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Solderability after Long-Term Storage

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Introduction

The effect of long-term storage on manufacturability and reliability is an area of major concern for companies that attempt to proactively manage component availability and obsolescence. A number of issues can arise depending on the technology and storage environment. Mechanisms of concern can include solderability, stress driven diffusive voiding, kirkendahl voiding, and tin whiskering. Of all of these, solderability / wettability remains the number one challenge in long-term storage.

Solderability Testing

In this case study, the solderability was assessed for components from three different reels stored for up to five years to determine how much additional storage life was available. The components were either an ASIC in a SOIC package or a MOSFET in a TO-252 package. In both situations, the lead frame plating was tin-based.

The type of plating material drives the appropriate solderability test regime. In this case, tin can either oxidize and/or form intermetallics with the base metal underneath. Both reactions can detrimentally reduce the solderability of the component. To assess these reactions, the components were subjected to steam aging to accelerate storage related effects on solderability. Elevated temperature accelerates tin-copper intermetallic growth and the steam accelerates tin oxide formation. The components were then tested for solder wettability using a wetting balance test.

Steam Aging

The steaming apparatus was constructed as per IPC-TR-464. Components are placed in the "dead bug" position on an inert and heat resistant polypropylene stage. With this method, components are held at approximately 93°C, between 80% and 90% relative humidity (RH), and no more than 1 1/2" from the surface of the boiling water.

Each day exposed to this accelerated steam aging method is considered equivalent to one year in storage. Three components from each reel were aged for 0, 12, 24, 48 and 72 hours, corresponding to 0, 0.5, 1, 2 and 3 years of additional storage.

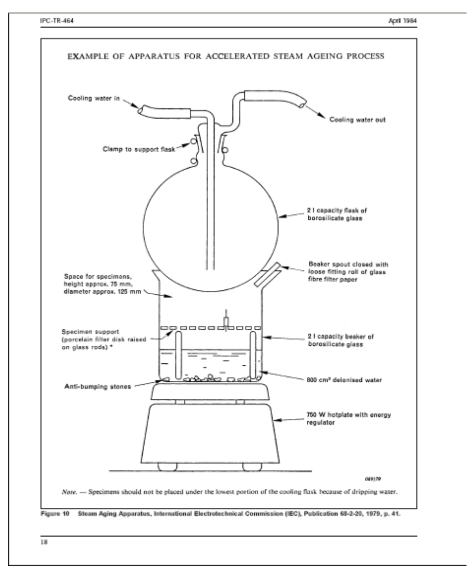

Figure 1: Apparatus for Steam Aging

Solderability Measurements

Measurements of the wettability of the leads were performed by using a solder meniscus measuring device (Wetting Balance) for each component. All the parts were tested with a standard RMA flux. The recommended procedure is detailed in IPC/EIA J-STD-002C. Three components from each reel were tested. The acceptance criterion from J-STD-002C is provided in Chart 1 below with Set A more stringent than Set B.

Parameter	Description	Suggested Criteria[1]	
		Set A	Set B
T_0	Time to buoyancy corrected zero	≤1 second	≤2 seconds
F2	Wetting force at two seconds from start of test	50% of maximum theoretical wetting force at or before two seconds[2]	Positive value at or before two seconds
F5	Wetting force at five seconds from start of test	No less than 90% of the F2 Value	No less than 90% of the F2 Value
AA	Integrated value of area of the wetting curve from start of test	Area calculated using sample buoyancy and 50% maximum theoretical force[3]	> zero (0)

Chart 1: J-STD-002C Wetting Criterion

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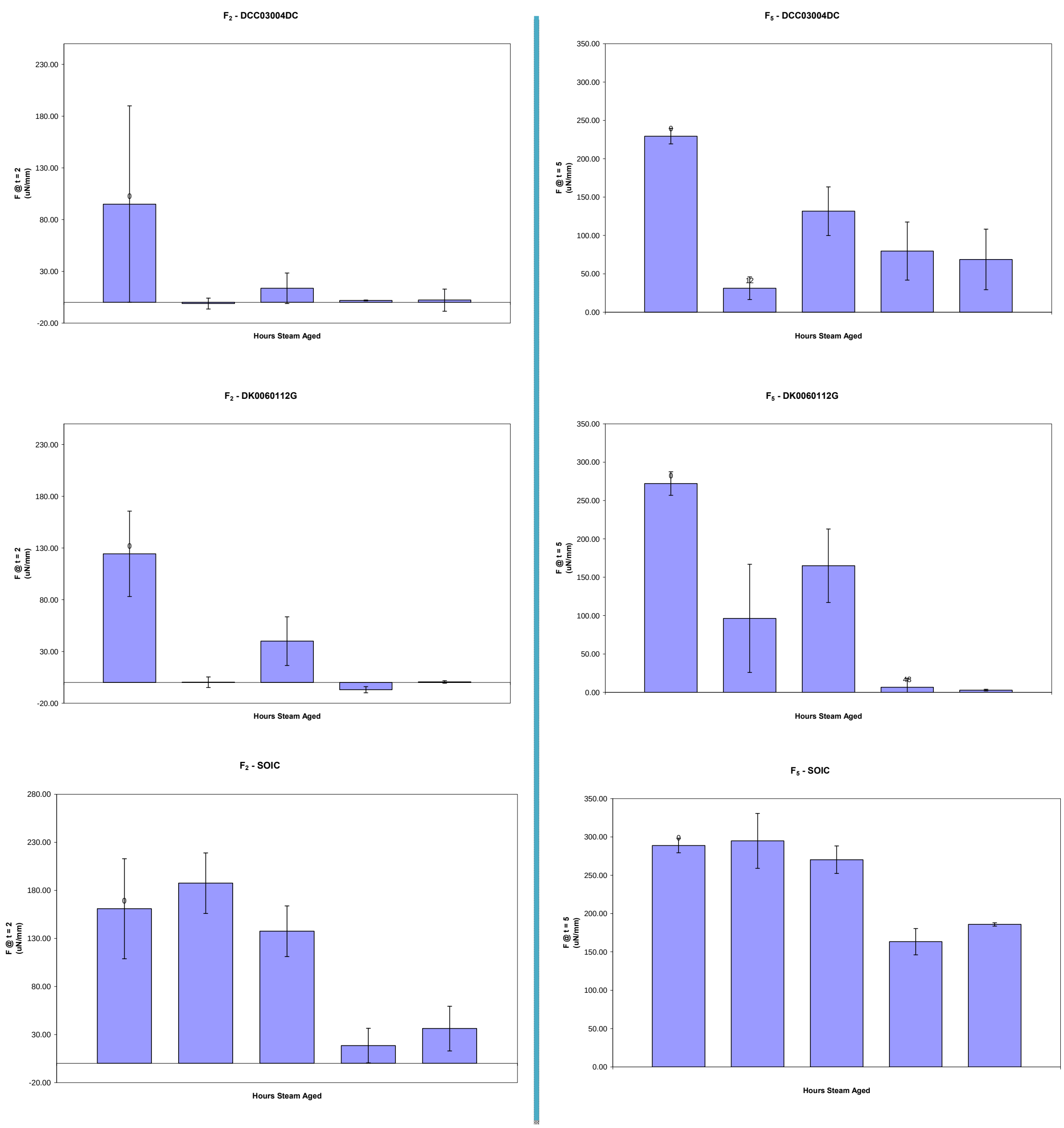
Solderability Results

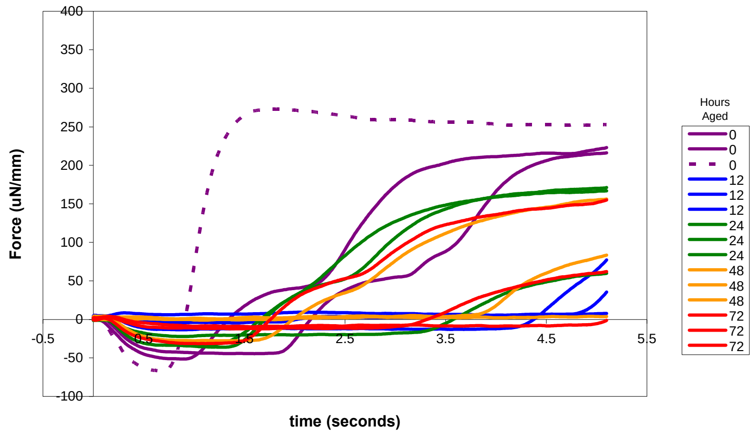
The figures below exhibit the mean wetting forces of the components at 2 and 5 seconds after contact with the solder. These forces indicate the adhesion of the solder to the leads after being dipped.



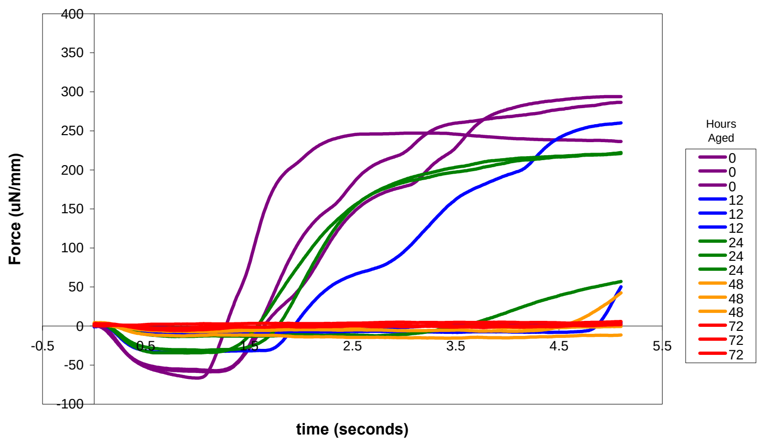
Wettability Force at t = 2 seconds (left column) and t = 5 seconds (right column)

The figures below display the profile of the wetting forces for each sample throughout the test. As samples are aged further, both the resistive force (as the lead contacts the solder sample) and the adhesive force (as it is removed) drop in magnitude and build more slowly.

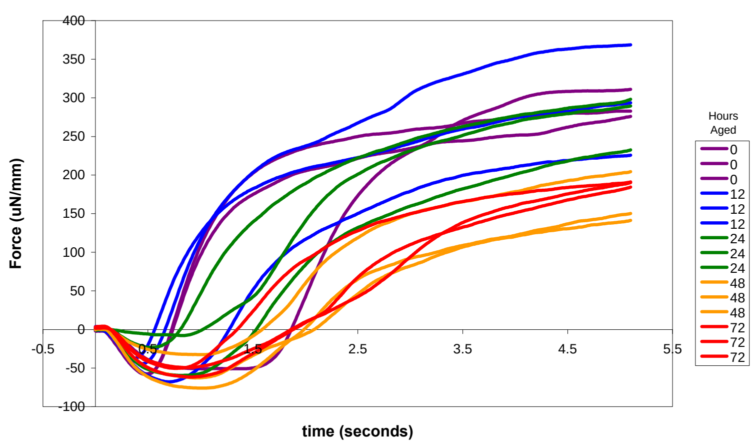
TO252 (production year 2003). Solderability is already impaired. The dashed line indicates a part which was tested with a more active water soluble flux. Notice the significant improvement in wettability. This suggests the mechanism for poor wetting is thick oxide (as opposed to intermetallic formation).



TO252 (production year 2000). Even though this part is older, its initial solderability is superior to the 2003 part. After 12 hours of steam aging (equivalent to six months), solderability has deteriorated.



SOIC (production year N/A). Solderability degrades slowly. The part does not become completely unwettable, like the TO252 parts, but fails IPC criteria after 24 hours of steam aging (equivalent to 1 year of storage).



Discussion and Conclusion

The data displayed above and an overview of addition results in Tables 2 and 3 below demonstrate some interesting findings in regards to solderability after long-term storage. The first is that the same components produced by the same manufacturer can display very different behaviors in regards to long-term solderability. This was seen with the TO252 parts, where the parts fabricated in 2000 had better wettability than the parts fabricated in 2003. Therefore, any component or obsolescence storage strategy should involve an initial solderability assessment of each part and date code combination.

The second is that even within the same date code, components may pass and fail certain IPC criteria. Before proceeding with solderability testing, a sufficient number of parts must be tested and some attempt should be made to correlate specific IPC criteria to the particular design and assembly parameters relevant to the part in question.

The final finding is that any concern with poor solderability, if driven by oxidation formation, can be potentially mitigated through the use of more aggressive flux formulations. This may require contingency planning for assembly of components after long-term storage, including movement from L to M to possibly H flux chemistries and introducing modified cleaning processes to ensure these chemistries are effectively removed after soldering. It also clearly demonstrates that the most critical parameter to control during long-term storage is temperature, as oxide formation can be potentially remedied while intermetallic formation cannot.

Table 2: Performance of stored components

					Acceptance criteria					
					*Set A			Set B		
Part type	Production Year	T_0	F_2	F_5	$T_0 \leq 1sec$	$F_2 \geq F_{(max)}$ µN/mm	$F_5 \geq F_{(max)}$ µN/mm	$T_0 \leq 2sec$	$F_{t \leq 2} > 0$	$F_5 \geq F_2$
TO252	2003	2.14	-27.2	215.3	fail	fail	pass	fail	fail	pass
TO252	2003	1.33	40.3	220.7	fail	fail	pass	pass	pass	pass
TO252	2003	0.90	271.7	252.6	pass	pass	pass	pass	pass	pass
TO252	2000	1.63	49.3	293.8	fail	fail	pass	pass	pass	pass
TO252	2000	1.58	111.1	285.7	fail	fail	pass	pass	pass	pass
TO252	2000	1.26	212.7	237.1	fail	pass	pass	pass	pass	pass
SOIC	N/A	1.85	41.8	309.9	fail	fail	pass	pass	pass	pass
SOIC	N/A	0.72	205.6	273.4	pass	pass	pass	pass	pass	pass
SOIC	N/A	0.71	235.2	282.9	pass	pass	pass	pass	pass	pass

Table 3: Performance of stored and then steam aged components

						Acceptance criteria					
						*Set A			Set B		
Part type	Production Year	Steam age time	T_0	F_2	F_5	$T_0 \leq$ 1sec	$F_2 \geq F_{(max)}$ µN/mm	$F_5 \geq F_{(max)}$ µN/mm	$T_0 \leq$ 2sec	$F_{t \leq 2} >$ 0	$F_5 \geq F_2$
TO252	2000	12	1.92	11.6	258.8	fail	fail	pass	pass	pass	pass
TO252	2000	12	3.17	-2.5	4.1027	fail	fail	fail	fail	fail	pass
TO252	2000	12	4.85	-8.3	26.193	fail	fail	fail	fail	fail	pass
TO252	2003	12	4.36	-11.9	64.37	fail	fail	fail	fail	fail	pass
TO252	2003	12	2.00	-0.5	21.749	fail	fail	fail	fail	fail	pass
TO252	2003	12	---	9.2	7.3376	fail	fail	fail	fail	pass	fail
TO252	2000	24	1.76	50.1	220.59	fail	fail	pass	pass	pass	pass
TO252	2000	24	1.56	81.1	220.05	fail	fail	pass	pass	pass	pass
TO252	2000	24	3.56	-11.2	54.361	fail	fail	fail	fail	fail	pass
TO252	2003	24	1.65	30.4	166.31	fail	fail	fail	pass	pass	pass
TO252	2003	24	1.69	30.9	170.19	fail	fail	fail	pass	pass	pass
TO252	2003	24	3.56	-20.2	58.45	fail	fail	fail	fail	fail	pass
TO252	2000	48	2.90	-2.4	-0.686	fail	fail	fail	fail	fail	pass
TO252	2000	48	---	-13.7	-12.07	fail	fail	fail	fail	fail	pass
TO252	2000	48	4.51	-4.8	32.175	fail	fail	fail	fail	fail	pass
TO252	2003	48	1.97	1.5	155.07	fail	fail	fail	pass	pass	pass
TO252	2003	48	---	2.8	80.149	fail	fail	fail	fail	pass	pass
TO252	2003	48	1.86	1.3	3.8301	fail	fail	fail	pass	pass	pass
TO252	2000	72	4.55	-1.4	1.8347	fail	fail	fail	fail	fail	pass
TO252	2000	72	0.09	3.1	5.2133	pass	fail	fail	pass	pass	pass
TO252	2000	72	2.07	-0.1	1.496	fail	fail	fail	fail	fail	pass
TO252	2003	72	1.75	26.7	151.51	fail	fail	fail	pass	pass	pass
TO252	2003	72	---	-8.9	-5.52	fail	fail	fail	fail	fail	pass
TO252	2003	72	3.30	-11.3	60.236	fail	fail	fail	fail	fail	pass
SOIC	N/A	12	0.65	237.5	367.7	pass	pass	pass	pass	pass	pass
SOIC	N/A	12	0.55	208.1	292.0	pass	pass	pass	pass	pass	pass
SOIC	N/A	12	1.26	116.7	224.7	fail	fail	pass	pass	pass	pass
SOIC	N/A	24	1.01	140.0	287.4	fail	fail	pass	pass	pass	pass
SOIC	N/A	24	1.52	83.3	229.1	fail	fail	pass	pass	pass	pass
SOIC	N/A	24	0.79	189.0	294.2	pass	fail	pass	pass	pass	pass
SOIC	N/A	48	1.57	59.7	202.4	fail	fail	pass	pass	pass	pass
SOIC	N/A	48	1.97	1.5	148.4	fail	fail	fail	pass	pass	pass
SOIC	N/A	48	2.07	-5.8	139.2	fail	fail	fail	fail	fail	pass
SOIC	N/A	72	1.34	90.0	189.4	fail	fail	fail	pass	pass	pass
SOIC	N/A	72	1.87	8.8	181.0	fail	fail	fail	pass	pass	pass
SOIC	N/A	72	1.85	9.8	187.5	fail	fail	fail	pass	pass	pass

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