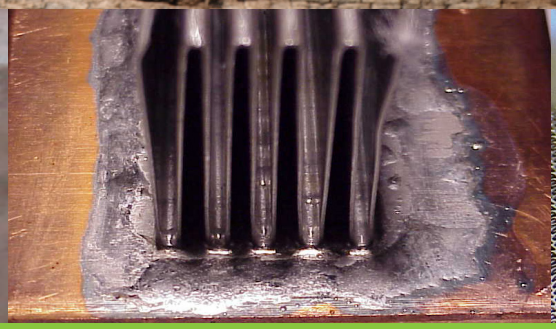
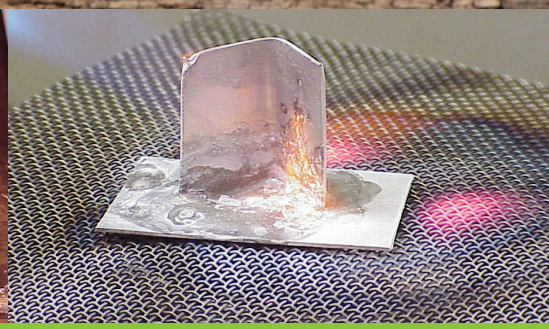
ALUMINUM SOLDERING

Handbook









The Aluminum Association

About the Aluminum Association

The Aluminum Association based in Arlington, Virginia, works globally to aggressively promote aluminum as the most sustainable and recyclable automotive, packaging and construction material in today's market. The Association represents U.S. and foreign-based primary producers of aluminum, aluminum recyclers and producers of fabricated products, as well as industry suppliers. Member companies operate approximately 180 plants in the United States with many conducting business worldwide.

Notice/Disclaimer

The use of any information contained herein by any member or non-member of The Aluminum Association is entirely voluntary. The Aluminum Association has used its best efforts in compiling the information contained in this book. While the Association believes that its compilation procedures are reliable, neither the Association nor its member companies warrant, either expressly or impliedly the accuracy or completeness of this information, or that it is fit for any particular purpose. The Aluminum Association and its member companies assume no responsibility or liability for the use of the information herein.

The Aluminum Association provides information and resources about aluminum products and aluminum-related technology as a service to interested parties. Information provided by the Aluminum Association is generally intended for users with a technical background and may be inappropriate for use by laypersons.

All Aluminum Association published standards, data specifications and other technical materials, including this book, may be reviewed and revised, reaffirmed or withdrawn without prior notice. Users are advised to contact the Aluminum Association to ascertain whether the information in this book has been superseded in the interim between publication and use.

ALUMINUM SOLDERING HANDBOOK

6th Edition
February 2017

Library of Congress Catalog Number 74-173196

The Aluminum Association
1400 Crystal Dr. Suite 430
Arlington, VA 22202

Acknowledgement

The Aluminum Association gratefully acknowledges the contribution of Superior Flux & Mfg. Co., Mr. William Avery and Dr. Yehuda Baskin, for their generous contribution to this revision.

USE OF THIS INFORMATION

Any data and information contained in this paper were compiled and/ or developed by the Aluminum Association, Inc. In the view of the variety of conditions and methods of use to which such data and information may be applied, the Aluminum Association and its member companies assume no responsibility or liability for the use of information contained herein. Neither the Aluminum Association nor any of its member companies give warranties, express or implied, with respect to this information.

Foreword

The principles underlying soldering of aluminum are identical to those that make metallurgical bonding of other metals possible. After aluminum's tough protective oxide coating is removed, the soldering of aluminum proceeds along lines similar to those used with other metals, utilizing essentially the same techniques and equipment. But, it is precisely the difficulty in removing aluminum's protective oxide coating that makes soldering of the metal challenging. This is why the role of cleaners and fluxes is so important in the aluminum soldering process.

Properly made, aluminum joints are long lasting, gas tight and strong. Depending on the solder chosen, aluminum joints can be as strong as the metal joined. When tested, these joints fail at the base metal.

Aluminum is joined by soldering when many joints are to be made simultaneously and economically; when nearby material precludes the higher heats of brazing and welding; when component distortion must be avoided; when temper loss is to be held to a minimum; when equipment investment funds are limited; and when rapid field repairs with hand-held tools are needed.

Soldered aluminum joints are widely used in spacecraft, electronics, electrical power plants and power lines, household goods, refrigeration systems and air conditioning. The list of current and future solder applications is virtually endless.

© Copyright 2017, The Aluminum Association, Inc.
Unauthorized reproduction by photocopy or any other method is illegal

Table of Contents

Chapter 1	**Introduction to Aluminum Soldering**	**13**
	Purpose of Aluminum Solder Connections	13
	Advantages of Soldering	13
	Basic Process	14
	Soldering with Flux	15
	Soldering without Flux	16
	Solder Heat	16
Chapter 2	**Aluminum Alloys**	**17**
	Breadth of Choice of Material	17
	Alloy Temper and Solderability	17
	Retention of Temper	17
	Distortion Eliminated	18
	Solderability and Alloying Elements	18
	Alloying Elements and Intergranular Penetration	18
	Solderable Casting Alloys	23
Chapter 3	**Solders for Aluminum**	**24**
	Creating Solder to Aluminum Intermetallic Bond	24
	Choice of Solder Alloy	24
	Tin-Zinc Solders	25
	Tin-Silver Solders	25
	Tin-Copper Solders	26
	Tin-Lead-Silver Solders	26
	Zinc-Aluminum Solders	27
	Low Temperature Aluminum Solder	28
	Soldering Temperatures	28
	Abrasion Solder	28
	Available Solder Forms	28
	Improving Aluminum Solderability by Coating	29
	Color Match	29
	Wiping Solders	29
Chapter 4	**Fluxes for Aluminum**	**30**
	Purpose of Using Flux on Aluminum	30
	Organic Fluxes	31
	Liquid Flux	31
	Paste Flux	32
	Solderpaste	32
	Core Flux in Wire Solder	33
	Flux Action on Aluminum	33
	Cleaning Flux Residues	34

	Reaction Fluxes	35
	Flux and Intergranular Penetration	37
Chapter 5	**Pre-Cleaning, Oxide Removal, and Surface Preparation**	**38**
	Measuring Oxide Thickness	39
	Oxide Removal	40
	Keeping the Parts Clean	41
	Cleaning, Oxide Removal, and Joint Quality	42
	Surface Preparation Pre-coating	43
	Tinning	43
	Plating with Chemical Energy	44
Chapter 6	**Post-Cleaning and Finishing**	**45**
	Organic Flux Residue	45
	Chloride Flux Residue Removal	46
	Testing for Flux Traces	47
	Finishing	48
Chapter 7	**Fixture and Joint Design**	**49**
	Casual Soldering	49
	Basic Solder-Joint Parameters	49
	Solder Joint Requirements	50
	Joint Clearance	50
	Suggested Joint Clearances	51
	Joints Must Be Vented	53
	Joint Types	54
	Calculating Overlap	55
	Locked Joints	56
	Designing Corrosion Resistance into a Joint	57
	Corrosion Consideration When Soldering to Other Metals	58
	Vibratory-Load Joint Design	58
	Pressure-Tight Vessels	59
	Solder Shape and Quantity	59
	Solder Placement	59
	Pre-Positioning Solder	60
	Dimensional Changes at Soldering Temperatures	61
	Design for Self-Fixturing	61
	Fixture Design	63
	Establishing and Holding Joint Clearance	64
	Applying Flux	65

Chapter 8	**Torch, Iron, and Hot-Plate Soldering**	**66**
	Torch Soldering	66
	Torch Heating Massive Parts and Castings	70
	Automatic Torch Soldering	70
	Hot-Plate Soldering	71
	Soldering Iron	72
Chapter 9	**Abrasion and Ultrasonic Soldering**	**74**
	Abrasion Soldering	74
	Abrasion Tool	76
	Solder	76
	Technique	76
	Ultrasonic Soldering	76
	Ultrasonic Solders	77
Chapter 10	**Furnace Soldering**	**78**
	Production Procedure	78
	Time and Temperature	79
	Heat Distribution Within Furnace	80
Chapter 11	**Other Soldering Techniques – Induction, Dip, Reaction, Wipe, and Radiant Heat**	**81**
	Induction Soldering	81
	Dip Soldering	84
	Reaction Flux Soldering Without External Solder	85
	Wipe Soldering	86
	Radiant Heat Soldering	87
Chapter 12	**Soldering Castings**	**88**
Chapter 13	**Soldering Aluminum to Other Metals and to Nonmetallics**	**90**
	Dissimilar Metal Joining Methods	91
	Choice of Flux and Solder	92
	Technique for Mixed Metal Soldering	92
	Soldering Aluminum to Nonmetallics	93
Chapter 14	**Joint Inspection, Testing, and Performance**	**94**
	Visual Inspection	94
	Nondestructive Tests	95
	Testing for Leaks	96
	Proof Testing	97
	Destructive Inspection	97
	Joint Performance	97
	Service Temperatures	98
	Corrosion Resistance	98
	Designing Corrosion Resistance into a Joint	101

Flux and Corrosion Resistance 103
Protected Joints 104
Corrosion Resistance Metal Joints 105

Chapter 15 Safety Measures 106

Tables

2-1 Composition and Solderability of Commercial Wrought Aluminum Alloys 21
2-2 Comparative Solderability of Various Aluminum Casting Alloys 23

3-1 Composition and Performance of Typical Solders for Use with Aluminum 25

4-1 Characteristics of Typical Soldering Fluxes for Aluminum 31
4-2 Organic Fluxes – General Physical Properties and Types of Usage 34

5-1 Surface Resistances 39

7-1 Approximate Coefficients of Thermal Expansion for Common Metals 61

8-1 Tip Orifice Diameter and Approximate Gas Pressure Used for Torch Soldering 67

13-1 Solderability of Aluminum to Other Metals and Nonmetals 90

14-1 Solution Potential in Volts of Commonly Soldered Metals 99
14-2 Alloys Tested Against a 0.1N Calomel Reference Electrode 100
14-3 Solder Systems Versus Exposure to Salt Spray 102

Figures

3-1	Effect of Composition of Zinc Solders, Soldering time, and Soldering Temperature on Rate of Inter-alloying between Zinc Solders and Aluminum Alloy 6061	27
4-1	Aluminum Fin Placed on Solder Foil, Flux, and Aluminum Base	32
4-2	Aluminum Fin Soldered to Aluminum Base After Solder Reflow	32
4-3	Dispensable Aluminum Flux Paste Placed on Metal Surface	32
4-4	Aluminum Fin Placed on Solderpaste Dispensed on Copper	32
4-5	After Solder Reflow Fins are Soldered to Copper	32
4-6	Wire Solder with Aluminum Core Flux in the Center of Wire	33
4-7	Soldering Aluminum to Aluminum with Wire Solder Containing Core Flux	33
4-8	Reaction Flux Placed Between Two Aluminum Parts with a Wire Solder of Zinc/Aluminum	35
4-9	The Flux Smokes as its Activation Temperature is Reached and the Solder Begins to Flow	35
5-1	Nonhazardous Cleaner Removing Oxides from Aluminum	40
5-2	Typical buildup of oxide on 1XXX Series Aluminum Alloys	42
5-3	X-ray of Carefully Cleaned and De-oxidized Solder Joints Comprising a Heat Exchanger	42
5-4	X-ray of Solder Joints Comprising a Similar Unit	42
5-5	Aluminum Plate Coated with Flux then Dipped into Molten Pot of Solder	43
5-6	Tinned Aluminum Plate	44
6-1	Cleaning Schematic for Multiple Stage Non-hazardous Cleaner with Flowing Water Rinses to make the Last Tank of Water as Clean as Possible	46
7-1	Joint Clearance Effects	51
7-2	Variable Dimension Design	52
7-3	Excellent Socket Joint Design	53
7-4	Vent Holes	53
7-5	Venting Shape Variations	53
7-6	Solder Joint Designs Frequently Used with Aluminum	54
7-7	Weep Holes	54
7-8	Calculating Needed Overlap by Formula	55
7-9	Lock Seam Designs	56
7-10	Design for Condensation	58
7-11	Typical Soldered Joints that have Proven Suitable for Pressure-Tight Containers	59
7-12	Soldered Joints after an Internally and Externally Positioned Ring of Solder has been Used	60
7-13	Twenty-one Suggestions for Making Assemblies to be Soldered Self-Fixturing	62
7-14A	How C-Clamp Springs May be Used to Hold Parts Lightly but Dependably	63

During Soldering
7-14B Simple Spring-Loaded Fixture Serves as Assembling and Aligning Aid 63
7-15 How Prick Punch Indentations and Similar Protrusions May be Used to Center and Hold Part in Place 64
7-16 Example of how Offset May be Used to Establish and Hold Joint Clearance Between Parts While they are Being Soldered 64

8-1 Typical Setup for Soldering a Tee Joint 68
8-2 Torch Soldering Using Aluminum Flux Cored Organic-Based Wire Solder 69
8-3 Torch Soldering Using Reaction Flux and Solid Solder 69
8-4 An Aluminum Sheet is Marked by High Temperature Resistance Paste to Limit the Area of Solder Flow 71
8-5 A Direct Aluminum Soldering Paste is Placed in the Designated Area 71
8-6 Heating on a Hot Plate Makes the Solder Paste Active to Bond to the Aluminum Metal 72
8-7 The Result is an Aluminum Sheet Made Solderable to the Solder Coating by All Kinds of Soldering Methods 72
8-8 Simple Setup for Soldering a Lap Joint with an Iron or Torch. 73
9-1 Spring-Loaded Table Top Support for Holding Work Piece Stationary as Solder is Applied 75
9-2 Spring Holding Fixture Holding Material Immobile While Torch Heating and Solder is Put into Place 75
9-3 Simple Guide and Weight Arrangement when Tinned Surfaces are Heated for Joining 75
9-4 Insulated Spring Holds Box Walls in Place while Tinned Ends are Heated for Joining 75

10-1 Reflow Oven for Soldering 79
10-2 Interior Schematic of the Convection Reflow Oven Showing Heated Forced Air Passing Through Multiple Heating Zones 79
10-3 Thermal Profile Developed from Temperature Probing a Heat Sink Through a Solder Reflow Oven 79

11-1 Induction Soldering 81
11-2 Induction Coil Forms 82
11-3 Insulated Aluminum Wire 84
11-4 Wire Immersed in Aluminum Soldering Flux 84
11-5 Wire Immersed in Solder 84
11-6 Soldered Aluminum Wire 84
11-7 Self-spacing Lap Joints Soldered with Reaction Flux Alone 86

12-1 Repair of Casting Surface Holes 89

13-1 Diagram of Aluminum Fins Soldered to a Copper Base 91
13-2 Soldered Aluminum Fins to a Copper Base 91
13-3 Plated Aluminum Surface Soldered with 63/37 Tin-Lead 92

13-4 Un-plated Aluminum Surface Soldered with 91/9 Tin-Zinc 92

14-1 Approximate Electrical Potential Developed Across Low-Temperature Solder Joint and Zinc Solder Joint 101
14-2 Effect of Chloride-Containing Flux Residue on Electrical Resistance of Aluminum-to-Copper Joint Exposed to an Industrial Atmosphere 103
14-3 Copper-plated Joint Walls Have More Positive Potential Than the Aluminum 105

1

Introduction to Aluminum Soldering

Soldering is an inexpensive and rapid means of permanently joining aluminum to aluminum and to other metals. Properly made joints are leak-proof and strong. Soldering is used for joining aluminum wires, making heat exchangers, spacecraft, plumbing and thousands of other applications far too numerous to list here.

Aluminum soldering can be straightforward when proper solder alloys, cleaners, and fluxes are used. Single joints are readily made in the field and shop with low-cost hand tools. Single and multiple joints, often numbering in the thousands, are automatically produced with comparatively low-cost equipment by semi-skilled personnel.

Purpose of Aluminum Solder Connections

The first step in proceeding with aluminum soldering is to understand the type of connection being made, as follows:

Tinning – This technique is used to render the relatively non-solderable surface of aluminum (by ordinary soldering fluxes) solderable by coating the aluminum with a more solderable alloy.

Thermal/Electrical – The connection described here will be able to transfer electrical or thermal energy from one metal into another through the connecting solder media.

Structural (Joint Formation) – The formation of a structural joint holding two metals involves the process of joint clearance and assistance of solder flow. This is an important consideration, since aluminum has a higher surface tension with respect to solder, than other metals, like copper. Therefore, when making a capillary joint one has to consider the space necessary to facilitate solder flow.

Load-Bearing – Like a thermal/electrical or a structural joint, this type of connection is also expected to bear a certain amount of stress. When creating a joint that is to bear a known amount of stress, joint design and solder alloy choice are key factors.

Advantages of Soldering

By the accepted American Welding Society definition, soldering is a joining process wherein coalescence between metal parts is produced by heating to suitable temperatures, generally below 449°C / 840°F, and by using a filler metal having a liquidus not exceeding 449°C / 840°F and below the solidus of the base metals. The solder is usually distributed between the properly fitted surfaces of the joint by capillary attraction. Brazing, by the same definition, is a similar process accomplished at temperatures above 449°C / 840°F, but below the melting point of the metals to be joined. Welding requires that