How to use Fusible Alloys

APPLICATION NOTE

Fusible alloys are materials that melt at less then 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".

The composition and physical properties of common fusible alloys are listed in the tables below. 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. Usually, about 24 hours is 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 work pieces 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. Then a fusible alloy is 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 conducive 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 of 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 work pieces 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 in.; however, a hot oil bath or oven heating is required to reach the 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 work piece 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.

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Form No. 97577 R2

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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 117 to 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 480°F-500°F required with eutectic tin lead and SAC solders, thus preventing damage to sensitive electronic devices.

Indalloy 281 and Indalloy 282 has shown great potential here with a melting point of 281°F and 282°F to 284°F. A modified wave soldering system that continuously floods the solder wave with flux operates with the solder bath at only 300 to 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	51In 32.5Bi 16.5Sn
Indalloy 38	52.5Bi 32Pb 15.5Sn
Indalloy 41	50Bi 28Pb 22Sn
Indalloy 42	46Bi 34Sn 20Pb
Indalloy 53	67Bi 33In
Indalloy 102	47.5Pb 39.9Sn 12.6Bi
Indalloy 117	44.7Bi 22.6Pb 19.1In 8.3Sn 5.3Cd
Indalloy 136	49Bi 21In 18Pb 12Sn
Indalloy 147	48Bi 25.6Pb 12.8Sn 9.6Cd 4In
Indalloy 158	50Bi 26.7Pb 13.3Sn 10Cd
Indalloy 160-190	42.5Bi 37.7Pb 11.3Sn 8.5Cd
Indalloy 162	66.3In 33.7Bi
Indalloy 174	57Bi 26In 17Sn
Indalloy 217-440	48Bi 28.5Pb 14.5Sn 9Sb
Indalloy 255	55.5Bi 44.5Pb
Indalloy 281-338	60Sn 40Bi
Indalloy 281	58Bi 42Sn
Indalloy 282	57Bi 42Sn 1Ag

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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	49Bi 21In 18Pb 12Sn	48Bi 25.6Pb 12.8Sn 9.6Cd 4.0In	50Bi 26.7Pb 13.3Sn 10Cd	42.5Bi 37.7 Pb 11.3Sn 8.5Cd	48Bi 28.5Pb 14.5Sn 9Sb	55.5Bi 44.5Pb	58Bi 42Sn	60Sn 40Bi
Liquidus	117	136	149	158	190	441	255	281	338
Temp (F)	E	E		E			E	E	
Solidus	117	136	142	158	160	217	255	281	280
Density lbs/in^3	0.3310	0.3255	0.3432	0.3461	0.3544	0.3360	0.3772	0.3093	0.2934
Tensile Strength lbs/in^2	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 30 sec lbs/in^2	_	_	_	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 hour	-0.0002	-0.0001	+0.0046	+0.0051	+0.0016	+0.0048	-0.0004	+0.0006	-0.0001
5 hour	-0.0002	-0.0002	+0.0046	+0.0051	+0.0018	+0.0049	0.0000	+0.0005	-0.0001
500 hour	-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". Wt. approx. 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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