective actions.	**Who is on the team**: Jerod Klink, CTO Konrad Hammel, Director of Hardware Engineering Brad Gall, VP of Supply Chain (Inertia – ODM partner) Mike Gaudet, Program Manager (Inertia – ODM partner) Adam Lucier, Product Development (Inertia – ODM partner) **Goals & Objectives**: Determine the root cause, incidence, severity and implement preventive measures in future production.
2	**Describe the Problem** What is the problem? What is the problem scope? Why is this a problem? Who is affected? Who is not? What provides us certainty?	The customer successfully deployed padlocks at scale. After successfully using them for several months, the customer started reporting AP3 failures characterized by “LED would not light”, or “unable to connect through the app”. These issues persisted on USB power, which is the failover mechanism for dead batteries. Within a few weeks, 2% of locks were shown to exhibit these symptoms. Build 7 was manufactured between November 2021 and January 2022 (Hardware ID range 1D4C1 to 226D8). We have no reports of AP3 prior to Build 7 having similar symptoms. An AP3 with these symptoms is unusable and needs to be removed from active service. Konrad designed that a USB current test to identify if a lock is affected by this issue.
3	**Interim Containment** What immediate actions do we take to contain the problem and limit impact?	For all locks in Sera4’s inventory, Sera4 coordinated a full screening of all locks. We found 1-2% that exhibited the signature that indicates they are affected by this issue. For all locks in distribution, we plan to develop a tester that anyone can use to easily and conclusively identify if a lock is affected. Any lock that is affected is automatically approved for an RMA.
4	**Identify Root Cause** Use a 5-whys methodology, a fishbone diagram or other root cause process.	1. Why did a recently deployed AP3 stop working? - AP3 because using the button did activate the LED or cause it to appear on the Teleporte App. 2. Why didn’t the AP3 respond to USB or button inputs - The AP3 didn’t respond to these inputs because the AP3 was in the reset state.

		3. Why was the AP3 in the reset state? - The AP3 reset circuit was triggered in conditions where it should not have been. 4. Why was the reset circuit triggered? - The C13 capacitor was passing current across its terminal when a capacitor should be an open circuit for a DC or low-frequency voltage. 5. Why did the capacitor behave unexpectedly? - The capacitor is defective. It has cracked because it absorbed moisture when it was not supposed to. The cracked capacitor can leak direct current: this is a clear failure in a capacitor. In researching possible root causes, we found the following article that describes the observed failure mode and explains it: *https://nepp.nasa.gov/files/29931/NEPP-BOK-2018-Teverovsky-Paper-NEPPWeb-BOK-Cracking-MLCC-TN65668.pdf*
5	**Identify Solutions** What are the possible solutions? Identify the best. Address the root cause. What Permanent Corrective Actions will we take?	Beyond containment and identification of the problem in build 7, rework is not practical and failing units should be discarded and not used. Two possible solutions were considered to ensure that this wasn't a problem in future production: 1. Replacing the defective component from a different source. This is a rare condition and if our current capacitor source is not reliable, then we can replace the capacitor from another trusted source. However, the risk persists regardless. We have no assurance that components from one lot to the next are any better from one supplier to the next. 2. Introduce PCBA baking prior to conformal coating. This baking of the assembled PCB evaporates all absorbed moisture in the components. After baking, the conformal coating creates a waterproof seal around the components, thereby eliminating the risk of moisture entering and cracking the capacitor. We chose to implement this solution as it has the highest reliability.
6	**Validation** Verify that the solution is working as expected. Check for undesirable side-effects.	We have always tested for increased current drain during factory production test. In order to validate that no locks with a similar issue pass production test in the future, we increased the resolution of the current test preformed at the factory from 1 mA(+/- 1 mA) pass/fail to a 20 uA (+/- 1 uA). We will validate that we see no failures with the same signature in subsequent production builds.
7	**Prevention** What improvements in systems and processes will prevent this and similar problems from recurring?	In addition to the new factory current testing, we are removing the reset circuit that relied on the failing component. See Inertia EC1233. This makes the recurrence of the exact same problem impossible.
8	**Congratulate the Team**	**Team disbanded and resolution complete on**: September 12, 2022.