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DATA SHEET

Soldering Alloys

SOLDERING ALLOYS include a wide range of alloying elements and properties. The common characteristics of these alloys is that they are used almost entirely for joining purposes, and that they have a liquidus (lowest temperature at which they are completely liquid) of less than 800 F, Table 1.

Solder Alloys

Tin-Lead: This is the largest single group and the most widely used of the soldering alloys. Most metals can be joined with these alloys. Joint clearances of 0.003 to 0.005 in. are recommended. Tin-lead solders are compatible for use with all types of base metal cleaners, fluxes, and heating methods.

Increasing the tin content of these solders produces better wetting and flow characteristics. Thus, when less tin is used, greater care should be exercised in surface preparation of the metals to be joined.

The highest melting-temperature solder in this group is that classified as 5A. This high-lead alloy is particularly suitable for use where operating temperature of the assembly may reach 300 F.

The most widely used solders—often referred to as general-purpose solders—of the tin-lead system are the classifications 35A through 50A. They provide optimum wetting and flow properties, good strength at low temperatures, and require less preparation time.

The 60A solder, almost the eutectic, is particularly adaptable to delicate work or when soldering temperature may be critical. The solder with the highest tin content, 70A, is used for soldering zinc.

Tin-Lead-Antimony: These ternary alloys are generally used, with few exceptions, in the same applications as the tin-lead solders. They are not recommended for use on aluminum, zinc, or galvanized steel, however. The addition of antimony—up to a maximum of 6 per cent of the tin content—does not seriously affect the wettability or flow characteristics, but it does increase the mechanical properties. Joint-clearance recommendations are the same as for the tin-lead alloy system.

These solders have almost the same properties as equivalent tin-lead solders with about 5 per cent more tin. The physical properties—tensile, creep, and hardness—are higher than the non-antimonial alloys.

Tin-Antimony: The 95 per cent tin-5 per cent antimony solder has the best electrical properties of any solder alloy. In addition, it has high strength at temperatures to 300 F, and excellent flow characteristics.

Tin-Silver: The tin-silver alloys exhibit the same characteristics as the tin-antimony solders and are used for delicate instrument work.

Tin-Zinc: This group of alloys is not considered highly important for soldering applications. Widest usage is for soldering aluminum—primarily where lower soldering temperature than zinc-aluminum solders is required.

Lead-Silver: The physical properties of these solders—tensile, creep, and shear strengths—are good to 350 F. Fatigue properties are also better than the non-silver solder alloys. The silver-lead solders, however, have poor wetting characteristics and are subject to humid-atmosphere corrosion in storage. The addition of 1 per cent tin, replacing silver, increases wetting and flow, and re-

—Table 1—Typical Solders

ASTM Classification	Composition (per cent by weight)					Temperature (F) Solidus	Liquidus	Pasty Range
			Tin	Lead				
5A			5	95		572	596	24
10A			10	90		514	573	59
15A			15	85		437	553	116
20A			20	80		361	535	174
25A			25	75		361	511	150
30A			30	70		361	491	130
35A			35	65		361	477	116
40A			40	60		361	455	94
45A			45	55		361	441	80
50A			50	50		361	421	60
60A			60	40		361	374	13
70A			70	30		361	378	17
		Tin	Antimony	Lead				
20C		20	1.0	79.0		363	517	154
25C		25	1.3	73.7		364	504	140
30C		30	1.6	68.4		364	482	118
35C		35	1.8	63.2		365	470	105
40C		40	2.0	58.0		365	448	83
		Lead	Silver	Tin				
2.5S		97.5	2.5	..		579	579	0
5.5S		94.5	5.5	..		579	689	110
1.5S		97.5	1.5	1.0		588	588	0
			Tin	Silver				
			96.5	3.5		430	430	0
			95	5		430	473	43
			Tin	Zinc				
			91	9		390	390	0
			80	20		390	518	128
			70	30		390	592	202
			60	40		390	645	255
			30	70		390	708	318
			Cadmium	Zinc				
			82.5	17.5		509	509	0
			40	60		509	635	126
			10	90		509	751	241
	Tin	Indium	Bismuth	Lead	Cadmium			
	8.3	19.1	44.7	22.6	5.3	117	117	0
	12	21	49	18	..	136	136	0
	12.8	4	48	25.6	9.6	142	149	7
	50	50	..	..	..	243	260	17
	48	52	..	..	..	243	243	0

duces susceptibility to corrosion. When tin is added to the lead-silver alloy, the silver content should be limited to 1.5 per cent, because, above this percentage, segregation occurs.

Cadmium-Zinc: The cadmium-zinc solders are useful in joining aluminum to itself or other metals. It is particularly useful in applications where service temperature is higher than allowed with the lower-melting alloys.

Zinc-Aluminum: Designed specifically for soldering aluminum, zinc aluminum solders provide high joint strength with good corrosion resistance. A [illegible] per cent zinc, 5 per cent aluminum solder has been used without flux in electronics applications.

Indium Solders: Indium solders are used only in special applications, for instance, in cryogenic applications. The 50 per cent indium, 50 per cent tin alloy is particularly useful in glass-to-glass and glass-to-metal soldering.

Fusible Alloys: These bismuth-containing solders are used where soldering must be performed at temperatures below 361 F. A representative group of these alloys is listed in Table 2. These solders are more sensitive to long-time loading above room temperatures (creep). The higher bismuth-content solders are not easily adaptable to high-speed soldering operations, nor do they easily wet the base metal.

Design Considerations

In designing for the use of the soldering alloys, little, if any, reliance should be placed on the strength of the solder. Instead, the joint should be designed to take advantage of the mechanical properties of the base metal by the use of such techniques as interlocking joints, edge reinforcing, or rivets.

No matter what type of mechanical method or device is used, there are basically only two types of joints—lap or butt—used in soldering. Lap joints are preferred because of the greater strength they impart to the assembly. Butt joints should be used only where sealing of the assembly is necessary.

Table 2—Fusible Alloys

Alloy	Composition (per cent by weight) Lead	Bismuth	Tin	Other	Temperature (F) Solidus	Liquidus	Pasty Range
Lipowitz	26.7	50	13.3	10 Cd	158	158	0
Bending (Wood's Metal)	25	50	12.5	12.5 Cd	158	165	7
Eutectic	40	52	....	8 Cd	197	197	0
Eutectic	32	52.5	15.5	....	203	203	0
Rose's	28	50	22	....	204	229	25
Matrix	28.5	48	14.5	9 Sb	217	440	223
Mold and pattern	44.5	55.5	....	....	255	255	0

Solder Forms and Shapes

Soldering alloys are commercially available in practically any desired shape, weight, or size. Typical examples of available forms are: Pig, slab, cake or ingot (rectangular or circular in shape), bar, paste, ribbon or tape (thicknesses of 1/16 to 3/16 in.), segment or drop (triangular bar or wire cut into pieces), pulverized or powdered, foil (thicknesses from 0.00125 in.), sheet (thicknesses from 0.010 to 0.100 in.), solid wire, flux core wire, and preforms.

Nonferrous Materials

Most of the nonferrous metals and alloys can be soldered, Table 3. Solderability depends on the alloy, the solders available, surface preparation, and soldering techniques. Some alloys require very special solders and/or fluxes and carefully controlled production methods.

Aluminum and Aluminum Alloys: The soldering of aluminum differs from the soldering of brass, copper, steel, and most other common metals in several ways. The most important difference is that aluminum oxide forms a more tenacious and refractory oxide, making mandatory the use of corrosive fluxes designed for aluminum. A second difference is that the soldering of aluminum requires special techniques to produce flow into certain types of joints. Thirdly, the solder composition influences corrosion resistance of solder joints much more with aluminum than with copper, brass, or steel. With proper attention to details, however, a large variety of solder joints can be made in aluminum base materials.

The commonly soldered wrought-aluminum alloys are: 1060, 1100, 1145, 3003, 5005, 6061, 7072, and 8112 Table 4. Aluminum castings, by virtue of their composition, generally exhibit poor solderability.

The use of solders with high zinc or tin content is usually recommended, Table 5. The tin-lead solders are not recommended because the joint has poor

Table 3—Surface Preparation Requirements for Soldering Metals and Alloys

Metal or Alloy	Flux Requirements: Non-Corrosive	Corrosive	Special Flux and/or Solder	Soldering Not Recommended
Aluminum			X	
Aluminum-Bronze			X	
Beryllium				X
Beryllium Copper		X		
Brass	X	X		
Copper	X	X		
Copper-Chromium		X		
Copper-Nickel		X		
Copper-Silicon		X		
Gold	X			
Inconel	X			
Lead	X	X		
Magnesium			X	
Manganese-Bronze				X
Monel		X		
Nickel		X		
Nichrome			X	
Platinum	X			
Silver	X	X		
Stainless Steel			X	
Steel		X		
Tin	X	X		
Tin-Zinc	X	X		
Titanium				X
Zinc		X		
Zinc Die Castings			X	

Table 4—Solderability of Aluminum Alloys

Alloy Group	Typical Alloy	Solderability	Recommended Flux
1xxx (Commercial purity or higher)	1060 1100	Good Good	Chemical or reaction Chemical or reaction
2xxx (Al-Cu)	2014	Fair*	Reaction
3xxx (Al-Mn)	3003	Good	Chemical or reaction
4xxx (Al-Si)	4043	Poor*	None
5xxx‡ (Al-Mg) or (Al-Mg-Mn)	5005 5050, 5154 5456, 5083	Good Fair* Poor*	Chemical or reaction Reaction Reaction
6xxx (Al-Mg-Si)	6061	Good*	Reaction
7xxx‡ (Al-Zn)	7072 7075	Good Poor	Reaction Reaction
8xxx‡ (Al-other)	8112	Good	Reaction

*Susceptible to intergranular penetration by solder.
†Solderable only with abrasion or ultrasonic techniques.
‡Solderability greatly affected by composition.

Table 5—Typical Solders for Aluminum

Composition (per cent)	Temperature (F) Solidus	Liquidus	Density (lb per cu in.)	Wetting Ability on Aluminum	Flux Type Commonly Used	Relative Corrosion Resistance
100 Zn	787	787	0.26	Good	Reaction	Very Good
95 Zn-5 Al	720	720	0.24	Good	Reaction	Very Good
91 Sn-9 Zn	390	390	0.26	Fair	Chemical & reaction	Fair
60 Sn-40 Zn	390	645	0.26	Good	Reaction	Good
30 Sn-70 Zn	390	708	0.26	Good	Reaction	Good

Table 6—Solderability of Copper and Copper Alloys

Metal	Solderability
Coppers (Includes tough-pitch oxygen-free phosphorized, arsenical, silver-bearing leaded, tellurium, and selenium copper.)	Excellent. Need only rosin or other noncorrosive flux.
Copper-tin alloys	Good. Easily soldered with activated rosin and intermediate fluxes.
Copper-zinc alloys	Good. Easily soldered with activated rosin and intermediate fluxes.
Copper-nickel alloys	Good. Easily soldered with intermediate and corrosive type fluxes.
Copper chromium and beryllium-copper	Good. Require intermediate and corrosive type fluxes.
Copper-silicon alloys	Fair. Silicon produces refractory oxides that require use of corrosive fluxes.
Copper-aluminum alloys	Difficult. May be soldered with help of very corrosive fluxes.
High-tensile manganese-bronze	Not recommended. Should be plated to insure consistent solderability.

Table 7—Characteristics of Commonly Used Solders for Copper and Copper Alloys

Composition (per cent)	Temperature (F) Solidus	Liquidus	Type and Uses
60 tin-40 lead	361	374	Quick-setting solder for fine electrical and tinsmith work.
50 tin-50 lead	361	421	General purpose solder.
95 tin-5 antimony	452	464	Quick-setting solder whose creep strength at elevated temperatures is higher than that of the usual tin-lead solders. Especially useful for electrical joints and hot-water copper-tube lines that operate at temperatures up to 250 F.

resistance to corrosion and exhibits a loss of strength due to aging.

Copper and Copper Alloys: Copper is one of the easiest metals to solder. Nearly all solders and fluxes can be used in soldering copper—the choice depends primarily on intended application of the assembly. The relatively low temperatures required to solder copper permit joints to be made with a minimum of distortion, softening, and scaling of the work. Also, minimum damage occurs to electrical insulation and protected coatings. The solderability of copper-base alloys ranges from excellent to poor, Table 6.

There are no serious problems in soldering most of the copper-base metals. However, those alloys with beryllium, silicon, and aluminum require special fluxing. Also, copper-zinc alloys (brasses) should not be soldered with tin-antimony or tin-lead-antimony solders containing more than 1 per cent of antimony or 0.02 per cent of arsenic, Table 7. The excess antimony contributes to the brittleness of the joint and arsenic may cause dewetting of the solder from the base metal.

Nickel and High-Nickel Alloys: Solder can be employed to join nickel and high-nickel alloys either to themselves or to any other solderable metals. Pure nickel and such alloys as Monel, K Monel, Permanickel, and Duranickel have good solderability. Alloys such as Inconel, Incoloy, Inconel X, and Nimonic 75 have fair solderability.

High-nickel alloys are usually specified because of their resistance to corrosive attack. When corrosion is a factor, the corrosion resistance of the solder alloy must also be considered. In some cases, the joint must be located so that the solder alloy will not be exposed to the corrosive environment. The higher tin content solders, such as 95 tin-5 antimony, usually are a better color match if appearance is important. However, the solder may oxidize in a different manner from the base metal and the joint may become noticeable after exposure.

On age-hardenable materials, the soldering should be done after aging. The temperature involved in soldering will not soften such metals as Duranickel, K Monel, and Inconel X, which have been fully age-hardened.

Any of the common types of solders may be used for joining the high-nickel alloys. It is usually desirable, however, to choose a relatively high-tin solder such as the 60 tin-40 lead or 50 tin-50 lead composition.

Zinc: Soldering of zinc is not difficult. Zinc-chloride fluxes containing some hydrochloric acid are generally used along with a soldering iron with controlled heat. Zinc alloys, such as are used in die castings, normally contain aluminum and are difficult to solder. These must be treated as though they were an aluminum alloy, and aluminum soldering procedures should be followed.

Ferrous Materials

Iron and Steel—As with other metals, solderability of steel is influenced by its alloying constituents. The low-alloy or mild steels are most easily soldered. Medium-carbon steels (0.30-0.45 per cent C) solder less readily than low carbon (0.30 per cent C or less), and surface preparation is consequently more critical. High-carbon steels (over 0.45 per cent C) are seldom soldered.

Iron and steel corrode easily, and any rust or mill scale must be totally removed from the surface prior to soldering. A hot alkaline cleaner followed by an acid dip will generally produce good soldering surfaces. These metals are frequently precoated with lead, tin, or some other metal to provide good corrosion protection in addition to improved solderability.

Mildly corrosive fluxes are necessary for soldering low-alloy steels. Special fluxes are available for the high-carbon steels and other materials such as stainless. Another important consideration is the necessity to provide absolutely clean surfaces prior to soldering.

Stainless: Commercially available lead-tin solders can be used in joining stainless steels. Stainless steels are formulated to withstand corrosive attack and are, therefore, difficult to flux chemically for soldering. Special highly corrosive stainless steel fluxes are used for soldering these alloys. If the soldered alloy is inaccessible and flux can't be removed after assembly, pretinning of parts may be necessary. Pretinning is accomplished using a corrosive flux and, after its removal, the parts may be assembled with a regular mild flux, thus eliminating the corrosion problem.

Cast Iron: Cast iron contains graphite which cannot be wetted by molten solder. Special cleaning methods are often required for this material. Electrochemical cleaning, abrasion, and chemical cleaning are used to prepare cast iron for soldering. Care should be taken in heating the cast iron to avoid cracking. Ordinarily high-tin lead-tin solders are suitable for making the joint once the casting has been properly prepared.

Composition	Tin	Lead	Antimony,	Bismuth max	Silver max	Copper, max	Iron, max	Zinc, max	Aluminum, max	Arsenic, max	Cadmium, max	Total of all others, max	Approximate melting range[1] Solidus	Liquidus
	%	%	%	%	%	%	%	%	%	%	%	%	°C (°F)	°C (°F)
Sn96	Remainder	0.10, max	...	...	3.6 to 4.4	0.20	...	0.005	...	0.05	0.005	...	221 (430)	221 (430)
Sn70	69.5 to 71.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	193 (379)
Sn63	62.5 to 63.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	183 (361)
Sn62	61.5 to 62.5	Remainder	0.20 to 0.50	0.25	1.75 to 2.25	0.08	0.02	0.005	0.005	0.03	0.001	0.08	179 (354)	179 (354)
Sn60	59.5 to 61.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.03	0.001	0.08	183 (361)	191 (376)
Sn50	49.5 to 51.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.025	0.001	0.08	183 (361)	216 (421)
Sn40	39.5 to 41.5	Remainder	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	238 (460)
Sn35	34.5 to 36.5	Remainder	1.6 to 2.0	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	185 (365)	243 (469)
Sn30	29.5 to 31.5	Remainder	1.4 to 1.8	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	185 (365)	250 (482)
Sn20	19.5 to 21.5	Remainder	0.80 to 1.2	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	184 (363)	270 (518)
Sn10	9.0 to 11.0	Remainder	0.20, max	0.03	1.7 to 2.4	0.08	...	0.005	0.005	0.02	0.001	0.10	268 (514)	29[illegible] (554)
Sn5	4.5 to 5.5	Remainder	0.50, max	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	308 (586)	312 (594)
Sb5	94.0, min	0.20, max	4.0 to 6.0	...	0.015	0.08	0.08	0.03	0.03	0.05	0.03	0.03	235 (455)	240 (464)
Pb80	Remainder	78.5 to 80.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (351)	277 (531)
Pb70	Remainder	68.5 to 70.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	254 (489)
Pb65	Remainder	63.5 to 65.5	0.20 to 0.50	0.25	0.015	0.08	0.02	0.005	0.005	0.02	0.001	0.08	183 (361)	246 (475)
Ag1.5	0.75 to 1.25	Remainder	0.40, max	0.25	1.3 to 1.7	0.30	0.02	0.005	0.005	0.02	0.001	0.08	309 (588)	309 (588)
Ag2.5	0.25, max	Remainder	0.40, max	0.25	2.3 to 2.7	0.30	0.02	0.005	0.005	0.02	0.001	0.03	304 (579)	304 (579)
Ag5.5	0.25 max	Remainder	0.40, max	0.25	5.0 to 6.0	0.30	0.002	0.005	0.005	0.02	0.001	0.03	304 (579)	380 (716)

[1]For information only.

Alloy Compositions From Federal Specifications QQS-571