

IPC-SPVC-WP-006

ROUND ROBIN TESTING AND ANALYSIS

LEAD-FREE ALLOYS

TIN, SILVER and COPPER

A WHITE PAPER REPORT by the
LEAD-FREE TECHNICAL SUBCOMMITTEE of the
IPC SOLDER PRODUCTS VALUE COUNCIL

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MISSION STATEMENT

In support of IPC's Mission Statement, IPC solder manufacturers recognize that the PWB and electronics assembly industries, comprised of the entire supply chain, must grow profitably. The Solder Products Value Council Steering Committee's objective is to identify and execute programs designed to enhance the competitive position of solder manufacturers and their customers.

SOLDER PRODUCTS VALUE COUNCIL MEMBERS

AIM	Koki Company Ltd.
Cookson Electronics	Nihon Superior Company Ltd.
Alpha Metals	P. Kay Metal Supply Inc.
Amtech	Qualitek
Avantec	Senju Metal Industry
EFD Inc.	Thai Solder Industry Corp.
Henkel Loctite	
Indium Corporation	
Kester Northrup	
Grumman	

IPC SOLDER PRODUCTS VALUE COUNCIL LEAD FREE ALLOY COMPARISON

Introduction and Statement of Problem

Due to marketing and legislative pressures in Asia and Europe, the electronics industry is moving to adoption of lead free solders. These lead free materials are considered by some to be environmentally preferable to the current lead containing solders that dominate electronics manufacturing.

Although the issue as to whether lead free solders are indeed environmentally preferred compared to lead containing solders is still under debate, market and legislative actions are forcing a change in materials used in electronics assembly.

Accordingly solder material suppliers are being asked to provide the electronics industry with solders that are lead free (per the accepted technical definition of that term) and yet still provide all the needed properties – including ease of assembly and reliability – the electronics industry has come to expect from lead containing solders.

At present there are a large number of materials that have been proposed as replacements for lead containing solder. Primary among these are the Tin/Silver/Copper (SAC) alloys.

There are several variations of the Tin/Silver/Copper alloys that have been suggested as the preferred replacements for Tin Lead solders. Two are of special interest: the Japanese adopted alloy of 96.5% Tin, 3.0% Silver and 0.5% Copper and the North American Electronics Manufacturing Initiative (NEMI) alloy of 95.5% Tin, 3.9% Silver, and 0.6% Copper.

Both of these alloys have undergone significant testing. And both of their sponsors believe that their particular choice is the best candidate for replacement of lead containing solders.

The IPC Solder Products Value Council members are technically capable of providing any alloy requested by their customers. However, provision of a range of materials may not, in the view of the IPC SPVC membership, be the best method of serving the needs of the industry.

The SPVC, as producers of solder alloys, believes it is in the best interests of the industry, from the standpoint of product consistency, quality, and the conservations of natural resources, for a consensus to be reached on a standard alloy for the electronics industry.

Methodology

In order to determine what material is best suited to be the standard alloy, the IPC SPVC members have reviewed the most likely candidates in the current list of contenders and carefully considered:

- What alloys are presently, through general acceptance, most likely to be used as Tin Lead solder replacements?
- What tests are applicable to make an accurate determination of the differences (if any) in the properties of the most likely candidates?

Alloy Choice

The majority of potential “standard” replacement alloys are composed of Tin, Silver, and Copper with Silver varying between 3 and 4% and Tin varying between 95.5 and 96.5%. The current “front runners” are (in % of Tin/Silver/Copper) the 96.5/3.0/0.5 (Japanese) and 95.5/3.9/0.6 (NEMI) alloys. Therefore, it should be expected that, from the cost and performance of the alloy, the Silver content should dominate. Accordingly, any comparison of alloys should be done on a material set that spans the range of Silver content from 3 to 4%. To cover that composition range the alloys chosen for testing by the IPC SPVC were:

- 96.5/3.0/0.5 Tin/Silver/Copper
- 95.5/3.8/0.7 Tin/Silver/Copper
- 95.5/4.0/0.5 Tin/Silver/Copper

Test Regimen for Alloy Comparison

There are two major areas of concern when considering whether a standard solder replacement for the existing tin lead eutectic solder can be determined.

1. What are the relative properties of the range of candidates and how do these properties affect the performance of the candidate material in assembly?
2. Once assembly is complete, is there any significant difference in the long-term interconnection reliability performance of the candidate materials?

Assembly Performance Comparison

A solder alloy’s assembly properties (and for this paper the term assembly will be limited to surface mount reflow assembly) are determined by the melt characteristics of the alloy and its ability to wet a substrate. The former determines the process parameters, e.g. reflow profile, for the alloy. The latter determines the ability of the alloy to form an inter-metallic bond between the substrate and components of the assembly.

After consideration the SPVC Technical Committee agreed that, as a first step in analyzing the three tin silver and copper alloys, the following tests were most suited for use in comparison of alloy properties:

- **Melt Characterization:** Differential Scanning Calorimetry (DSC, measured at rates of 3 and 10 ° C per minute)
- **Wetting Balance Responses:** Time to cross the zero line and maximum wetting force tested per IPC-TM-650, 2.4.14.2, Liquid Flux Activity, Wetting Balance Method using flux per J-STD-003A, 3.2.2, Flux. (Appendix 2)

- **Solder Spread** of a standard amount of alloy as determined by area of spread and diameter of the pattern of spread per IPC-TM-650, 2.4.46, Spread Test, Liquid or Extracted Solder Flux, Solder Paste and Extracted Cored Wires or Preforms (Appendix 3)

Assembly Performance Testing: Statistical Procedures Used

A total of seven member companies participated in the Solder Products Value Council alloy properties comparison testing. A complete summary of the data collected can be found in Appendix 1.

Analysis of the data was done using the JMP Statistical Software Package from SAS Institute. The Tukey-Kramer Analysis of Variance Method in this software package was used to test for differences between the sets of data as submitted.

There are a variety of methods to test the differences of group means (multiple comparisons) that vary in detail about how to size the test to accommodate different kinds of multiple comparisons. The All Pairs, Tukey HSD procedure gives a test that is sized for all differences among the means. This is the Tukey or Tukey-Kramer HSD (honestly significant difference) test. This test is an exact alpha-level test if the sample sizes are the same and conservative if the sample sizes are different.

The software package also provides a visual comparison of means by way of a comparison circles plot. A comparison of each pair of group means can be done visually by examining how the comparison circles intersect. (For example see Figures 1 and 2.) The outside angle of intersection visually indicates whether group means are significantly different. Circles for means that are significantly different either do not intersect or intersect slightly so that the outside angle of intersection is less than 90 degrees. If the circles intersect by an angle of more than 90 degrees or if they are nested, the means are not significantly different.

The means comparison method can be thought of as seeing if the actual difference in the means is greater than the difference that would be significant. This difference is called the LSD (least significant difference). The LSD term is used for Tukey-Kramer intervals and in context with intervals for other tests. In the comparison circles graph, the distance between the circles' centers represent the actual difference. The LSD is what the distance would be if the circles intersected at right angles.

Examples of Statistical Analysis

Figures 1 and 2 show the graphical analysis as applied to the time to reach zero force and the maximum wetting force in the wetting balance testing. Note the overlap of the data sets indicating that there is no significant difference between the alloys as tested at this particular location. A complete summary of the alloy analysis by location is shown in Table 1 below.

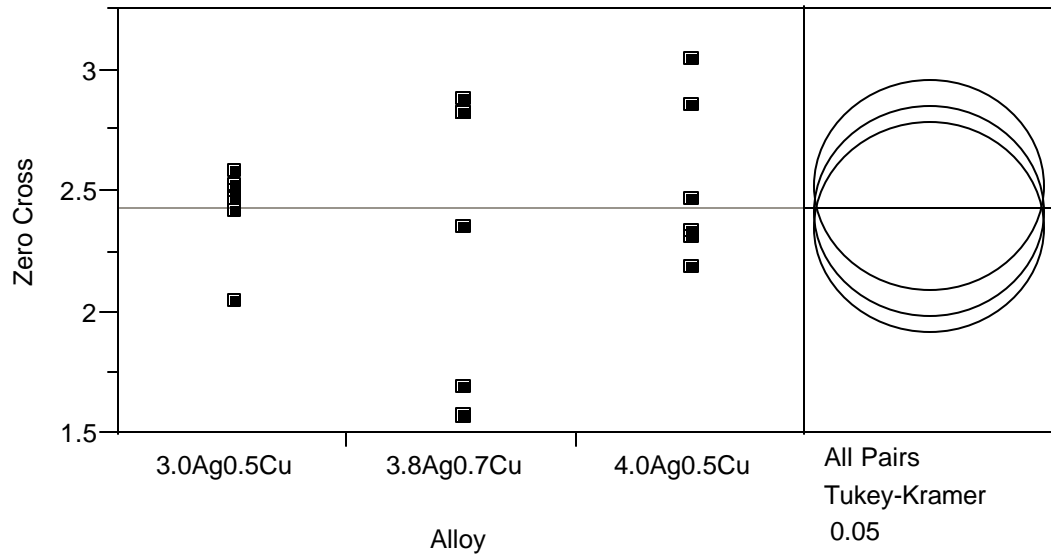


Figure 1 - Zero Crossing Time Analysis

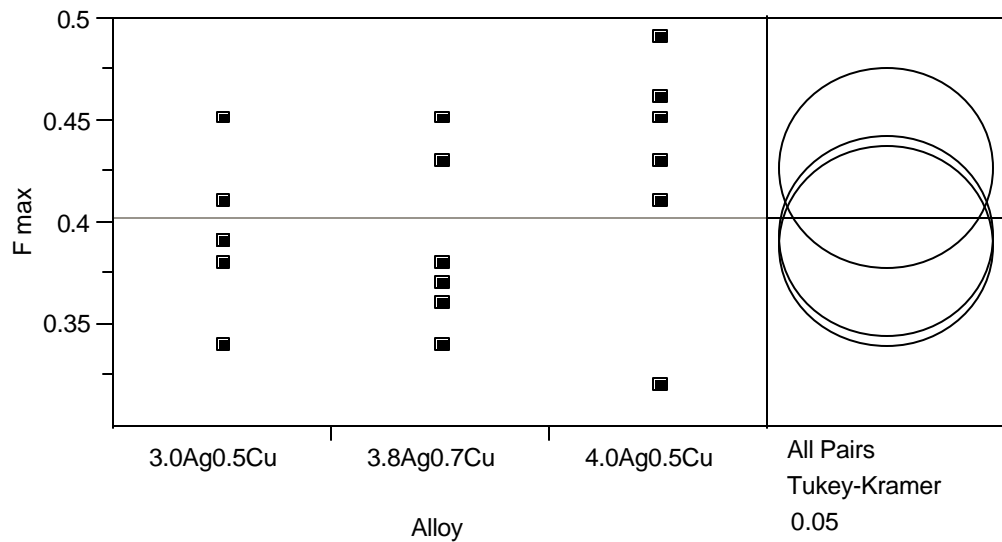


Figure 2 - Maximum Wetting Force Analysis

Table 1 – Alloy Analysis Summary by Individual Company Site

Property	Company Designation						
	A	B	C	D	E	F	G
Zero Crossing Time (secs)	NSD	NSD	NSD	SD	NSD	NSD	NSD
F Max (nM)	NSD	NSD	NSD	NSD	NSD	NSD	SD
Wetting Diameter (mm)	NA	SD	SD	NSD	NA	NSD	NSD
Melt Temperature ©	NA	SD	NSD	NA	NSD	NSD	SD

Key:

NA = Parameter not measured.

NSD = Not Statistically Different

SD = Statistically Different

The results of this round robin test, as analyzed by the “JMP” package, indicate that for the majority of parameters measured there is no significant difference in the alloys within a specific test site. Table 2 below shows a similar comparison done by alloy for all locations and a comparison for all parameters by company.

An illustration of the comparison of test results by alloy for all locations and by company for all alloys is shown in Figures 3 and 4 below for wetting force and zero crossing time.

As can be seen from Table 2 and Figures 3 and 4 the greatest difference between test results is due to the location of the test. A comparison of all alloy results indicates that alloy differences are small when compared to the variability of the test locations. As was noted above, within a single location the difference between alloys is generally not significant.

Table 2 - Analysis Summary by Alloy and Company

Property	Difference by Alloy	Difference by Company
Zero Crossing Time (secs)	NSD	SD
F Max (nM)	NSD	SD
Wetting Diameter (mm)	NSD	SD
Melt Temperature ©	NSD	SD

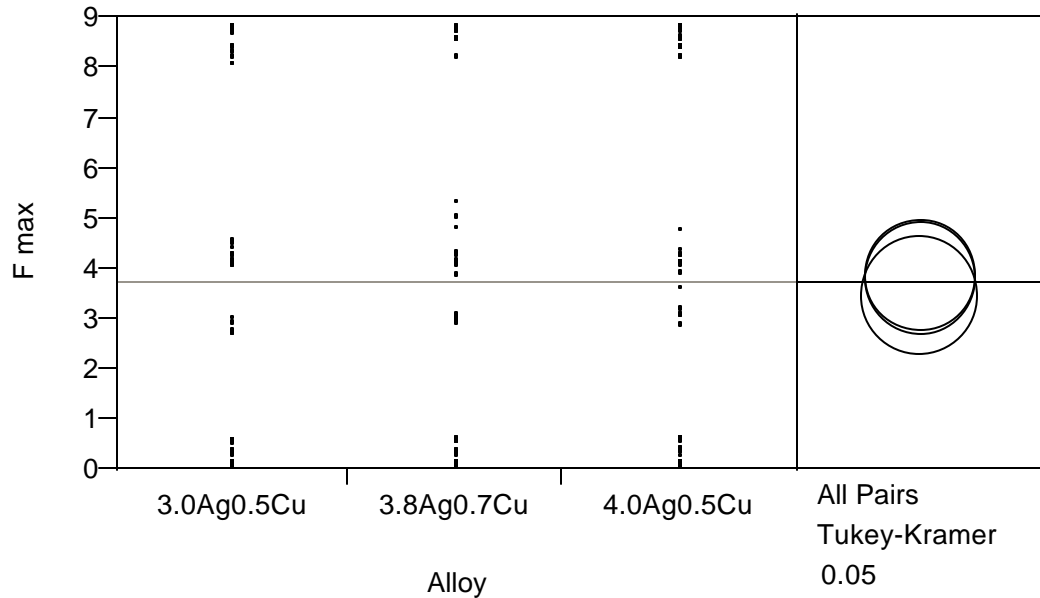


Figure 3 - Comparison of Alloys for All Locations

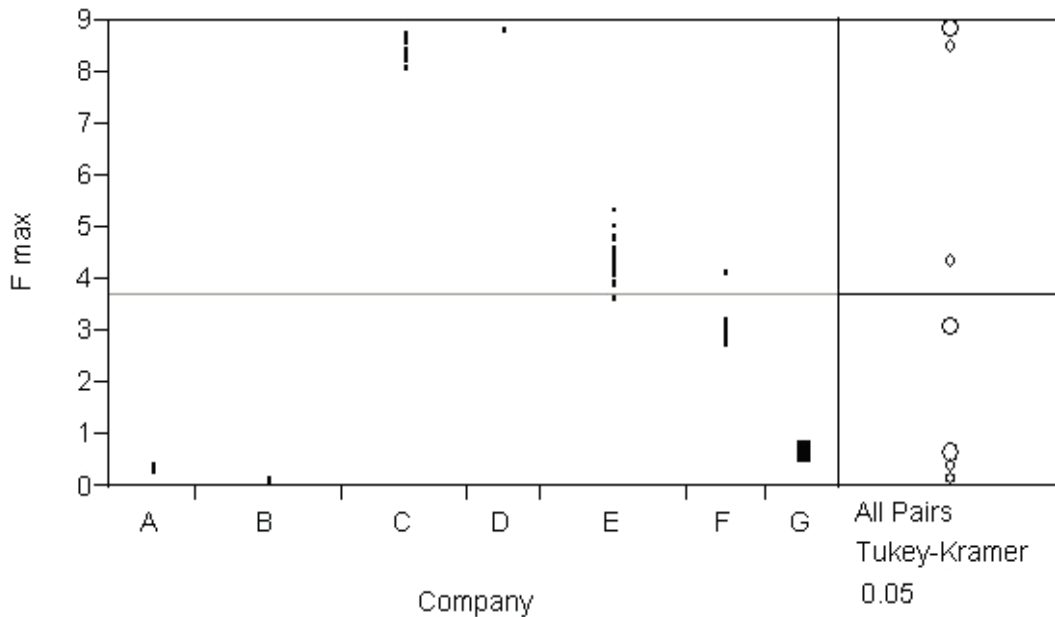


Figure 4 - Comparison of all Test Results between Locations

Conclusions Based on Assembly Performance Testing

Based on the results of the tests described above and the statistical analysis of the data gathered the difference between the alloys is not statistically significant. The difference in test procedures, between locations, is of more consequence than the variation in alloys. It can be assumed that, given this data, if there are no detectable differences found in actual assembly performance, e.g. solder defects, and long term thermal cycling that the variation in alloy properties over the range examined is of no consequence.

LONG TERM RELIABILITY COMPARISON

The assessment of long-term reliability requires a much larger investment of time and resources than the assessment of process affecting properties. At present no comprehensive set of material properties, comparable to those that are available for Tin Lead containing solders, exists for the lead free alloys.

After discussions within the group of companies comprising the IPC SPVC, leading industry reliability experts and a review of published data on lead free reliability testing, the IPC SPVC developed a long term interconnection reliability test program.

This program is not intended as an in-depth study of all material properties and attributes that affect long-term reliability of the Tin/Silver/Copper lead free systems. Rather, it is a carefully laid out approach whose purpose is to determine whether the alloy systems chosen show any significant difference that may impact long-term interconnection reliability.

The program comprises the following stages:

- Third party solder paste testing and evaluation.
- Test vehicle assembly of two separate test vehicles.
- Interconnection optical and electrical inspection, repair of any defective connections and data logging of all inspection and repair activities.
- Cycling to failure of the assemblies using both fast and slow thermal cycles.
- Periodic metallographic analysis of structural changes in the thermal cycled interconnections.
- Data analysis of interconnection failures at the end of the thermal test program (end of program being defined as the point at which a statistically significant number of failures have been logged as a function of time).

Third Party Solder Paste Testing

All members of the IPC SPVC have the capability of providing both the alloys and flux vehicles needed to produce lead free solder pastes. In order to eliminate any possible conflict of interest, volunteer members of the IPC SPVC will provide assembly quantity paste samples of the lead free candidates to IPC. These samples will be re-labeled and given to Engent Inc., an independent test laboratory based in Norcross, GA, for evaluation of the pastes based on the recommendations of two electronics manufacturing services (EMS) companies that will perform the assembly. Engent Inc. will forward the anonymous material judged best to the assembly companies for use in the next stage of the trial.

Test Vehicle Assembly

The EMS companies, Flextronics and Solectron, have volunteered to provide their test vehicles for the next phase of the testing. 160 test PCBs will be assembled at each of these EMS companies with 40 PCBs used for each of the three lead free alloy pastes and for a Tin-Lead eutectic control. (The eutectic control paste will be the standard paste now in use at each EMS company).

Inspection, Test, Repair, and Data Logging

All test vehicles that are assembled will be tested electrically. In addition, a 100% inspection per IPC-A-610 will be done. Defective solder interconnections will be repaired.

All results of the test and inspection, as well as details on any repair operations, will be carefully catalogued.

Long Term Thermal Cycling

A second independent test laboratory has agreed to provide thermal cycling with electrical monitoring of the assembled vehicles. Two thermal profiles will be used.

1. Thermal cycling from -40°C to 125°C per JEDEC JESD22-A104B (July 2000, Condition G of Table 1)
2. Thermal cycling for 0°C to 100°C per IPC-9701 Test Condition 1

These conditions have been chosen to provide:

1. A point of reference with previous studies of thermal cycling of lead free Tin/Silver/Copper alloys, i.e., the wider temperature range of the JEDEC test with the shorter cycle, and
2. Slow thermal cycling conditions to examine wear-out modes that may not be detectable by the shorter cycling condition.

All these tests will be run until there are judged to be significant interconnection failures to give meaningful statistical analysis.

Periodic Metallographic Analysis

Periodic metallographic analysis is to be done on the thermally cycled samples. Samples from all four test cells for the two test vehicles will be withdrawn from the test chambers and cross-sectioned. Changes in the microstructure of the interconnections will be tracked.

Data Analysis

Data analysis of interconnection failures will be done at the end of the thermal test program. End of testing is herein defined as the point at which a statistically significant number of failures have been logged as a function of time.

As noted above, the intent of this study is not to provide a comprehensive study of the material properties of the lead free alloys. Rather, the intent is to determine if, from the standpoint of assembly and reliability results, there is any significant difference in the three systems over the range of alloy composition.

Appendix 1 - Data Tables of Testing Participants

COMPANY A - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
A	4.0Ag0.5Cu	2.3	0.46			
A	4.0Ag0.5Cu	2.18	0.49			
A	4.0Ag0.5Cu	2.33	0.41			
A	4.0Ag0.5Cu	2.46	0.43			
A	4.0Ag0.5Cu	3.04	0.32			
A	4.0Ag0.5Cu	2.85	0.45			
A	3.0Ag0.5Cu	2.5	0.39			
A	3.0Ag0.5Cu	2.41	0.41			
A	3.0Ag0.5Cu	2.04	0.45			
A	3.0Ag0.5Cu	2.52	0.34			
A	3.0Ag0.5Cu	2.57	0.39			
A	3.0Ag0.5Cu	2.46	0.38			
A	3.8Ag0.7Cu	2.34	0.43			
A	3.8Ag0.7Cu	2.82	0.34			
A	3.8Ag0.7Cu	1.56	0.37			
A	3.8Ag0.7Cu	1.68	0.45			
A	3.8Ag0.7Cu	2.88	0.36			
A	3.8Ag0.7Cu	2.82	0.38			

COMPANY B - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
B	4.0Ag0.5Cu	0.46	0.158	6.804	36.36	219.3
B	4.0Ag0.5Cu	0.66	0.143	6.591	34.119	219.5
B	4.0Ag0.5Cu	0.55	0.142	6.652	34.753	219.3
B	4.0Ag0.5Cu	0.52	0.154	6.537	33.562	219.6
B	4.0Ag0.5Cu	0.74	0.151	6.68	35.046	218.7
B	4.0Ag0.5Cu	0.7	0.135			
B	4.0Ag0.5Cu	0.57	0.15			
B	4.0Ag0.5Cu	0.45	0.169			
B	4.0Ag0.5Cu	0.71	0.15			
B	4.0Ag0.5Cu	0.6	0.159			
B	3.0Ag0.5Cu	0.56	0.146	6.688	35.13	225.1
B	3.0Ag0.5Cu	0.49	0.142	6.871	37.079	223.3
B	3.0Ag0.5Cu	0.61	0.151	6.646	34.69	224.4
B	3.0Ag0.5Cu	0.62	0.132	6.684	35.088	226.6
B	3.0Ag0.5Cu	0.53	0.155	6.782	36.125	220.3
B	3.0Ag0.5Cu	0.63	0.173			
B	3.0Ag0.5Cu	0.59	0.158			
B	3.0Ag0.5Cu	0.6	0.149			
B	3.0Ag0.5Cu	0.57	0.168			
B	3.0Ag0.5Cu	0.5	0.149			
B	3.8Ag0.7Cu	0.5	0.142	6.614	34.357	
B	3.8Ag0.7Cu	0.47	0.116	6.496	33.142	
B	3.8Ag0.7Cu	0.71	0.129	6.629	34.513	
B	3.8Ag0.7Cu	0.54	0.15	6.445	32.624	
B	3.8Ag0.7Cu	0.7	0.155	6.588	34.088	
B	3.8Ag0.7Cu	0.59	0.158			
B	3.8Ag0.7Cu	0.57	0.147			
B	3.8Ag0.7Cu	0.54	0.139			
B	3.8Ag0.7Cu	0.43	0.177			
B	3.8Ag0.7Cu	0.74	0.151			

COMPANY C - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
C	4.0Ag0.5Cu	1	8.79	6.7	35.25	216.9
C	4.0Ag0.5Cu	0.9	8.46	7.1	39.59	216.65
C	4.0Ag0.5Cu	0.7	8.69	6.65	34.73	
C	4.0Ag0.5Cu	0.75	8.46	6.56	33.79	
C	4.0Ag0.5Cu	0.9	8.3	6.4	32.19	
C	4.0Ag0.5Cu	0.55	8.46			
C	4.0Ag0.5Cu	0.95	8.46			
C	4.0Ag0.5Cu	0.8	8.29			
C	4.0Ag0.5Cu	0.8	8.62			
C	4.0Ag0.5Cu	0.55	8.62			
C	3.0Ag0.5Cu	0.7	8.39	7	38.48	217.8
C	3.0Ag0.5Cu	0.7	8.72	7.4	43.01	216.76
C	3.0Ag0.5Cu	0.7	8.13	7.1	39.59	
C	3.0Ag0.5Cu	0.85	8.39	6.7	35.26	
C	3.0Ag0.5Cu	0.75	8.3	7.15	40.15	
C	3.0Ag0.5Cu	0.7	8.79			
C	3.0Ag0.5Cu	0.85	8.39			
C	3.0Ag0.5Cu	1	8.13			
C	3.0Ag0.5Cu	0.95	8.46			
C	3.0Ag0.5Cu	0.9	8.46			
C	3.8Ag0.7Cu	0.85	8.3	6.6	34.21	216.85
C	3.8Ag0.7Cu	0.87	8.62	6.75	35.78	216.28
C	3.8Ag0.7Cu	0.95	8.62	6.8	36.32	
C	3.8Ag0.7Cu	0.95	8.62	6.8	36.32	
C	3.8Ag0.7Cu	0.7	8.79	6.9	37.39	
C	3.8Ag0.7Cu	1.15	8.79			
C	3.8Ag0.7Cu	1				
C	3.8Ag0.7Cu	0.8				
C	3.8Ag0.7Cu	1				
C	3.8Ag0.7Cu	1.05				

COMPANY D - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
D	4.0Ag0.5Cu	0.58	8.84	8.1	51.28	
D	4.0Ag0.5Cu	0.58	8.87	9.2	66.48	
D	4.0Ag0.5Cu	0.57	8.87	7.76	47.29	
D	4.0Ag0.5Cu	0.59	8.87	8.51	56.88	
D	4.0Ag0.5Cu	0.6	8.86	8.31	54.24	
D	3.0Ag0.5Cu	0.52	8.86	7.83	48.09	
D	3.0Ag0.5Cu	0.52	8.86	7.92	47.78	
D	3.0Ag0.5Cu	0.53	8.86	7.66	45.96	
D	3.0Ag0.5Cu	0.51	8.86	7.88	48.77	
D	3.0Ag0.5Cu	0.53	8.85	7.92	49.2	
D	3.8Ag0.7Cu	0.6	8.86	8.04	50.77	
D	3.8Ag0.7Cu	0.59	8.85	7.93	49.35	
D	3.8Ag0.7Cu	0.57	8.86	8.43	55.77	
D	3.8Ag0.7Cu	0.58	8.84	8.27	53.76	
D	3.8Ag0.7Cu	0.63	8.84	7.92	49.22	

COMPANY E - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
E	4.0Ag0.5Cu	1.2	4.19			216.89
E	4.0Ag0.5Cu	1.19	4.12			216.38
E	4.0Ag0.5Cu	1.78	3.66			216.35
E	4.0Ag0.5Cu	1.1	4.32			216.36
E	4.0Ag0.5Cu	1.15	4.16			
E	4.0Ag0.5Cu	0.94	4.85			
E	4.0Ag0.5Cu	1.11	4.2			
E	4.0Ag0.5Cu	0.99	3.99			
E	4.0Ag0.5Cu	1.11	4.45			
E	4.0Ag0.5Cu	1.28	4.33			
E	3.0Ag0.5Cu	1.22	4.21			216.76
E	3.0Ag0.5Cu	1.38	4.19			216.49
E	3.0Ag0.5Cu	1.22	4.49			216.71
E	3.0Ag0.5Cu	1.29	4.12			216.85
E	3.0Ag0.5Cu	1.23	4.12			
E	3.0Ag0.5Cu	1.33	4.6			
E	3.0Ag0.5Cu	1.37	4.32			
E	3.0Ag0.5Cu	1.3	4.23			
E	3.0Ag0.5Cu	1.04	4.65			
E	3.0Ag0.5Cu	1.2	4.35			
E	3.8Ag0.7Cu	1.21	4.39	7.25	41.3	216.7
E	3.8Ag0.7Cu	0.83	5.1	7	38.5	216.56
E	3.8Ag0.7Cu	1.18	4.21	7.5	44.2	216.75
E	3.8Ag0.7Cu	1.01	4.89	7.5	44.2	216.64
E	3.8Ag0.7Cu	0.99	5.37	7.5	44.2	
E	3.8Ag0.7Cu	1.06	4.19			
E	3.8Ag0.7Cu	1.09	4.2			
E	3.8Ag0.7Cu	1.06	4.34			
E	3.8Ag0.7Cu	1.31	4.15			
E	3.8Ag0.7Cu	1.21	3.94			

COMPANY F - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
F	4.0Ag0.5Cu	1.39	3.15	8.14	52	215.4
F	4.0Ag0.5Cu	1.84	3.26	7.9	49	215.4
F	4.0Ag0.5Cu	1.52	3.25	8.14	52	215.4
F	4.0Ag0.5Cu	2.11	2.94	8.67	59	
F	4.0Ag0.5Cu	1.96	3.11	7.65	46	
F	3.0Ag0.5Cu	1.79	2.79	7.82	48	216
F	3.0Ag0.5Cu	1.89	2.84	7.82	48	216
F	3.0Ag0.5Cu	2.13	2.8	8.22	53	216
F	3.0Ag0.5Cu	2.12	3.09	7.31	42	
F	3.0Ag0.5Cu	1.96	3	8.14	52	
F	3.8Ag0.7Cu	1.77	2.99	7.65	46	216
F	3.8Ag0.7Cu	1.92	3.11	8.06	51	216
F	3.8Ag0.7Cu	1.56	3.06	7.49	44	216
F	3.8Ag0.7Cu	2	3.03	8.37	55	
F	3.8Ag0.7Cu	1.65	3.04	7.74	47	

COMPANY G - DATA TABLE

Company	Alloy	Solderability		Spread Test		Melt Point
		Zero Cross	Fmax	Diameter	Area	DSC
G	4.0Ag0.5Cu	0.53	0.64	6.46		219
G	4.0Ag0.5Cu	0.58	0.68	5.76		219
G	4.0Ag0.5Cu	0.43	0.68	5.8		219
G	4.0Ag0.5Cu	0.48	0.67	5.73		
G	4.0Ag0.5Cu	0.5	0.67	5.98		
G	4.0Ag0.5Cu			5.76		
G	4.0Ag0.5Cu			6.03		
G	3.0Ag0.5Cu	0.44	0.62	6.05		222
G	3.0Ag0.5Cu	0.44	0.63	6.14		222
G	3.0Ag0.5Cu	0.42	0.62	6.2		223
G	3.0Ag0.5Cu	0.38	0.64	5.96		
G	3.0Ag0.5Cu	0.48	0.6	6.09		
G	3.0Ag0.5Cu			6.09		
G	3.0Ag0.5Cu			6.08		
G	3.8Ag0.7Cu	0.54	0.67	5.6		220
G	3.8Ag0.7Cu	0.42	0.67	5.86		220
G	3.8Ag0.7Cu	0.44	0.65	5.91		221
G	3.8Ag0.7Cu	0.5	0.61	6.33		
G	3.8Ag0.7Cu	0.56	0.62	6.33		
G	3.8Ag0.7Cu			6.33		

**Appendix 2 - IPC-TM-650, 2.4.14.2
Liquid Flux Activity Wetting
Balance Method, Using Flux
Defined in J-STD-003A, 3.2.2.**



IPC-TM-650 TEST METHODS MANUAL

Number 2.4.14.2	
Subject Liquid Flux Activity, Wetting Balance Method	
Date 1/95	Revision
Originating Task Group Flux Specifications Task Group (5-24a)	

1.0 Scope This test prescribes the recommended test method for assessing the activity of liquid fluxes using a wetting balance.

2.0 Applicable Documents

ISO 1634

3.0 Test Specimen

3.1 The test specimen shall be a copper coupon complying with ISO 1634-CU-ETP Condition HA. The width shall be 6.0 ±0.25 mm wide; the length should be 25.0 ± 1 mm long or as appropriate to the test equipment. The thickness shall be 0.5 ±0.05 mm.

4.0 Apparatus and Reagents

4.1 Apparatus

4.1 A meniscus force measuring device (wetting balance) which includes a temperature-controlled solder pot containing solder maintained at 245 ±3°C. *Note:* Reaction rate is very sensitive at this temperature.

Solder composition shall be Sn60/Pb40 or Sn63/Pb37.

4.2 A chart recorder, data logger, or computer capable of recording force as a function of time with a minimum recorder speed of 10 mm/s.

4.3 A mechanical dipping device as shown in Figure 1 shall be used. This device shall be present to produce an immersion and emersion rate of 20–25 mm per second to a depth of 6.0 ±0.1 mm and a dwell time of 5.0 ±0.5 seconds.

5.0 Procedure

5.1 Preparation

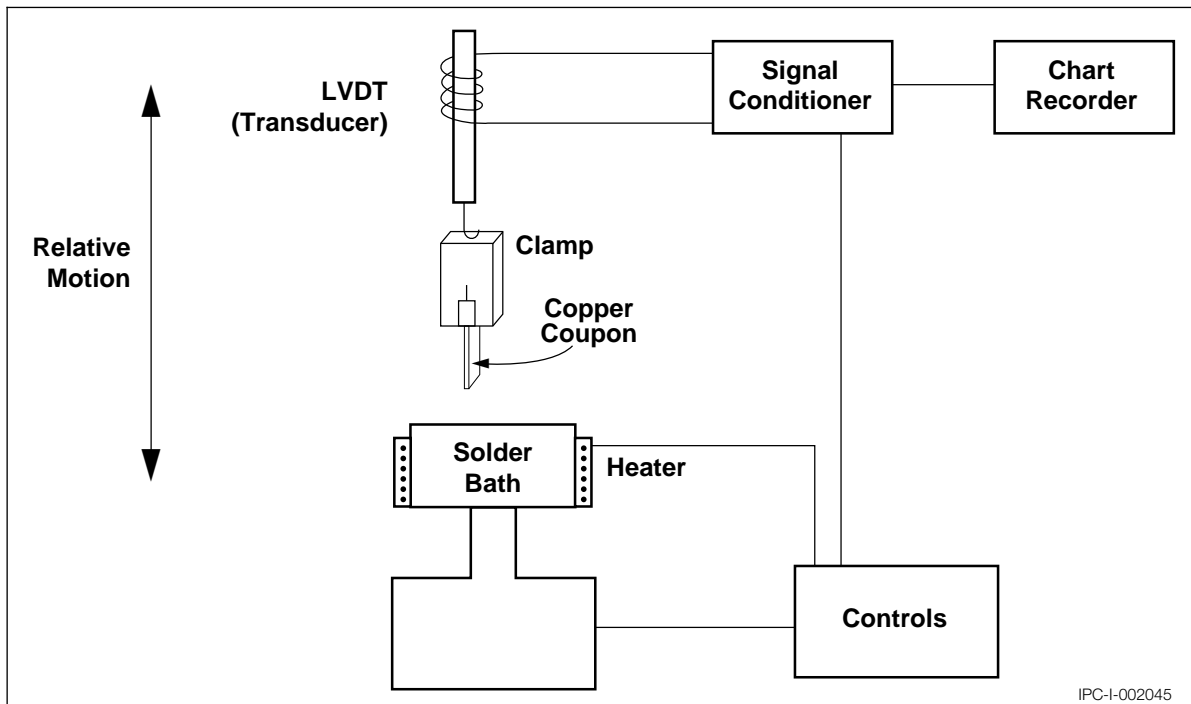


Figure 1 Wetting Balance Apparatus

IPC-TM-650		
Number 2.4.14.2	Subject Liquid Flux Activity, Wetting Balance Method	Date 1/95
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5.1.1 The test coupon should be cleaned (degreased) by immersion in a suitable solvent, then cleaned using a 10±1% fluoroboric acid dip.

5.1.2 The coupon shall then be washed with water and dried.

5.2 Test

5.2.1 After mounting the specimen in a suitable holder, the coupon should be immersed in the liquid flux at room temperature to a minimum depth of 10 mm.

5.2.2 Excess flux is to be immediately drained off by standing the specimen vertically on a clean filter paper for 1–5 seconds.

5.2.3 After partial drying, it should be mounted in the test equipment.

5.2.4 The surface of the molten solder shall be skimmed just prior to immersing the specimen in the solder.

5.2.5 The specimen in its holder shall be held for approximately 10±1 second, 3 mm above the solder pot. The test shall be started and the specimen immersed only once using an immersion and emersion rate of 20–25 mm per second to a depth of 5.0 ±0.1 mm and a dwell time of 5.0 ±0.5 seconds.

5.2.6 During the test, the wetting curve shall be recorded on a suitable device for use in the evaluation.

5.3 Evaluation Using the coupon as specified, fluxes which shall be evaluated for the following:

1. A wetting time (Tw) for the wetting curve to cross the corrected zero axis after the start of the test. (See Figure 2)
2. A maximum wetting force, Fmax, taken after correction for buoyancy (See 6.2).

6.0 Note This test method can be useful in requalifying materials that have exceeded the recommended shelf life. In addition, the method can help evaluate fluxing power prior to manufacturing operations on critical applications.

6.1 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.

6.2 Correction for Buoyancy For the wetting balance to obtain wetting force values that are relatable to one another, it is necessary to correct for the variability in specimen sizes, in particular width and thickness. This is done by correcting for the volume of the sample immersed in the solder. The following formula may be used to calculate the buoyant force correction:

$$P_b = \rho gV$$

- ρ = Density of solder @ 245°C (8.15g/cm³)*
- g = Acceleration of gravity (9810 mm/s²)
- V = Immersed volume of coupon (cm³)
= width x thickness x immersion depth

When the buoyancy force is calculated it should be used to correct the zero axis. This correction is required to obtain both the proper measurement of wetting times as well as wetting forces. All measurements of wetting times and wetting forces must be made from the corrected zero axis. In the case of an upright curve, the new corrected zero axis will be below the instrument zero.

*For Sn60/Pb40 Alloy

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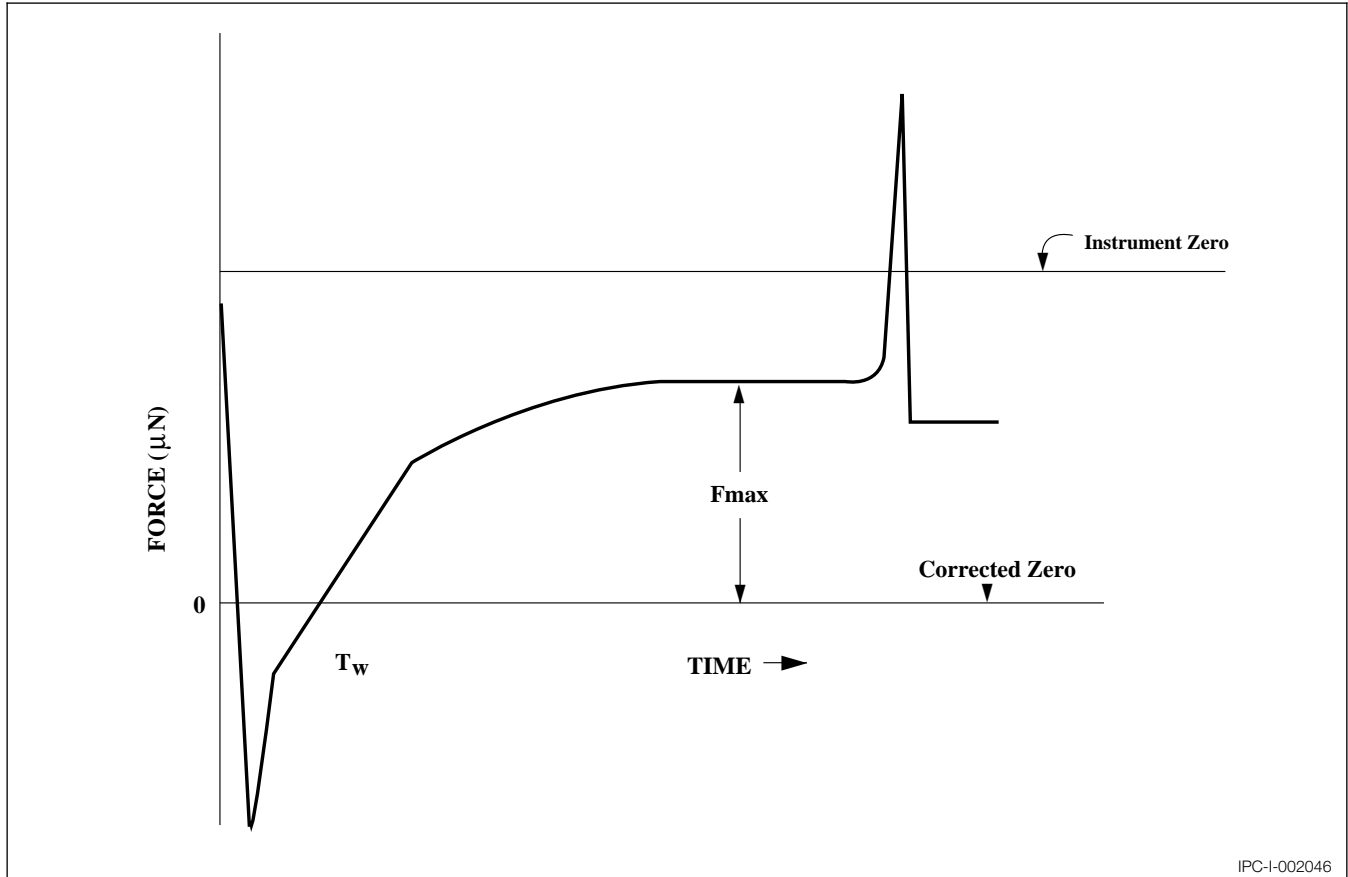


Figure 2 Wetting Balance Curve

Note: The vertical force measured by the wetting balance is made up from two forces—the buoyancy force, and the wetting force caused by the contact angle changing from initial non-wetting to wetting.

The buoyancy force may be considered during the test, and is equal to the weight of the solder displaced, when the specimen is immersed into the solder.

The only changing force is the wetting force, caused by the changing contact angle, as the specimen solders.

The corrected zero (buoyancy) line is the force when the contact angle is 90°, or when the bath surface has returned to horizontal, having been initially depressed by the immersed sample.

The wetting balance curve is centered on the corrected zero (buoyancy) line since the only parameter that changes during the test is the contact angle. θ . See equation 1:

$$F = \gamma \rho \cos \theta - g \rho v \quad \text{Equation 1}$$

$$\text{Buoyancy} = g \rho v \quad \text{Equation 2}$$

where

F = The measured force in micronewtons

γ = Surface tension of molten solder (400 $\mu\text{N mm}^{-1}$)

ρ = Specimen perimeter in mm

θ = Contact angle

g = Gravitational acceleration ($9.81 \times 10^{-3} \text{ mm—sec}^{-2}$)

ρ = Solder density (8000 $\mu\text{g mm}^{-3}$)

v = immersed volume in mm^3

The corrected zero line (buoyancy) is a fixed reference point from which the force measurements should be taken. This line should also be used as a reference point for any time measurements.

Altering the specimen dimensions changes the immersed volume and hence the buoyancy, and so alters the position of the corrected zero line; but the wetting curve still remains centered on this line. Similarly, any change in immersion depth will also alter the immersed volume, with the same effect on the buoyancy.

Although use of the corrected zero line will cancel small variations in the specimen immersed volume and the immersion depth, large changes will affect the rate of heat transfer into the specimen, which will affect both T_w , the time to recross the corrected zero (buoyancy) line and the time to reach F max.

**Appendix 3 - IPC-TM-650, 2.4.46,
Spread Test, Liquid or Extracted
Solder Flux, Solder Paste and
Extracted Cored Wires or Preforms**



IPC-TM-650 TEST METHODS MANUAL

1.0 Scope This test method will give an indication of activity of wave solder fluxes, core solder fluxes, and solder paste.

2.0 Applicable Documents

ASTM B-36 Brass Plate, Sheet, Strip, and Rolled Bar

J-STD-006 Requirements for Solder Wire

3.0 Test Specimen

3.1 A minimum of 10 ml of first article or production specimen of liquid flux furnished in a new clean glass container.

3.2 For paste flux and solder paste flux 10 ml of the diluted material (35%).

3.3 For preform and cored wire 10 ml of the extracted material.

4.0 Apparatus and Reagents

4.1 Five (5) replicates of 0.25 mm thick 70/30 brass (per ASTM-B-36 C2600 HO2) approximately 40 x 75 mm.

4.2 Degreased steel wool #00.

4.3 Sn60 1.5 mm diameter Type S solid wire solder per J-STD-006.

4.4 Solder pot containing at least 2 kg of solder and no less than 25 mm in depth.

5.0 Test

5.1 Specimen Preparation

5.1.1 Clean five (5) brass coupons with steel wool.

5.1.2 Using a flat strip of brass, bend the opposite ends parallel to the curve of the metal coil to stiffen and flatten the test coupon.

5.1.3 Cut a 30 mm length of solid wire solder

5.1.4 Wrap the cut length of solder around a 3 mm mandrel.

Number 2.4.46	
Subject Spread Test, Liquid or Extracted Solder Flux, Solder Paste and Extracted Cored Wires or Preforms	
Date 1/95	Revision
Originating Task Group Flux Specifications Task Group (5-24a)	

5.1.5 Cut the coil into individual rings to make a preform of the solder.

5.2 Test

5.2.1 Maintain solder pot at 260 +/-10°C.

5.2.2 Place the preformed solder in the center of the test coupon.

5.2.3 Place one drop (0.05ml) of flux in center of preform on the test coupon.

5.2.4 Carefully place the coupon on the surface of the solder bath for 15 seconds.

5.2.5 Remove the coupon in a horizontal position and place on a flat surface allowing the adhered solder to solidify undisturbed.

5.2.6 Remove all flux residue with a suitable solvent.

5.3 Evaluation

5.3.1 Measure the solder spread area by comparing to circles (pre-drawn) with areas similar to those listed in Table 1. The mean of the spread of all five samples tested is to be reported.

Table 1 Typical Spread Areas Defined in mm²

Diameter in mm	Area in mm ²
10.00	78.54
10.70	90.00
11.28	100.00

Table 1 is intended as an aid in defining areas in mm².

6.0 Notes

6.1 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.