APPLICATION NOTE

How to Use Fusible Alloys

Introduction

Fusible alloys are materials that melt at less than 149°C (300°F), well below the melting point of tin-lead eutectic solders and SAC alloys. Bismuth is the major component of many of these alloys and influences the melting point, as well as gives these materials the unique characteristic of expansion upon solidification. This expansion, which can continue for hours or even days after solidification, has proven to be a useful property in many processes.

Fusible alloys are classified as either eutectic or non-eutectic. In eutectic alloys, the melting point coincides with the freezing point. Non-eutectic alloys exhibit a range between the melting and freezing points in which the materials are "mushy" or "pasty," since both solid and liquid phases are present in the alloy.

The composition and physical properties of common fusible alloys are listed in the the tables that follow. Although most of the alloys do not have high strength or hardness, they have many industrial uses.

Anchoring

This application takes advantage of alloy growth after freezing. In a typical installation, a part is mounted in an oversized hole and the alloy is cast around the part. Approximately 24 hours is usually required for the alloy to grow sufficiently to hold the part securely. Indalloy®217–440 has been used in such applications to hold punch heads for sheet metal piercing, vertical columns for drop hammers, and permanent magnets in work holding fixtures.

Chucks, Jigs, and Fixtures

Fusible alloys are used to hold delicate and irregular shaped workpieces in polishing and machining operations. For example, the extremely low melting point of Indalloy®117, Indalloy®136, and Indalloy®158 allows them to be cast against eyeglass lenses to hold them through the grinding and polishing operations. Afterward, the alloy is melted off in warm water and re-circulated for reuse.

Similarly, Indalloy®158 and Indalloy®281 are used to secure thin foil sections on jet engine turbine blades, allowing the critical "fir tree" pattern at the blade root to be machined more accurately. In a typical fixture, the foil section is positioned within a hollow hard steel matrix box. A fusible alloy is then cast around the foil and it grows to secure the blade for machining of the protruding root section. After machining, the alloy is melted off for reuse.

Electroforming Mandrels

The low melting point of fusible alloys makes them useful as mandrels for electroformed copper or nickel parts. A fusible alloy core is made by casting into a mold producing an electrically conductive pattern. Copper or nickel is then deposited on conductive surfaces to the required thickness. The core is melted out, leaving a dimensionally precise part with a smooth surface finish. Fusible alloy mandrels can also be used when the internal part configuration will not allow the removal of a hard metal core.

Bending

Bending thin-walled tubing and channels without adequate support can wrinkle, flatten, or rupture the part wall. Indalloy®158 and Indalloy®255 have long been used to support workpieces during bending or formatting to prevent damage.

Normally, the part should be lubricated before filling to prevent galling and to allow for clean alloy removal. The growth property of the alloys ensures complete part filling, and flaws in a tube wall can often be detected by bulges or leaks of molten alloy through microscopic cracks.

Indalloy®158 is the most widely used for this application, and it can be melted out with hot water. Indalloy®255 is used for tubes with diameters larger than 1.5 inches. However, a hot oil bath or oven heating is required to reach the 124°C (255°F) melting temperature.

With Indalloy®255, the tube or channel can be bent as soon as the alloy solidifies. Indalloy®158 must be forced-chilled by immersion in cold, circulating water immediately after filling. This results in a fine-grain crystalline structure that adequately supports the workpiece during formation.

Encapsulation Molds

Molds for potting transformers and other electronic components are often machined from aluminum or steel. These molds are permanent and can be used an almost unlimited number of times. They also are expensive, time-consuming to make, and difficult to modify.

An alternative to these expensive molds is to utilize the fusible alloy for molding. Preformed plastic cups are used for this application and are available in a wide variety of shapes and sizes. After the component has been potted and the resin cured, this plastic mold becomes an integral part of the unit.

The process of dip molding (slush casting) has been widely accepted by the electronics industry, where the configuration of the potted part permits easy withdrawal of an alloy shell from the dip mandrel. Indalloy®281 is best suited to this application. After the unit is positioned in the tin-shell alloy cavity, encased in resin, and the resin cured, the alloy mold is cracked off and returned to the melt pot for reuse.

Dies

Drop hammer dies for short-run sheet metal forming are made by casting fusible alloys against wood or plaster patterns. Dies made of these comparatively soft alloys will survive a quick blow but will deform in a squeeze operation.

Fire Protection

One of the earliest uses of fusible alloys was as the melt-out element in sprinkler heads. Several compositions are used, depending on the location of the sprinkler head in the building. Indalloy®158 is the most commonly used, but alloys covering the temperature range of 47°C (117°F)–100°C (212°F) are also used. Other fire protection applications include fusible links on fire doors and safety plugs in pressure and process tanks.

Electronic Joining

In the last few years, considerable interest has developed in the use of fusible alloys in electronic assembly. This is due to the need for low-temperature solders to assemble complex integrated circuits onto printed circuit boards, and in surface mount assemblies. The objective is to permit wave soldering at temperatures well below the 249°C (480°F)– 60°C (500°F) required with eutectic tin-lead and SAC solders, thus preventing damage to sensitive electronic devices.

Indalloy®281 and Indalloy®282 have shown great potential here with a melting point of 138°C (281°F) and 139°C (282°F) to 140°C (284°F). A modified wave soldering system that continuously floods the solder wave with flux operates with the solder bath at only 149°C (300°F)–166°C (330°F). Joint properties are comparable to those of tin-lead solders, with superior fatigue and copper dissolution characteristics. Other alloys being considered include Indalloy®38 and Indalloy®255.

The increased use of fusible alloys in electronic applications has prompted ASTM to issue specification B-774-00, Standard Specification for Low Melting Point Alloys, which describes alloy composition and use.

Conclusion

Fusible alloys are versatile industrial materials that can be utilized in particular applications and processes to reduce time and money. With the characteristics of low melting point, expansion upon solidification, and the ease of reuse, fusible alloys are able to be utilized in applications that would prove difficult using a standard soft solder or alloy.

Cross Reference—Indalloy® Number to Alloy Composition

Indalloy® Number	Alloy Composition
Indalloy®19	51.0In/32.5Bi/16.5Sn
Indalloy®38	52.5Bi/32.0Pb/15.5Sn
Indalloy®41	50.0Bi/28.0Pb/22.0Sn
Indalloy®42	46.0Bi/34.0Sn/20.0Pb
Indalloy®53	67.0Bi/33.0In
Indalloy®102	47.5Pb/39.9Sn/12.6Bi
Indalloy®117	44.7Bi/22.6Pb/19.1In/8.3Sn/5.3Cd
Indalloy®136	49.0Bi/21.0In/18.0Pb/12.0Sn
Indalloy®147	48.0Bi/25.6Pb/12.8Sn/9.6Cd/4.0In
Indalloy®158	50.0Bi/26.7Pb/13.3Sn/10.0Cd
Indalloy®160–190	42.5Bi/37.7Pb/11.3Sn/8.5Cd
Indalloy®162	66.3In/33.7Bi
Indalloy®174	57.0Bi/26.0In/17.0Sn
Indalloy®217–440	48.0Bi/28.5Pb/14.5Sn/9.0Sb
Indalloy®255	55.5Bi/44.5Pb
Indalloy®281–338	60.0Sn/40.0Bi
Indalloy®281	58.0Bi/42.0Sn
Indalloy®282	57.0Bi/42.0Sn/1.0Ag

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Properties of Commonly Requested Fusible Alloys

Indalloy® Number	117	136	147	158	160–190	217–440	255	281	281–338
Alloy Composition	44.7Bi 22.6Pb 19.1In 8.3Sn 5.3Cd	49.0Bi 21.0In 18.0Pb 12.0Sn	48.0Bi 25.6Pb 12.8Sn 9.6Cd 4.0In	50.0Bi 26.7Pb 13.3Sn 10.0Cd	42.5Bi 37.7 Pb 11.3Sn 8.5Cd	48.0Bi 28.5Pb 14.5Sn 9.0Sb	55.5Bi 44.5Pb	58.0Bi 42.0Sn	60.0Sn 40.0Bi
Liquidus °C (°F)	47 (117)	58 (136)	65 (149)	70 (158)	88 (190)	227 (441)	124 (255)	138 (281)	170 (338)
Eutectic	E	E		E			E	E	
Solidus °C (°F)	47 (117)	58 (136)	61 (142)	70 (158)	71 (160)	103 (217)	124 (255)	138 (281)	138 (280)
Density lbs/in³	0.3310	0.3255	0.3432	0.3461	0.3544	0.3360	0.3772	0.3093	0.2934
Tensile Strength lbs/in²	5,400	6,300	_	5,990	5,400	13,000	6,400	8,000	7,500
Brinell Hardness No.	16.5	16.5	_	14.5	15	19	15	23	23.5
Maximum Load 30sec lbs/in²	_	_	_	10,000	9,000	16,000	8,000	15,000	15,000
Safe Load Sustained	_	_	_	300	300	300	300	500	500
Electrical Conductivity Compared with Pure Copper (% IACS)	4.5	2.4	_	4	4.3	3	4	4.5	5

Cumulative Growth and Shrinkage Time after Casting

2 min	+0.0005	+0.0003	+0.0020	+0.0025	-0.0004	+0.0008	-0.0008	+0.0007	-0.0001
6 min	+0.0002	+0.0002	+0.0022	+0.0027	-0.0007	+0.0014	-0.0011	+0.0007	-0.0001
30 min	0.0000	+0.0001	+0.0040	+0.0045	-0.0009	+0.0047	-0.0010	+0.0006	-0.0001
1 hour	-0.0001	0.0000	+0.0046	+0.0051	0.0000	+0.0048	-0.0008	+0.0006	-0.0001
2 hours	-0.0002	-0.0001	+0.0046	+0.0051	+0.0016	+0.0048	-0.0004	+0.0006	-0.0001
5 hours	-0.0002	-0.0002	+0.0046	+0.0051	+0.0018	+0.0049	0.0000	+0.0005	-0.0001
500 hours	-0.0002	-0.0002	+0.0052	+0.0057	+0.0025	+0.0061	+0.0022	+0.0005	-0.0001

Measurements are in inches per inch compared to cold mold dimensions. Test bar ½" x ½" x 10". Weight approximately one pound.
All data represent predictable characteristics and can be relied on only as a guide.

All information is for reference only. Not to be used as incoming product specifications.

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