002C/003B TASK GROUP

Designed Experiment For
Pb-Free Solderability Test Parameters
September 2004

Table of Contents

002C/003B TASK GROUP

Designed Experiment For
Pb-Free Solderability Test Parameters
September 2004

1. **Statement of problem**
   1.1. *Determine/develop/investigate a set of solderability test parameters for Pb-free soldering for inclusion into the J-STD-002C specification revision.*

2. **Objective of experiment**
   2.1. *Determine/Develop solderability parameters*
      2.1.1. Solder Alloy
      2.1.2. Flux Activity
      2.1.3. Solder Temperature
      2.1.4. Sample Condition

   2.2. *Evaluation Methods*
      2.2.1. Dip & Look visual inspection
      2.2.2. Wetting Balance measurements
         2.2.2.1. Globule method
         2.2.2.2. Bath method

3. **Schedule**
   3.1. *Completed Tasks*
      3.1.1. Develop Plan: Feb 25, 2004
      3.1.2. Obtain specimens: Mar 30, 2004
      3.1.3. Pre-test conditioning: May 1, 2004
      3.1.4. Distribute Specimens: September 16, 2004
      3.1.5. Start Testing Specimens: September 20, 2004

3.2. Scheduled Tasks

3.2.1. Send in test data: December 22, 2004

3.2.2. Analyze data: January 2005

3.2.3. Group review of Data: February 2005

3.2.4. Task Group Review: February 2005

3.2.5. Vote on ballot/specification: March 2005

3.2.6. Coordinate Working Draft with EIA/JEDEC/IEC: April 2005

3.2.7. Specification Revision complete: June 2005

4. Test Specimens

4.1. Component surface finishes:

4.1.1. Plated copper 1 cm2 foil coupon (control)

4.1.2. Au/Pd/Ni

4.1.3. Matte Tin

4.1.4. Sn/Pb (85/15)

4.1.5. Si/Ni/Cu

4.2. Board surface finishes:

4.2.1. HASL

4.2.2. Electroless nickel/Immersion gold (ENIG)

4.2.3. Immersion silver

4.2.4. Immersion tin

4.2.5. OSP

4.3. Component suppliers:

4.3.1. Photocircuits: Plated copper ~1cm^2 foil coupons (control)

4.3.2. Texas Instruments: SOIC 14, 16, 20 (Au/Pd/Ni)

4.3.3. Kemet 0805 tantalum capacitors (Matte tin)

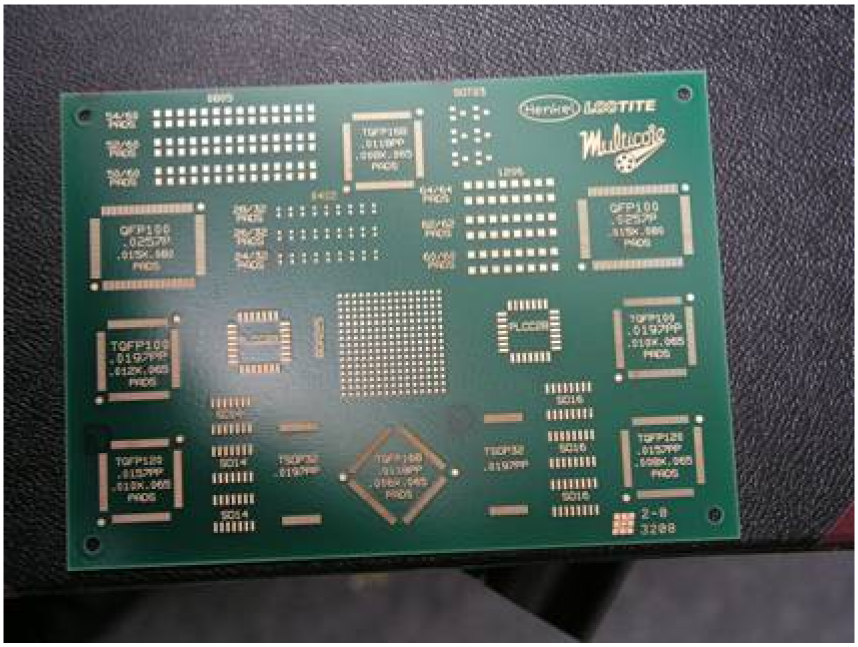
4.3.4. TDK: 0805 capacitors (Sn/Ni.Cu)

4.3.5. Intersil: SOIC 14 (Matte tin & Sn-Pb)

4.3.6. Allegro: TSSOP 8 (Matte tin - “marginal” & “control”)

4.4. Assembly Supplier:

4.4.1. Henkel Loctite: Test Vehicle



5. Test Locations

5.1. Component Testers

5.1.1. Dip and Look

5.1.1.1. Intersil

5.1.1.2. Collins

5.1.2. Wetting balance – Globule

5.1.2.1. RIM

5.1.2.2. Concoat

5.1.2.3. NPL

5.1.3. Wetting balance – bath method

5.1.3.1. Loctite

5.1.3.2. Concoat

5.1.3.3. Robisan

5.1.3.4. AVX

5.1.3.5. Texas Instrument

5.2. Board Testers

5.2.1. Wetting Balance – Globule

5.2.1.1. Concoat and NPL

5.2.1.2. Metronolec

5.2.1.3. RIM

5.2.1.4. Loctite

5.2.2. Wetting Balance – bath method

5.2.2.1. Photocircuits

5.2.2.2. Concoat and NPL

5.2.2.3. Loctite

5.2.3. Dip and Look

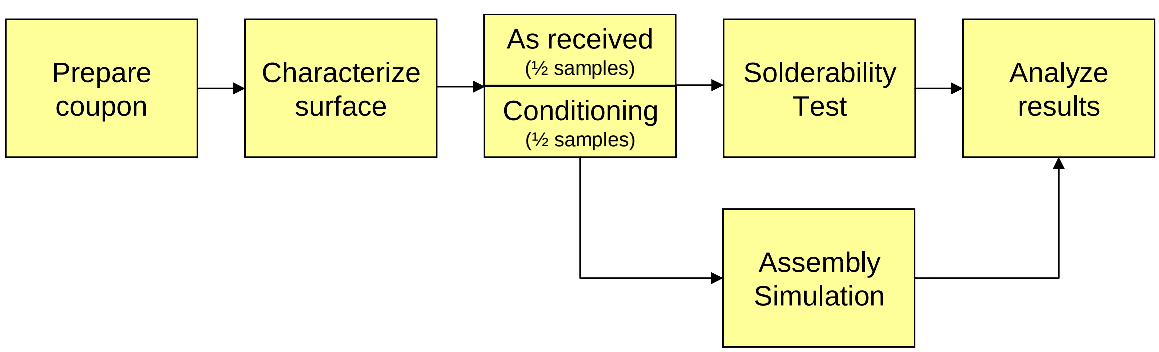
5.2.3.1. Collins

5.2.3.2. Robisan

5.3. Vehicle Assembly

5.3.1. Collins

6. Process flow



7. Response variables

7.1. Table 1 shows measurements to be recorded during the experiment.

Table 1 Response Variables

	Response Variable	Type	Anticipated Range	Measurement Equipment*
1	Force at 2 seconds	Quantitative	-300 to +400 µN/mm	Wetting balance
2	Time to 2/3 max	Quantitative	2 to 5 seconds	Wetting balance
3	Time to zero force (buoyancy corrected)	Quantitative	0.25 to 3 seconds	Wetting balance
4	Max force	Quantitative	-300 to +400	Wetting balance
5	Visual	Qualitative	0 to 100 percent	Microscope

* Use equipment that is evaluated using normal calibration procedures. Also verify wetting balance operation with a copper foil coupon specimen for each tester per method (in the procedure)

8. Input Variables

8.1. Table 2 shows input variables to be included in the experiment.

Table 2 Input Variables

	Variable	Levels
1	Solder	Sn 63, SAC
2	Flux Activation	0.2%, 0.5%
3	Temperature*	235ºC, 245ºC, 255ºC
4	Conditioning	Conditioned, Unconditioned

* Some experimentation will investigate only two temperatures (235ºC and 255ºC)

8.2. Single-Point Test

8.2.1. Purpose: to test high temperature

8.2.2. Locations and Methods

8.2.2.1. RIM (Wetting Balance Globule)

8.2.2.2. NPL (Wetting Balance Globule)

8.2.2.3. Intersil (Dip and Look)

8.2.3. Components

8.2.3.1. Texas Instruments: SOIC 16 (Au/Pd/Ni)

8.2.3.2. Allegro: TSSOP 8 (Matte tin - “marginal” & “control”)

8.2.4. Parameters

8.2.4.1. Solder alloy: SAC

8.2.4.2. Flux: 0.5

8.2.4.3. Solder test temperature: 265ºC

8.2.4.4. Sample conditioning: As received versus conditioned

9. Experimental Design Strategy (Components)

9.1. Experimental Minimum Requirements (per experiment)

9.1.1. 3 test locations

9.1.2. 3 components

9.1.2.1. 12 replicates (Dip and look, wetting balance [globule])

9.1.2.2. 6 replicates (wetting balance [bath])

9.2. Implemented Designs

9.2.1. Full Factorial

9.2.2. D-Optimized (3 temperature levels)

9.2.3. D-Optimized (2 temperature levels)

9.3. Statement of Design

9.3.1. Ideally, each type of component would have been subjected to a full-factorial experiment with a large number of replicates. Unfortunately, there were too few of some types of components for such a rigorous experimental design. In order to achieve statistical tenability, each experiment will be replicated a minimum of twelve times and will be performed by at least three separate test locations. To maintain these requirements, partial-factorial designs have been applied to less plentiful component types. Two partial designs will be used: a D-Optimized experimental design with three temperature levels or a D-Optimized with two (15 or 11 runs, respectively, vs. 24 for a full-factorial). It is anticipated effects demonstrated by both the full- and partial-factorial experiments will be sufficiently similar to reasonably assume effects evident only in the full experiments will also be similar in the partial experiments.

9.3.2. Full randomization of the order of experiments was prohibitively difficult. It is expected all experiments involving one type of solder will proceed before the other experiments. It is also anticipated that experiments at the same temperature levels will be performed in “blocks”.

10. Standard Operating Procedures (Components)

10.1. Apparatus

10.1.1. Apparatus will be in accordance with IPC J-STD-002B, ¶4.2.1.1

10.1.2. Apparatus will be calibrated using control experiments prior to component experimentation

10.2. Copper Control Coupons

10.2.1. Control sample preparation

10.2.1.1. Using tweezers, coupon will be placed and swirled in acetone for 30 seconds.

10.2.1.2. Coupon will be removed and "patted dry" on a paper towel.

10.2.1.3. Coupon will be placed in a 20% v/v nitric acid solution and swirled for 30 seconds.

10.2.1.4. Coupon will be removed from acid, then placed and swirled in DI water for 30 seconds.

10.2.1.5. Coupon will be patted dry with paper towel.

10.2.2. Control Experiment

10.2.2.1. Levels

10.2.2.1.1. 0.2% Flux Activation

10.2.2.1.2. Sn63 Solder

10.2.2.1.3. 245ºC Solder Temperature

10.2.2.2. Control Procedures

10.2.2.2.1. Flux procedures shall follow experimental procedures (¶ 9.4.1)

10.2.2.2.2. Dip and Look

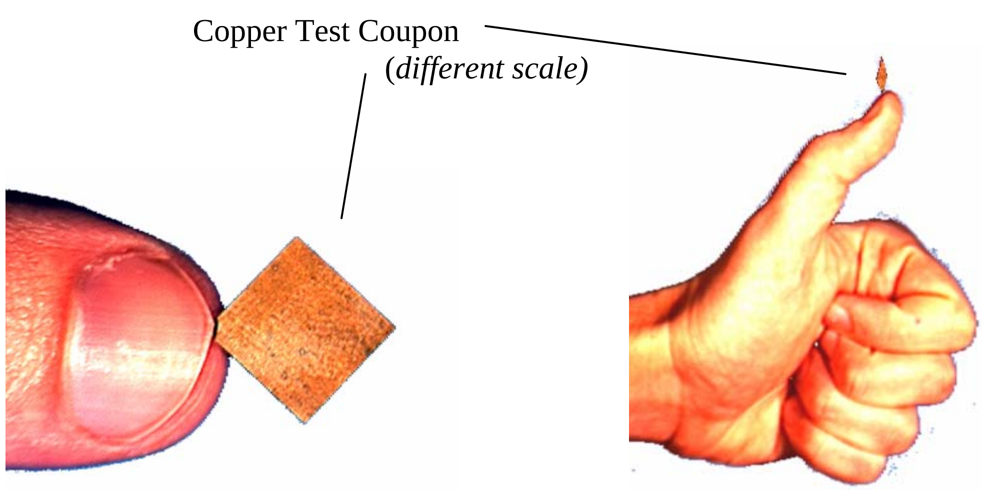
- 10.2.2.2.2.1. Shall follow experimental procedures (¶ 9.4.2)

10.2.2.2.3. Wetting Balance (globule)

- 10.2.2.2.3.1. 4mm \ 200mg globule
- 10.2.2.2.3.2. Clip 4
- 10.2.2.2.3.3. 0.2mm immersion depth
- 10.2.2.2.3.4. 45º immersion angle
- 10.2.2.2.3.5. 1.0mm/sec immersion speed

10.2.2.2.4. Wetting Balance (bath)

- 10.2.2.2.4.1. Clip 20
- 10.2.2.2.4.2. Depth 3.0mm immersion depth
- 10.2.2.2.4.3. 90º immersion angle
- 10.2.2.2.4.4. 20mm/sec immersion speed



10.3. Component Preparation

10.3.1. Randomization

10.3.1.1. Each component type was “poured” into a pile.

10.3.1.2. Pile was divided into smaller piles.

10.3.1.3. Piles were rearranged.

10.3.1.4. Piles were recombined.

10.3.1.5. Division, rearrangement, recombination done numerous (5-10) times

10.3.2. Conditioning

10.3.2.1. Temperature: 150ºC

10.3.2.2. Time: 12 hours

10.3.2.3. Components conditioned in stainless steel trays

10.3.2.4. Components conditioned leads-up (“dead-bugged”)

10.3.2.5. All conditioning performed at same time

10.3.2.6. All conditioning performed in same oven.

10.3.2.7. Conditioning oven remained closed during conditioning.

10.3.2.8. Conditioned components stored in sealed nitrogen back-filled sealed Kapak bags.

10.4. Experimental Procedures

10.4.1. Flux

10.4.1.1. Maintenance

10.4.1.1.1. Shall be covered when not in use

10.4.1.1.2. Total exposure to air shall be limited to 30 minutes

10.4.1.2. Application

10.4.1.2.1. Dip and Look

10.4.1.2.1.1. Surfaces to be tested shall be immersed for 5-10 seconds

10.4.1.2.1.2. Droplets of flux shall be removed by blotting

10.4.1.2.2. Wetting Balance

10.4.1.2.2.1. Surfaces to be tested shall be coated with flux using a cotton swab

10.4.1.2.3. Applied uniformly, necessary to cover surfaces to be tested

10.4.1.2.4. Fluxed surfaces shall be allowed to dry for 5 to 20 seconds prior to immersion

10.4.2. Dip-and-Look

10.4.2.1. Dross and burned flux shall be skimmed from the surface of the molten solder immediately before dipping.

10.4.2.2. Immersion Depth

10.4.2.2.1. Surfaces to be tested shall be immersed a minimum of 3mm beneath solder surface

10.4.2.3. Immersion Speed

10.4.2.3.1. Immerse and withdraw the specimen in the solder at 25 ± 6mm per second

10.4.2.4. Immersion Angle

10.4.2.4.1. 90º (leaded components).

10.4.2.4.2. 20º and 45º (nonleaded components)

10.4.3. Wetting Balance (Globule)

10.4.3.1. Clips

10.4.3.1.1. Clip 8 (8-14 leaded components)

10.4.3.1.2. Clip 9 (16-20 leaded components)

10.4.3.1.3. Clip 30 (0805 capacitors)

10.4.3.2. Globule / Pellet

10.4.3.2.1. 4mm Globule, 200mg pellet (leaded components)

10.4.3.2.2. 2mm Globule, 25mg pellet (nonleaded components)

10.4.3.3. Immersion Depth

10.4.3.3.1. 0.2mm (4mm globule)

10.4.3.3.2. 0.04mm (2mm globule)

10.4.3.4. Immersion Speed

10.4.3.4.1. 1.0 mm/sec (4mm globule)

10.4.3.4.2. 0.2 mm/sec (2mm globule)

10.4.3.5. Immersion Angle

10.4.3.5.1. 45º (4mm globule)

10.4.3.5.2. 90º (2mm globule)

10.4.4. Wetting Balance (Bath)

10.4.4.1. Clip

10.4.4.1.1. Clip 8 (8-14 leaded components)

10.4.4.1.2. Clip 9 (16-20 leaded components)

10.4.4.1.3. Clip 30 (0805 capacitors)

10.4.4.2. Immersion Depth

10.4.4.2.1. 0.2mm (leaded components

10.4.4.2.2. 0.1mm (0805 capacitors)

10.4.4.3. Immersion Speed

10.4.4.3.1. 1.0 mm/sec

10.4.4.4. Immersion Angle

10.4.4.4.1. 45º (leaded components)

10.4.4.4.2. 90º (0805 capacitors)

10.5. Data Transfer

10.5.1. Spreadsheets

10.5.1.1. Collins shall provide each test location with an Xcell spreadsheet unique to that locations' experiments

10.5.1.2. Spreadsheet will have a separate row for each replicate

10.5.1.3. Each spreadsheet row will include details for that replicate

10.5.1.3.1. Component type for experiment

10.5.1.3.2. Unique numerical ID for replicate

10.5.1.3.3. Experiment number (of experiments for that location)

10.5.1.3.4. Replicate number (of replicates for that experiment)

10.5.1.3.5. Component Condition

10.5.1.3.6. Flux

10.5.1.3.7. Solder

10.5.1.3.8. Solder Temperature

10.5.1.4. Each spreadsheet row will include blanks for that replicate

10.5.1.4.1. Date experiment was performed

10.5.1.4.2. Component-lead group

10.5.1.4.3. Response variables

10.5.1.5. Spreadsheets shall be returned electronically to Collins as experimentation is completed

10.6. Data Collection

10.6.1. Wetting Balance

10.6.1.1. Response data shall be collected and stored electronically.

10.6.1.2. Date of experiment shall be recorded either manually or as part of electronic data collection

10.6.1.3. Component-lead grouping shall be recorded either manually or as part of electronic data collection

10.6.1.4. Collected data shall be manually or electronically transferred to Xcell spreadsheet

10.6.2. Dip and Look

10.6.2.1. Examination shall be performed at 10x magnification

10.6.2.2. Date of experiment shall be manually recorded

10.6.2.3. Component-lead grouping shall be manually recorded

10.6.2.4. Response data shall be manually recorded

10.6.2.5. Collected data shall be transferred to Xcell spreadsheet

11. Assembly Specimen Preparation

11.1. Get assembly specimen physical dimensions from Brian Toleno Loctite

11.2. Assembly Specimen surface finish shall be immersion silver and OSP.

11.3. See Figure in paragraph 4.4.1 for the Assembly Specimen illustration.

11.4. Dave Hillman Collins to list assembly process info.

11.5. Inspect specimens to J-STD-001, Class 3.

11.6. If anomalies occur, distinguish between problems with lead and land wetting.

Appendix A

Components, Suppliers, Abbreviations, and Finishes

Component	Supplier	Abbreviation	Finish
0805 Capacitors	TDK	TDK	Sn-Ni-Cu
0805 Tantalum Capacitors	Kemet	K	Matte Tin
14-lead SOIC	Intersil	IA	Matte Tin
14-lead SOIC	Intersil	IB	Tin-Lead
14-lead SOIC	Texas Instrument	TIC	Ni-Pd-Au
16-lead SOIC	Texas Instrument	TIB	Ni-Pd-Au
20-lead SOIC	Texas Instrument	TIA	Ni-Pd-Au
8-lead TSSOP*	Allegro	AA	Matte Tin
8-lead TSSOP	Allegro	AB	Matte Tin

*manufacturer indicated "poor solderability"

Appendix B

Components and their Experimental Designs

Component Abbreviation	Experimental Design	Number of Experiments	Number of Replicates*
AA	Nonlinear Full Factorial	24	12 \ 6
AB	Nonlinear Full Factorial	24	12
IA	Linear D-Optimal	11	48 \ 12
IB	Nonlinear Full Factorial	24	24 \ 6
K	Linear D-Optimal	11	12
TDK	Nonlinear D-Optimal	15	12
TIA	Linear D-Optimal	11	30 \ 6
TIB	Nonlinear Full Factorial	24	24
TIC	Nonlinear Full Factorial	24	24 \ 6

* Dip and Look, Wetting Balance (Globule) \ Wetting Balance (Bath)

Appendix C

Lab Assignments by Method and Lab

Dip and Look

AVX	AA	TDK	TIA	AB	
Collins	TIB	IB	IA	TIA	AA
Intersil*	AA	TIA	IA	TIB	AB
Robisan	IA	IB	TIA	TIC	TDK
Texas Instruments	TIB	IB	K	TIA	AB

Wetting Balance (Globule)

Concoat (globule)	AB	TIA	AA	IB	TDK	
NPL*	TIA	AB	AA	K	TIC	
RIM*	TDK	IA	TIC	TIA	IB	AB

Wetting Balance (Bath)

Concoat (bath)	TDK	TIC	K	TIA	IA
Loctitce	TIA	IA	K	AA	IB

*single point tester

Appendix D

Lab Assignments by Component

Component Abbreviation	Number of Locations	Locations
AA	6	a,b,c, f, g, h
AB	6	a, c, e, f, h, i
IA	6	b, c, d, f, g, i
IB	6	b, d, e, f, g, i
K	3	e, f, g
TDK	5	a, d, e, f, i
TIA	all	all
TIB	3	b, c, e
TIC	4	d, f, h, i

Location key			
a :	AVX	f :	Concoat
b :	Collins	g :	Loctitce
c :	Intersil	h :	NPL
d :	Robisan	i :	RIM
e :	Texas Instruments		