REFERENCES

1. Wassink, R. J. K. Soldering in Electronics. 2nd ed. England: Electrochemical Publication, 1994, 1-11.
2. Ishida, T. A vision of electronics in the 21st century. Journal of SMT 2000 (April 2000): 6-10.
3. Rocak, D.; Stopar, V.; and Plut, J. F. Solder paste for fine line printing in hybrid microelectronics. Microelectronic Journal 26 (1995): 441-447.
4. Thwaites, C. J. Soft-soldering handbook. 3rd ed. Middlesex: International Tin Research Institute, 1982, 7-11.
5. Wassink, R. J. K. Soldering in Electronics. 2nd ed. England: Electrochemical Publication, 1994, 204-262.
6. Prasad, R. P. Surface Mount Technology Principles and Practice, New York: Van Nostrand Reinhold, 1989, 311-347.
7. Japanese Standards Association. JIS Z 3282:1999(Soft solders-chemical composition and forms). Tokyo: Japanese Standard Association, 1999, 1-51.
8. Wassink, R. J. K. Soldering in Electronics. 2nd ed. England: Electrochemical Publication, 1994, 540-622.
9. Wassink, R. J. K. Soldering in Electronics. 2nd ed. England: Electrochemical Publication, 1994, 11-35.
10. NEC Electronic Corporation. Semiconductor device mount manual. NEC Electronic Corporation. Kanakawa[Online]. 1995-2004. Available from: http://www.necel.com/pkg/en/mount [2004, January 1].
11. Snyder, J. L .; and Johnson, P. D. "Process for the manufacture of metal joining paste", U.S. Patent 4,218,248, (1980).
12. Stayner, R. A.; and Lowe, W. "Wax-flux composition containing a succinimide salt of an alkylaryl sulfonic acid for soldering", U.S. Patent 3,954,494, (1976).
13. Cooper, R. N. "Flux for use in soldering", U.S. Patent 4,151,015, (1979).
14. Snyder, J. L .; and Johnson, P. D. "Process for the manufacture of metal joining paste", U.S. Patent 4,218,248, (1980).
15. Mastrangelo, A.J. "Metal-joining paste and vehicle therefor", U.S. Patent 4,273,593, (1981).

16. Hasegawa, E.; and Kato, R. "Solder paste for electronic parts", U.S. Patent 4,740,252, (1988).

17. Goobich, J.; and Cronin, T. "RMA Solder Pate", U.S. Patent 5,064,482, (1991).

18. Davis, J.L.; Pennisi, P. W ; Nounou, F.; and Landreth, B. D. "Solder pastes using alcohol blends as rheological aids" ,U.S. Patent 4,995,921, (1991).

19. Degani, Y. "Solder paste", U.S. Patent 5,150,832, (1992).

20. Frazier, J.D. "Solder flux/paste compositions", U.S. Patent 5,118,364, (1992).

21. Lutz, K.; Baer, H. J.; Starz, K. A.; Leske, W.; and Mueller, H. "Screen-printable paste for manufacturing electrically conductive coatings", U.S. Patent 5,011,627, (1992).

22. Gomi, T.; Ota, H.; and Kaneko, K. "Additive for fluxes and soldering soldering pastes", U.S. Patent 5,127,968, (1992).

23. Takemoto, M.; Onishi, T.; and Aihara, M. "Soldering flux composition", U.S. Patent 5,211,763, (1993).

24. Degani, Y. "Solder paste and method of using the same", U.S. Patent 5,211,764, (1993).

25. Qiao, X.; and Corbin, S.F. "Development of transient liquid phase sintered (TLPS) Sn-Bi solider paste"Materials Science and Engineering A, (2000), 283, 38-45.

26. Katsuoka, R.; Udono, N; Shibuya, T.; Sekiguchi, K.; and Matsui, K. "Flux composition", U.S. Patent 6,075,080, (2000).

27. Kubota, M.; Iha, M.; and Watanabe, S. "Paste composition, circuit board using the same, ceramic green sheet, ceramic substrate, and method for manufacturing ceramic multilayer substrate", U.S. Patent 6,183,669, (2001).

28. Currie, M.; Elyassi; A.; Freeman, G.; Warwick, M.; and Wilding, I. "Lead free solder paste", U.S. Patent 6,592,020, (2003).

29. Schneider, A. F. Alpha Metals, Inc. Understanding the flux requirements of J-STD-004 and its relationship to the soldering requirements of J-STD-001B. Cookson Electronics Assembly Materials: New Jersey [Online]. 2001-2003. Available from: http://www.alphametals.com/products/fluxes/PDF/jstd004.pdf=J-STD-004[2003, January 20].

30. Japanese Standards Association. JIS Z 3197:1999(Testing method for soldering flux). Tokyo: Japanese Standard Association, 1999.

31. The Institute for Interconnecting and Packaging Electronic Circuits. Paste Flux Viscosity - T-Bar Spindle Method: Solder Paste . Northbrook: The Institute for Interconnecting and Packaging Electronic Circuits, 1995.

32. The Institute for Interconnecting and Packaging Electronic Circuits. Solder Paste-Slump Test. Northbrook: The Institute for Interconnecting and Packaging Electronic Circuits, 1995.

33. The Institute for Interconnecting and Packaging Electronic Circuits. Corrosion, Flux. Northbrook: The Institute for Interconnecting and Packaging Electronic Circuits, 1995.

34. Japanese Standards Association. JIS Z 3284:1994(Solder paste). Tokyo: Japanese Standard Association, 1994, 1-44.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

APPENDICES

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

APPENDIX A

Flux classification

A.1 Quality classification of flux: JIS Z 3284

JIS Z 3284 classifies the flux in 3 types as shown in the table A.1.

Table A.1: classification of flux.[34]

Symbol	Activity	Chloride content of flux component	Electrical insulation,Ω		Copper Plate corrosion	Copper Mirror corrosion
			Condition A	Condition B		
I	Low	0.03 or under	$1x10^{11}$ min	$1x10^{11}$ min	No corrosion	No corrosion
II	Medium	Over 0.03 to and incl.0.1	$1x10^{11}$ min	$1x10^{11}$ min	No corrosion	-
III	High	Over 0.1 to and incl.0.5	$1x10^{11}$ min	$1x10^{11}$ min	No corrosion	-

A.2 Quality classification of flux: J-STD-004

J-STD-004 first divides all fluxes into 1 of 4 categories decided on the basis of composition. Each composition category is then subdivided into 1 of 6 flux activity levels according to the corrosive or conductive properties of the flux and flux residues. When the 4 composition categories and 6 activity levels are taken together, the result is 24 flux classifications.

The flux composition categories and their symbols are:

Rosin (RO)

Resin (RE)

Organic (OR)

Inorganic (IN)

Flux activity levels are determined by results for copper mirror testing, corrosion testing, surface insulation resistance (SIR) and halide content. The activity levels are;

L = Low or no flux/flux residue activity

M = Moderate flux/flux residue activity

H = High flux/flux residue activity

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Each of the three activity levels is further characterized using 0 or 1 to indicate the absence or presence of halide in the flux. This results in six flux types;

L0

L1

M0

M1

H0

H1

(1) The Institute for Interconnecting and Packaging Electronic Circuits

(2) Electronic Industries Association 3

Table A.2, taken from J-STD-004, lists the 4 composition categories in the 1st column, the 6 flux activity levels/flux types in the 2nd column and the resulting 24 flux classifications with their "flux designator" symbols in the 3rd column.4

Table A.2: Composition categories of flux[29]

Flux Materials of Composition	**Flux Activity Levels (% Halide)/Flux Type**	**Flux Designator**
ROSIN (RO)	Low (0%) L0	ROL0
	Low (<0.5%) L1	ROL1
	Moderate (0%) M0	ROM0
	Moderate (0.5-2.0%) M1	ROM1
	High (0 %) H0	ROH0
	High (>2.0%) H1	ROH1
RESIN (RE)	Low (0%) L0	REL0
	Low (<0.5%) L1	REL1
	Moderate (0%) M0	REM0
	Moderate (0.5-2.0%) M1	REM1
	High (0 %) H0	REH0
	High (>2.0%) H1	REH1
ORGANIC (OR)	Low (0%) L0	ORL0
	Low (<0.5%) L1	ORL1
	Moderate (0%) M0	ORM0
	Moderate (0.5-2.0%) M1	ORM1
	High (0 %) H0	ORH0
	High (>2.0%) H1	ORH1
INORGANIC (IN)	Low (0%) L0	INL0
	Low (<0.5%) L1	INL1
	Moderate (0%) M0	INM0
	Moderate (0.5-2.0%) M1	INM1
	High (0 %) H0	INH0
	High (>2.0%) H1	INH1

A ROL1 flux classification, for example, indicates a rosin flux, with a low activity level, containing halide at less than 0.5%. Most of the former Military type RMA fluxes conform to J-STD-004 classification ROL1. Many, if not most low solids no-clean wave solder fluxes are type ORM0, organic, moderate activity, without halides. Most water-soluble paste fluxes are type ORH0, organic, high activity, without halides. 5 Table A.3, taken from J-STD-004, lists the test requirements for establishing the flux activity levels/flux types. The actual table in J-STD-004 has 11 footnotes, which should be consulted for additional information.

Table A.3: Lists the test requirements for establishing the flux activity levels/flux types [29]

FLUX TYPE	COPPER MIRROR	QUALITATIVE HALIDE		QUANTITATIVE HALIDE	CORROSION TEST	CONDITIONS FOR PASSING 100 MEGHOM SIR REQUIREMENTS
		SILVER CORMATE (Cl, Br)	Spot Test (F)	(Cl, Br, F)		
L0	No evidence of minor break through	Pass	Pass	0.0%	No evidence of corrosion	Both cleaned and uncleaned
L1		Pass	Pass	<0.5%		
M0	Break through in less than 50% of test area	Pass	Pass	0.0%	Minor corrosion acceptable	Cleaned or uncleaned
M1		Fall	Fall	0.5 to 2.0%		
H0	Break through in more than 50% of test area	Pass	Pass	0.0%	Major corrosion acceptable	Cleaned
H1		Fall	Fall	>2.0%		

A.3 Flux selection

Section 6.3 of J-STD-004 draws an approximate analogy between L, M and H type fluxes and the "traditional" classes of rosin-based fluxes (R, RMA, RA and RSA), as well as water-soluble and synthetic activated fluxes, and the newer low solids "no-clean" flux types. These comparisons are reproduced in Table A.4 below. They do provide some help to the user in selecting somewhat equivalent flux types in J-STD-004 to what they may have been using according to other former flux classifications.

Table A.4 Draws an approximate analogy between L, M and H type fluxes and the "traditional" classes of rosin-based fluxes [29]

L0 Type Fluxes:	All R,
	Some RMA
	Some Law Solids "No-Clean"
L1 Type Fluxes:	Most RMA,
	Some RA
M0 Type Fluxes:	Some RA,
	Some Low Solids "No-Clean"
M1 Type Fluxes:	Most RA, Some RSA
H0 Types Fluxes:	Some Water Soluble
H1 Types Fluxes:	Some RSA,
	Most Water Soluble and Synthetic Activated

Other analogies can be made in addition to those presented in Table A.4 For example, some low solids "no-clean" fluxes are L1 Type and some water-soluble fluxes are M0 Type.

J-STD-001B (Requirements for Soldered Electrical and Electronic Assemblies) is the general standard covering materials, methods and verification criteria for producing quality soldered interconnections and assemblies. This standard establishes three general end-use product classes for electronic assemblies, based largely upon their functional performance requirements:

Class I - General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly, such as consumer electronic products.

Class II - Dedicated Service Electronic Products

Includes products where continued performance and extended life is required and for which uninterrupted service is desired, but not critical. Typically the end-use environment would not cause failures. Included here would typically be computers, industrial, telecommunications equipment and some automotive electronics.

Class III - High Performance Electronic Products

Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required. This would typically include Military weapon and defense systems, aerospace, life support systems and under-the-hood automotive electronics. The user has the responsibility to determine the class into which his electronic product belongs. There may be overlap of equipment

between classes. Section 4.2 of J-STD-001B covers flux requirements. The flux used must be in accordance with J-STD-004, however, little guidance is provided for selecting from among the 24 flux classifications. Only for Class III electronic assemblies are flux types specified, the requirement being fluxes conforming to activity levels L0 or L1 of flux materials rosin (R0), resin (RE) or organic (OR), except organic flux activity level L1 shall not be used for no-clean soldering. Other activity levels of flux materials may be used for Class III assemblies provided data-demonstrating compliance with the testing requirements of Appendix D of J-STD-001B is available. Appendix D testing includes surface insulation resistance (SIR) and visual inspection for corrosion, dendrite formation and mealing of conformal coating. It also includes optional resistivity of solvent extract (ROSE) and ion chromatography (IC) testing. No requirements or guidelines are provided for selecting suitable flux types for Class I and Class II assemblies, which, together, comprise the majority of all electrical and electronic products produced.

To assist users in selecting flux types per J-STD-004, the writer proposes the following table (Table A.5) of acceptable flux types. It takes into consideration the two most important factors of the electronic class of product being produced, i.e., end-use requirements and whether flux residues will be removed using a post solder cleaning process or whether a "no-clean" soldering process is intended.

Table A.5: Acceptable Flux Types[29]

Electronic Product Class	PROCESS WITH POST SOLDER CLEANING			NO-CLEAN SOLDERING PROCESS		
	Rosin (RO)	Resin (RE)	Organic (OR)	Rosin (RO)	Resin (RE)	Organic (OR)
I	L0, L1, M0, M1, H0, H1			L0,L1,M0,M1	L0,L1,M0,M1	L0,M0
II	L0, L1, M0, M1			L0,L1,M0	L0,L1,M0	L0,M0
III	L0, L1			L0,L1	L0,L1	L0

NOTE:

Other flux types may be used if testing has been conducted per Appendix D of J-STD-001B and data demonstrating material and process compatibility is available for review. For example, a large computer manufacturer (Electronic Product Class II) has successfully used an ORH1 flux type for many years. They have determined that the soldering and cleaning processes they use with their assemblies achieves acceptable levels of ionic cleanliness and electrical reliability. It can be seen that acceptable flux

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

types for Class III products in Table A.5 are identical to the requirements in J-STD-001B for Class III products. ORL1 fluxes are not permitted with no-clean processes because there is little or no rosin or resin present to encapsulate their potentially corrosive halide components. For Class II products, the table would allow all the flux types for Class III products, adding M0 and M1 types with post solder cleaning, but only M0 type with no-clean processing. For Class I products, the table would allow all the flux types for Class II and III products, adding H0 and H1 type with post solder cleaning and M1 rosin and resin types with no-clean processing. Inorganic fluxes are not recommended for electronic assembly applications.

The Table of Acceptable Flux Types has been formally proposed to the IPC Joint National Standard for Soldering Task Group. It is being considered for inclusion in the J-STD-001 Handbook being developed to assist users in implementing the Standard. It should be noted that the tests in J-STD-004 were originally developed for use with old technology fluxes. Some of the corrosion test methods do not readily lend themselves for use with the newer flux types such as "low solids no-clean" and "VOC-free". This is an area in need of further work by the IPC Flux Specifications Task Group. Finally, it should be mentioned that some flux users contact their suppliers inquiring as to what has replaced the Government's Qualified Products List (QPL) for fluxes? The answer is that there is no industry product listing authority. Flux suppliers can be contacted to obtain J-STD-004 classifications and test data for their specific flux products in all forms; liquid flux, paste flux, solder-paste flux, flux cored solder and solder-perform flux. Most users will accept J-STD-004 classification information from a reputable supplier. Some may elect to verify the information by conducting their own testing or contracting with an independent test laboratory to perform the work.[29]

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

APPENDIX B

Solder paste flux quality testing methods

B.1 Flux content test

Flux content was tested by take specimen of 30 $\pm$ 1 grams as W1 (g), measuring to the nearest 0.001 g, from evenly mixed solder paste and put it into a 100 ml beaker. Then 20 ml of glycerin was added and fused by heating. When solder and flux were separated completely, the beaker was left to cool down and solidify.

Next, the solidified solder was taken out from the beaker and washed it with water, and after immersing it in 2-propanol for about 5 minutes, then the sample was washed and dried it at room temperature. Then, the sample was measured the accurate mass of it as W2 (g) and calculated the flux content from the formula

$$F = \frac{W1-W2}{W1} \times 100$$

Where, F was flux content (wt%), W1 was the mass (g) of specimen prepared and W2 was the mass (g) of solidified solder.[30]

B.2 Viscosity test

I. The container of paste flux was placed in water bath at 25 $\pm$ 0.5°C.
II. When medium had attained thermal equilibrium, the container was placed under spindle so that it was at center of surface.
III. Then, the Brookfield was started at 5 revolutions per minute and started the helipath stand on descending.
IV. Two minutes after the spindle has cut into the top surface of the medium, the value was recorded. Check that spindle was not touching bottom of container.
V. The spindle was removed from the paste flux. the flux was stirred vigorously by spatula for 15 to 20 seconds and re-measured viscosity.
VI. The viscosities were calculated from the values recorded after 2

minutes of medium penetration.[31]

B.3 Tackiness Test as per Singapore Asahi method

The tackiness property of solder paste flux was tested by Singapore Asahi method. Homogenize the solder paste by hand stirring with spatula then apply a layer of solder paste of approximately 1 to 2 mm height onto half of slide. The slide was placed on top of a beaker and left in the room environment of 23 to 25 ^{O}C and 50 to 60 % RH. The tackiness was checked of the paste every hourly and rechecked 24 hours with spatula and also whether skinning occurred on the surface of the solder paste. The paste should be not had skinning or lost its tackiness within 24 hours after print.

B.4 Electric insulation resistance test

The surface insulation resistance tested by mega-ohmmeter. The solder paste was uniformly printed to the thickness of about 100 μm in thickness, which was machined in the slit shape at the electrode part of the overlap of the comb-shaped electrode to meet the electrode pattern. The coated test specimen was placed in a drier to be set to 150 ^{O}C for 2 min, and then, melted for 30 s on the hot plate to be maintained at 260 ^{O}C (capable of maintaining for 15 s or longer after the solder was melted) After it was left to be cooled as it was, the test piece was made. After the printing and reflowing, the test piece was checked for any adhesion of dusts or the like by using a magnifier, and remove them with a pair of tweezers or the like if any and keep the test specimen in the temperature at 40 $\pm$ 2 ^{O}C and relative humidity 60 % to 95 % 168 hours. Wiring the electrode should be executed by using the coaxial cable, and the insulation resistance between the terminals should be measured at the test voltage of DC 100 V by using an insulation tester before test piece was placed in a thermo hygrostat. The test piece should be placed in a clean thermo hygrostat to be set to meet the conditions as specified by paying attention that a coagulated drop may not fall on the comb-shaped pattern. The insulation resistance should be measured at DC 100 V in the condition where the test piece was placed in the thermo hygrostat at the time of 24 hours, 96 hours, and 168 hours after the test piece was placed in it. The measurement value should be read after one minute.[34]

B.5 Corrosion, Flux

1. The solder pot was heated so that solder bath stabilizes at 235 ±5°C.
2. One gram of solder paste was placed into the depression in the test panel.
3. Using tongs, lower each test panel onto the surface of the molten solder.
4. The test panel was allowed to remain in contact until solder specimen in the depression of the test panel melts. Maintain this position for 5 ±1 seconds.
5. Test specimen was carefully examined at 20X magnification for subsequent compare after humidity exposure. The observations was recorded, especially any discoloration.
6. The test panel was heated to 40 ±1°C for 30 ±2 minutes.
7. The humidity chamber was set to 40 ±1°C and 93 ±2%relative humidity.
8. Each test specimen was suspended vertically (and separately) in the humidity chamber.
9. The specimens were exposed to the above environment for 240 hours (10 days). M and H might be tested in the cleaned, as well as unclean, condition.
10. The specimens were carefully examined prior to placing them in the environmental chamber. Discoloration should be noted.
11. The tested specimens were moved after the appropriate exposure period, from humidity chamber, this specimens was examined at 20X magnification and compare with observations noted in paragraph
12. Corrosion was described as follows:

3.3.1.A.12.1Excrescences at the interfaces of the flux residue and copper boundary, or the residues or discontinuities in the residues.

3.3.1.A.12.2Discrete white or colored spots in the flux residues.[33]

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

B.6 Wetting effect and de-wetting test

1. The solder bath was set to the temperature of 235 $\pm$ 2 ^{O}C.
2. The solder paste was left as it was until the temperature of solder paste was reached to the room temperature.
3. The copper plate and the brass plate were cleaned with isopropyl alcohol.

4. The one side of the test plate was dipped in the water and polished with the polishing paper. The test plate was polished in one direction first, and then, in the direction orthogonal to the first direction.
5. The surface was wiped again with isopropyl alcohol.
6. The solder paste was stirred with spatula to make it uniform.
7. The metal mask was placed on the surface of the plate with in one hour after the surface was polished.
8. The solder paste was coated cover the holes of the metal mask completely by using the spatula as a squeegee.
9. The metal mask was removed from the substrate.
10. The paste coated test plate was dried for one minute at the temperature of 150 ^{O}C in the air circulating type drier when the pre-drying was specified.
11. The surface of the solder bath was cleaned with the scraper.
12. The test piece that's the surface coated with the solder paste was placed horizontally, and heated it on the solder bath so that the molten solder and the substrate might be thermally contacted with each other sufficiently.
13. The substrate was taken in the horizontal position until the solder on the substrate was melted.
14. The substrate was cooled in the substrate in the horizontal position until the solder on the substrate was settled.
15. The degree of spread was checked. As shown in the table B.1

Table B.1 The degree of spread

Classification of the degree of spread	Condition of spread
1	Condition where the solder dissolved from the solder paste wets the test plate, and the wetted area becomes larger than the past-coated area.
2	Condition where all of coated part by the solder paste was wetted.
3	Condition where almost all the solder paste-coated part was wetted by the solder (including the de-wetted)
4	Condition where no solder seemed wetted, and the molten solder becomes one or more solder balls (non-wetting)

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Remark:

1. The solder might be sometimes expanded to the outward of the major spread area along the file groove due to the capillary effect on the brass plate. This excessive spread had no luster, and need not be evaluated.
2. A small solder ball might be found. This shows that the degree of the reflow was insufficient, and need not be evaluated.
3. The temperature of the solder bath was set to 235 $\pm$ 2 ^{O}C, taking into consideration the use of eutectic solder. For other alloy than the eutectic solder, the temperature of the solder bath was set higher then the liquidus temperature of the alloy by 50 $\pm$ 2 ^{O}C. When VSP was used, the test temperature shall be set to 215 $\pm$ 2 ^{O}C.[34]

B.7 Slump test as per Singapore Asahi method

Slump was tested by specimen preparation using the stencil 76 mm x 25mm x 0.2 mm. Deposited solder paste pattern should be uniform in thickness with no solder particles separated from the pads. One test specimen should be marked # 1 and one specimen as # 2. Specimen #1 should be stored for 10 to 20 minutes at 25$\pm$ 5 ^{O}C and 50 $\pm$ 10 % relative humidity and examined for slump and specimen # 2 should be heated to 150 $\pm$ 10 ^{O}C for 10 to 15 minutes, cooled to ambient and examined for slump. Percentage of slump was calculated from

$$\% \text{ Slump} = \frac{D_H - D_I}{D_I} \times 100$$

Where

D_H was average diameter of solder paste after heating.

D_I was average diameter of solder paste before heating.[30]

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

VITA

Miss Kanlaya Phaphon was born on September 1, 1977. She received her
r's Degree of Science in Chemistry from Faculty of Science, Chulalongkorn
ity in 1999. She began her Master study in the program of Petrochemistry and
Science, Faculty of Science, Chulalongkorn University in 2002, and
ed the program in 2004.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย