Alloy™ DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 Fax 440-338-4634
Mem-Serv@po.ASM-Intl.org

ASM INTERNATIONAL®
The Materials Information Society

Table of Contents

Aluminum **al395-1**

(1xxx Series) Commercially Pure Aluminum, 99.00% or Greater al395-1

(2xxx Series) Aluminum Copper al387-1

(4xxx Series) Aluminum Silicon al385-1

(5xxx Series) Aluminum Magnesium al275-1

(6xxx Series) Aluminum Magnesium Silicon al386-1

(7xxx Series) Aluminum Zinc al388-1

Aluminum Alloy **al383-1**

(4xxx Series) Aluminum Silicon al383-1

Aluminum Copper Alloy al346-1

Aluminum Magnesium Alloy al275a-1

Aluminum Magnesium Silicon Alloy al340-1

Aluminum Silicon Alloy al347-1

Aluminum Zinc Alloy al350-1

Cast Aluminum Copper Alloy al315-1

Cast Aluminum Magnesium Alloy al323-1

Cast Aluminum Silicon Alloy al199-1

Sintered Powder Aluminum Alloy al146-1

Unclassified Aluminum Alloy al1-1

Unclassified Cast Aluminum Alloy al2-1

Unclassified Wrought Aluminum Alloy al3-1

Welding Filler Aluminum Alloy al78-1

Carbon Matrix Composite **cp1-1**

Carbon Fiber Reinforced Carbon Matrix Composite cp1-1

Cast Iron **ci40-1**

Austenitic Cast Iron ci40-1
Compacted Graphite Cast Iron ci39-1
Corrosion Resistant Silicon Cast Iron fe109-1
Ductile Cast Iron ci1-1
Gray Cast Iron ci15-1
Malleable Cast Iron ci6-1
Unclassified Cast Iron ci2-1
Unclassified Corrosion Resistant Cast Iron ci3-1
White Cast Iron ci9-1

Cobalt **co15-1**

Cobalt Chromium Nickel Tungsten co15-1
Cobalt-Chromium-Tungsten co121-1
Unclassified Cobalt co111-1

Copper **cu712-1**

Beryllium Copper Alloy cu712-1
Brasses cu697-1
Bronzes cu696-1
Copper-Nickels cu703-1
Coppers cu702-1
High Copper Alloys cu725-1
Nickel Silvers cu707-1

Copper Alloy **cu2-1**

Aluminum Bronze cu2-1
Beryllium Copper cu3-1
Brass cu41-1
Brasses cu683-1
Bronzes cu685-1
Cast Aluminum Bronze cu283-1

Cast Beryllium Copper	cu11-1
Cast Commercially Pure Copper	cu370-1
Cast Copper Nickel	cu319-1
Cast High Copper Alloy	cu504-1
Cast Leaded Tin Bronze	cu269-1
Cast Manganese Bronze	cu57-1
Cast Nickel Silver	cu275-1
Cast Red Brass	cu317-1
Cast Silicon Brass	cu320-1
Cast Tin Bronze	cu218-1
Cast Yellow Brass	cu342-1
Commercially Pure Copper	cu97-1
Copper Nickel	cu52-1
High Copper Alloy	cu257-1
Leaded Brass	cu9-1
Nickel Silver	cu54-1
Phosphor Bronze	cu43-1
Silicon Bronze	cu1-1
Sintered Powder Copper Alloy	cu293-1
Thermocouple Copper Alloy	cu274-1
Tin Brass	cu169-1
Unclassified Brass	cu21-1
Unclassified Bronze	cu12-1
Unclassified Cast Bronze	cu227-1
Unclassified Cast Copper Alloy	cu332-1
Unclassified Copper Alloy	cu4-1
Unclassified Welding Filler Copper Alloy	cu30-1
Unclassified Wrought Copper Alloy	cu400-1
Welding Filler Bronze	cu582-1
Welding Filler Copper Nickel	cu617-1

Epoxy Resin **p26-1**

Epoxy Novolac Resin p26-1

Unclassified Epoxy Resin p15-1

Epoxy Resin Matrix Composite **cp7-1**

Aramid Fiber Reinforced Epoxy Resin Matrix Composite cp7-1

Fluoroplastic Matrix Composite **cp18-1**

Unclassified Polymer Matrix Composite cp18-1

Iron Alloy **fe126-1**

Magnetically Soft Iron Alloy fe126-1

Unclassified Iron Alloy fe138-1

Low Melting Alloy **pb1-1**

Bearing Lead Alloy pb1-1

Bearing Tin Alloy sn1-1

Lead Antimony Alloy pb9-1

Solder Tin Indium Alloy sn13-1

Tin Antimony Alloy sn8-1

Unclassified Bismuth Alloy bi1-1

Unclassified Indium Alloy in1-1

Unclassified Lead Alloy pb2-1

Unclassified Tin Alloy sn4-1

Magnesium **mg74-1**

Cast Magnesium Rare Earth mg74-1

Wrought Magnesium-Aluminum-Zinc mg78-1

Magnesium Alloy **mg4-1**

Unclassified Cast Magnesium Alloy mg4-1

Unclassified Magnesium Alloy mg1-1

Unclassified Wrought Magnesium Alloy mg2-1

Metal Matrix Composite **cp15-1**

Metal Matrix Composite cp15-1

Miscellaneous **mn3-1**

Manganese mn3-1

Silver ag13-1

Unclassified Miscellaneous Alloy nd1-1

Miscellaneous Carbide Based Material **cer5-1**

Unclassified carbide based material cer5-1

Miscellaneous Ceramic Material **cer3-1**

Unclassified Ceramic Material cer3-1

Miscellaneous Composite **cp19-1**

Unclassified Composite cp19-1

Miscellaneous Iron Alloy **fe92-1**

Electrical Steel fe92-1

Low Expansion Iron Nickel Alloy fe4-1

Magnetically Soft Iron Cobalt Alloy fe118-1

Unclassified Electrical Resistance Iron Alloy fe30-1

Unclassified Iron Alloy fe2-1

Unclassified Iron Superalloy fe56-1

Unclassified Low Expansion Iron Alloy fe3-1

Unclassified Magnetically Soft Iron Alloy fe1-1

Unclassified Permanent Magnet Iron Alloy fe17-1

Miscellaneous Nitride Based Material **cer4-1**

Unclassified Nitride Based Material cer4-1

Miscellaneous Nonferrous Alloy **mn1-1**

Unclassified Manganese Alloy mn1-1

Miscellaneous Oxide Based Material	**cer1-1**
Unclassified Oxide Based Material	cer1-1
Miscellaneous Silicate Based Material	**cer2-1**
Unclassified Silicate Based Material	cer2-1
Miscellaneous Thermoplastic	**cp13-1**
Unclassified Thermoplastic	cp13-1
Miscellaneous Thermoplastic Matrix Composite	**cp14-1**
Aramid Fiber Reinforced Thermoplastic Matrix Composite	cp14-1
Nickel	**ni635-1**
Commercially Pure or Low-Alloy Nickel	ni635-1
Iron Nickel Cobalt	ni636-1
Nickel Copper	ni651-1
Nickel with Chromium and/or Iron, Molybdenum	ni508-1
Unclassified Nickel	ni600-1
Nickel Alloy	**ni12-1**
Cast Nickel Base Alloy	ni12-1
Commercially Pure Nickel	ni125-1
Electrical Resistance Nickel Chromium Alloy	ni524-1
Magnetically Soft Nickel Alloy	ni5-1
Nickel Beryllium Alloy	ni138-1
Nickel Chromium Alloy	ni4-1
Nickel Chromium Molybdenum Alloy	ni324-1
Nickel Copper	ni595-1
Nickel Copper Alloy	ni21-1
Nickel Iron Chromium Alloy	ni562-1
Nickel Molybdenum Alloy	ni330-1
Nickel Phosphorus Alloy	ni332-1

Nickel Superalloy ni203-1
Nickel with Choromium and/or Iron, Molybdenum ni582-1
Sintered Powder Nickel Alloy ni225-1
Thermocouple Nickel Alloy ni69-1
Unclassified Electrical Resistance Nickel Alloy ni41-1
Unclassified Low Expansion Nickel Alloy ni81-1
Unclassified Magnetically Soft Nickel Alloy ni133-1
Unclassified Nickel Alloy ni1-1
Unclassified Surfacing Filler Nickel Alloy ni78-1
Unclassified Welding Filler Nickel Alloy fe112-1
Welding Filler Nickel Chromium Alloy ni515-1
Welding Filler Nickel Iron Chromium Alloy ni540-1

Noble Metal Alloy pd1-1

Commercially Pure Palladium pd1-1
Commercially Pure Silver ag6-1
Electrical Contact Silver Alloy ag7-1
Silver Copper Alloy ag9-1
Solder Silver Alloy ag1-1
Unclassified Gold Alloy au1-1
Unclassified Iridium Alloy ir1-1
Unclassified Platinum Alloy pt1-1
Unclassified Rhodium Alloy rh1-1
Unclassified Silver Alloy ag2-1

Plastic Alloy cp17-1

Polyamide Alloy cp17-1
Polycarbonate Acrylonitrile Butadiene Styrene Polymer Alloy p2-1
Polypropylene Alloy p24-1

Polyamide **p4-1**

Nylon p4-1

Nylon 6 p1-1

Nylon 66 cp3-1

Polyamide Thermoplastic Elastomer **p11-1**

Polyamide Thermoplastic Elastomer p11-1

Polycarbonate **p5-1**

Unclassified Polycarbonate p5-1

Polyester **p13-1**

Polybutylene Terephthalate p13-1

Polyimide **cp5-1**

Polyetherimide cp5-1

Polyimide Matrix Composite **cp11-1**

Carbon Fiber Reinforced Polyimide Matrix Composite cp11-1

Polymeric Fiber Reinforcement **cp10-1**

Aramid Fiber Reinforcement cp10-1

Polymeric Fiber Reinforcement cp22-1

Polysulfide **p3-1**

Polyphenylene Sulfide p3-1

Polyurethane Thermoplastic **p10-1**

Rigid Thermoplastic Urethane p10-1

Refractory **w27-1**

Tantalum ta13-1

Tungsten w27-1

Refractory Alloy	**co89-1**
Cobalt Chromium Alloy	co89-1
Cobalt Molybdenum Alloy	co101-1
Cobalt Nickel Alloy	co61-1
Cobalt Superalloy	co95-1
Unclassified Beryllium Alloy	be1-1
Unclassified Chromium Alloy	cr1-1
Unclassified Cobalt Alloy	co1-1
Unclassified Hafnium Alloy	hf1-1
Unclassified Molybdenum Alloy	mo1-1
Unclassified Niobium Alloy	cb1-1
Unclassified Rhenium Alloy	re1-1
Unclassified Tantalum Alloy	ta1-1
Unclassified Tungsten Alloy	w1-1
Unclassified Zirconium Alloy	zr1-1
Zirconium	zr11-1
Steel	**sa13-1**
Abrasion Resistant Steel	sa13-1
Air Hardening Tool Steel	ts592-1
Air-Hardening Medium-Alloy Cold Work	ts602-1
Alloy Structural Steel	sa11-1
Austenitic	ss861-1
Austenitic Stainless Steel	ss5-1
Bearing Steel	sa16-1
Boron Steel	sa302-1
Carbon Tool Steel	cs57-1
Cast Alloy Steel	sa19-1
Cast Austenitic Stainless Steel	ss538-1
Cast Duplex Stainless Steel	ss541-1
Cast Martensitic Stainless Steel	ss273-1

Chromium	fe136-1
Chromium Molybdenum	sa138-1
Chromium Molybdenum Steel	sa8-1
Chromium Molybdenum Vanadium Steel	sa494-1
Chromium Stainless Steel	ss631-1
Chromium Steel	sa27-1
Chromium Vanadium Steel	sa26-1
Cold Work Tool Steel	ts38-1
Corrosion Resistant Steel	sa7-1
Die Steel	ts1-1
Duplex	ss885-1
Duplex Stainless Steel	ss462-1
Ferritic	ss874-1
Ferritic Stainless Steel	ss129-1
Free Machining Stainless Steel	ss633-1
Free Machining Steel	cs9-1
Heat Resistant Austenitic Stainless Steel	ss643-1
Heat Resistant Steel	sa1-1
High Alloy Steel	sa172-1
High Carbon Steel	cs32-1
High Speed Tool Steel	ts2-1
High Strength Low Alloy Steel	sa5-1
High Strength Structural Steel	cs24-1
High Carbon High-Chromium Cold Work	sa582-1
High-Manganese	cs138-1
Hot Work	ts600-1
Hot Work Tool Steel	ts25-1
Low Alloy Steel	sa124-1
Low Alloy Tool Steel	ts52-1
Low Carbon Steel	cs33-1
Low-Alloy (HSLA)	cs136-1

Manganese	mn4-1
Manganese Carbon Steel	cs1-1
Manganese Steel	sa6-1
Maraging	fe140-1
Maraging Steel	sa154-1
Martensitic	fe148-1
Martensitic Stainless Steel	ss70-1
Medium Carbon Steel	cs37-1
Medium-Carbon	sa601-1
Mold Steel	ts59-1
Molybdenum High-Speed	ts304a-1
Molybdenum Steel	sa33-1
Molybdenum/Molybdenum Sulfide	sa541-1
Nickel Chromium	fe145-1
Nickel Chromium Molybdenum	co120-1
Nickel Chromium Molybdenum Steel	sa14-1
Nickel Molybdenum Steel	cs156-1
Nickel Steel	sa2-1
Nonresulfurized	cs144-1
Oil-Hardening Cold Work	ts649-1
Precipitation Hardening	ss876-1
Precipitation Hardening Semiaustenitic Stainless Steel	ss693-1
Precipitation Hardening Stainless Steel	ss3-1
Pressure Vessel Steel	sa328-1
Reinforcing Steel	sa295-1
Resulfurized	cs31-1
Resulfurized Carbon Steel	cs2-1
Shock Resisting Tool Steel	ts17-1
Shock-Resisting	ts562-1
Silicon	sa543-1
Silicon Steel	fe88-1

Spring Steel	cs11-1
Structural	cs150-1
Structual Steel	cs25-1
Tungsten High-Speed	ts249-1
Ultrahigh Strength Steel	sa62-1
Ultrahigh-Strength	cs137-1
Unclassified	cs62-1
Unclassified Alloy Steel	sa3-1
Unclassified Carbon Steel	cs3-1
Unclassified Cast Stainless Steel	ss2-1
Unclassified High Strength Steel	cs18-1
Unclassified Stainless Steel	ss1-1
Unclassified Tool Steel	ts11-1
Unclassified Welding Filler Steel	cs73-1
Valve Steel	sa152-1
Water Hardening Tool Steel	ts32-1
Welding Filler Stainless Steel	ss195-1
Styrenic Resin	**p34-1**
Polystyrene	p34-1
Unclassified Acrylonitrile Butadiene Styrene Polymer	p17-1
Superalloy	**co95a-1**
Cobalt Superalloy	co95a-1
Iron-Base Superalloys	cs151-1
Nickel Superalloy	ni680-1
Titanium	**ti140-1**
Alpha and near Alpha Titanium	ti140-1
Alpha Beta Titanium	ti133-1
Beta and near Beta Titanium	ti94-1
Unalloyed or Low-Alloy Titanium	ti131-1

Titanium Alloy	**ti54-1**
Alpha Beta Titanium	ti54-1
Alpha Titanium	ti75-1
Beta Titanium	ti27-1
Commercially Pure Titanium	ti11-1
Unalloyed or Low-Alloy Titanium	ti132-1
Unclassified Titanium Alloy	ti1-1
Vinyl Ester Resin	**p31-1**
Elastomer Modified Vinyl Ester Resin	p31-1
Epoxy Novolac Vinyl Ester Resin	p35-1
Unclassified Vinyl Ester Resin	p12-1
Zinc Alloy	**zn1-1**
Unclassified Cast Zinc Alloy	zn1-1
Unclassified Zinc Alloy	zn5-1

Alloy DIGEST™
DATA ON WORLDWIDE METALS AND ALLOYS

ALCOTEC WELD FILLER WIRE 4145

Filing Code: AI-383
Aluminum

December 2002

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 Mem-Serv@asminternational.org
Fax 440-338-4634 www.asminternational.org

ALCOTEC WELD FILLER WIRE 4145 (Aluminum Welding and Brazing Filler Wire)

AlcoTec weld filler wire 4145 is a general-purpose high-silicon-containing wire for both welding and brazing. The alloy is often used instead of 2319 for welding higher-strength alloys because of its low melting temperature and high fluidity.

ALMIGWELD is a registered trade mark of AlcoTec Wire Corporation.

Chemical Composition, wt.%:

Silicon	3.6–4.6
Iron	0.8 max
Copper	0.10 max
Manganese	0.05 max
Magnesium	0.10–0.30
Zinc	0.10 max
Titanium	0.15 max
Beryllium	0.0008 max
Others, each	0.05 max
Others, total	0.15 max
Aluminum	bal

Physical Properties:

Density, kg/m^3 (lb/in.^{3})	2740 (0.099)
Melting range, approximate, °C (°F)	520–585 (970–1085)
Anodize color	Gray

Weldability:

Typical procedures are given in Table 1. The alloy is widely preferred by welders because of its wetting ability.

Specification Equivalents:

ANSI/AWS A5.10 (ER and R)
ANSI/AWS A5.8
AMS 4184
Brazing alloy BAlSi3
UNS A94145

General Characteristics:

Alloy 4145 was originally developed as a brazing alloy because of its low melting temperature and high fluidity. The principal alloying elements are silicon and copper. It is heat treatable, but provides very low susceptibility to weld cracking when used with 2*xxx* series alloys, aluminum-copper castings, or aluminum-copper-silicon castings. It can be used in elevated-temperature service applications. The alloy is often preferred over 2319 when metal inert gas (MIG) welding because it wets out better, provides a brighter-looking weld, and produces less smut. Alloy 4145 does, however, have lower weld tensile strengths than 2319, and it is not suited for welding high-magnesium-containing alloys.

Product Forms Available:

Alcotec produces ALTIGWELD filler rods in 914 mm (36 in.) straight lengths designed for gas tungsten arc (GTA) welding or

Table 1 Typical Semiautomatic GMA Procedures for Fillet and Lap Welding Aluminum

	DC (EP) range(a)			DC (EP) suggested(a)				
Wire diameter, in.	Amps	Volts	Base thickness, in.(b)	Amps	Volts	Wire feed, ipm	Gas flow, cfh	Approximate consumption, lb/100 ft(c)
0.030	100–130	18–22	0.094	100	22	500	30	0.75
	125–150	20–24	0.125	120	22	600	30	1
0.035	85–120	20–23	0.094	110	22	480	30	0.75
	125–150	20–24	0.125	130	22	566	30	1
	170–190	21–26	0.250	170	23	740	35	4
0.047	125–150	20–24	0.125	150	23	360	30	1
	180–225	22–26	0.187	180	23	410	30	2.3
	170–240	24–28	0.250	190	24	470	40	44
0.062	190–260	21–26	0.250	200	23	265	50	4
	240–300	22–27	0.375	230	24	300	50	9
	260–310	22–27	0.500	260	26	340	60	16
	280–320	24–28	0.750	280	27	385	65	36
	290–340	26–30	1.000	300	28	420	70	64
0.094	280–360	26–30	0.750	320	29	170	60	36
	300–400	26–32	1.000	330	30	180	80	64

(a) Metal thickness of 0.75 in or greater for fillet welds sometimes employs a double vee bevel of 50° or greater included vee with $^3/_{32}$ to $^1/_8$ in. land thickness on the abutting member. (b) Electrode consumption given for weld on one side only, and based on leg length equal to plate thickness. (c) For 5*xxx* series electrodes use a welding amperage on the high side of the range and an arc voltage in the lower portion of the range. 1*xxx*, 2*xxx*, and 4*xxx* series electrodes would use the lower amperage and higher arc voltages.

brazing operations. The standard sizes available are 1.6 mm ($^1/_{16}$ in.), 2.4 mm ($^3/_{32}$ in.), 3.2 mm ($^1/_8$ in.), 4.0 mm ($^5/_{32}$ in.), and 4.8 mm ($^3/_{16}$ in.). These can be placed in 0.45 kg (1 lb) tube packs, 4.5 kg (10 lb) boxes, 9 kg (20 lb) boxes, or 22.6 kg (50 lb) boxes. Spooling is available as noted in Table 1.

ALMIGWELD welding wire is available in the standard sizes 0.75 mm (0.030 in.), 0.9 mm (0.035 in.), 1.0 mm (0.040 in.), 1.2 mm ($^3/_{64}$ in.), 1.6 mm ($^1/_{16}$ in.), and 2.4 mm ($^3/_{32}$ in.).

Applications:

Applications in the automotive industry include cylinder heads, blocks, and pans for strength-to-weight ratio and heat transfer in the welding of both A380 and A319 castings.

In the aerospace industry, applications include structural elements for strength-to-weight ratio and extreme-temperature service life when welding 2014 to itself.

Other applications include the defense industry where the alloy is used in missiles for strength-to-weight ratio to weld 2014 to itself, the recreation industry where the alloy is used in baseball bats to weld 7050 to itself, and the transportation industry where the alloy is used in cylinder heads and forged pistons to prevent weld cracking when welding 2218, 2618, A201.0, A242.0, and A240.0 to themselves.

Producer:

AlcoTec Wire Corporation
Traverse City, MI 49686-9263
(231) 941-4111
(231) 941-9154 (fax)

ISSN: 002-614X

Alloy DIGEST™
ALCOA 1*XXX* SERIES
DATA ON WORLDWIDE METALS AND ALLOYS
Filing Code: Al-395
Aluminum
July 2005

*Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 cust-srv@asminternational.org
Fax 440-338-4634 www.asminternational.org*

ALCOA 1*XXX* SERIES
(Extruded Non-Heat-Treated Aluminum Alloys)

Aluminum 1*xxx* series alloys are nonhardenable by heat treatment. They have high purity, high conductivity, and good corrosion resistance and are easily formed.

Chemical Composition, wt.%:

(Typical)

	Alloy 1060	Alloy 1100	Alloy 1350
Silicon	0.25 max	0.95 min (Si + Fe)	0.10 max
Iron	0.35 max	···	0.40 max
Copper	0.05 max	0.05–0.20	0.05 max
Manganese	0.03 max	0.05 max	0.01 max
Magnesium	0.03 max	···	···
Chromium	···	···	0.01 max
Zinc	0.05 max	0.10 max	0.05 max
Titanium	0.03 max	0.05 max	···
Others, each	0.03 max(a)	0.05 max	0.03 max(a)
Others, total	···	0.15 max	0.10 max
Aluminum	99.6 min	99.0 min	99.5 min

(a) Vanadium plus titanium 0.02% max, boron 0.05% max, gallium 0.03% max

Physical Properties:

	1060	1100	1350
Density, kg/m^3 (lb/in.^{3})	2699 (0.0975)	2713 (0.098)	2699 (0.0975)
Solidus, °C (°F)	646 (1195)	643 (1190)	646 (1195)
Liquidus, °C (°F)	657 (1215)	657 (1215)	657 (1215)
Coefficient of linear thermal expansion, average, 20–100 °C (68–212 °F), 10^{-6}/K (10^{-6}/°F)	23.6 (13.1)	23.6 (13.1)	23.8 (13.2)
Electrical conductivity, typical, O temper for 1060 and 1100, H111 temper for 1350, %IACS	62	59	61.0 min
Thermal conductivity, typical, 25 °C (77 °F), O temper for 1060 and 1100, H111 temper for 1350, W/m · K (Btu/(ft · h · °F))	234 (135)	222 (128)	234 (135)

Mechanical Properties:

See Table 1. Temper designations and definitions are shown in Table 2.

Formability:

Comparative characteristics for these alloys to others are shown in Fig. 1 for several tempers.

Table 1 High-Purity 1xxx Series Mechanical and Physical Property Limits

Standard tempers(a)	Tensile strength		Yield strength, 0.2% offset, min		Elongation in 2 in. or 4*D* (b), min, %	Shear strength, typical	
	MPa	ksi	MPa	ksi		MPa	ksi
1060							
F	No properties apply						n/a
O	59–97	8.5–14.0	17	2.5	25.0	48	7
H112	59 min	8.5 min	17	2.5	25.0		n/a
1100							
F	No properties apply						n/a
O	76–107	11.0–15.5	21	3.0	25.0	62	9
H112	76 min	11.0 min	21	3.0	25.0		n/a
1350							
F	No properties apply				(d)		n/a
H111(c)	59 min	8.5 min	24	3.5	(d)		n/a

All specified section or wall thicknesses. The thickness of the cross section from which the test specimen is taken determines the applicable mechanical properties. (a) The mechanical property limits for standard tempers are listed in *Aluminum Standards and Data* and *Tempers for Aluminum and Aluminum Alloy Products* published by the Aluminum Association. (b) For materials of such dimensions that a standard test specimen cannot be taken, or for shapes thinner than 0.062 in., the test for elongation is not required. *D* = specimen diameter. (c) For bus bar only, minimum flatwise bend radius = 1 × thickness at room temperature through an angle of 90° without cracking and with no evidence of slivers or other imperfections. Applicable to widths up through 12 in. (d) Elongation figures are not required for this particular alloy.

The flatwise minimum bending radius for 1350-H111 is 1 × thickness for all thicknesses and 90° bend with width to thickness ratio not exceeding 12 and widths not exceeding 100 mm (4 in.).

Machinability:

These alloys have relatively poor machinability.

Specification Equivalents:

UNS A91060 (1060)
UNS A91100 (1100)
UNS A91350 (1350)

General Characteristics:

Alcoa Engineered Products markets several alloys in the 1*xxx* series for many specialty applications. The alloys are non-heat-treatable, have the highest purity of aluminum compared to other series of aluminum alloys, and are offered as extruded sections with a minimum purity of 99.5% aluminum by weight. Some specific alloys offer aluminum contents as high as 99.0% aluminum by weight while some go to 99.6%. This alloy group offers the best corrosion resistance of any aluminum alloy group

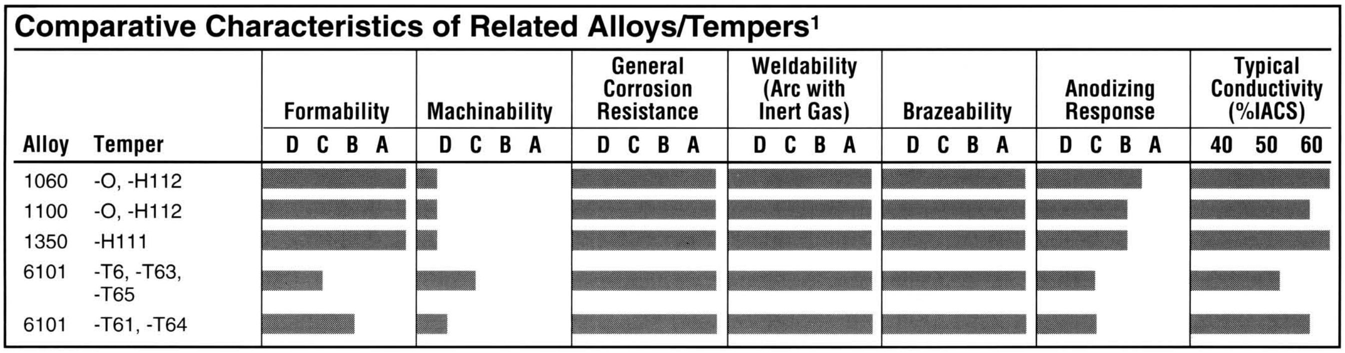


Fig. 1 Comparative characteristics of related alloys and tempers. A, excellent; B, good; C, fair; D, poor. For further details of explanation of ratings, see Aluminum Association's *Aluminum Standards and Data* manual.

and displays excellent forming, welding, brazing, and finishing characteristics. Excellent forming characteristics permit these alloys to be easily impacted, cold drawn, deep drawn, and bent into various configurations. These alloys can be extruded as profiles, rod, and bar. Three of the common alloys available are 1060, 1100, and 1350. Other 1*xxx* series alloys may be available through special inquiry.

Table 2 1*xxx* Series Temper Designations and Definitions

Alloy	Alloy description	Standard temper	Standard temper definition
1060	Highest purity available at Alcoa. High conductivity	F	As fabricated. There is no special control over thermal conditions, and there are no mechanical property limits.
		O	Annealed. Applies to products that are annealed to obtain the lowest-strength temper.
		H112	Same minimum properties as O temper, but no maximum. Strain-hardened temper via the extrusion process to develop minimum property 1100 requirements.
1100	Similar to but slightly stronger than 1060	F	As fabricated. There is no special control over thermal conditions, and there are no mechanical property limits.
		O	Annealed. Applies to products that are annealed to obtain the lowest-strength temper.
		H112	Same minimum properties as O temper, but no maximum. Strain-hardened temper via the extrusion process to develop minimum property require ments.
1350	Highest conductivity aluminum available in extrusions	F	As fabricated. There is no special control over thermal conditions, and there are no mechanical property limits.
		H111	Minimum 61.0% IACS conductivity. Strain-hardened temper via the extru sion process to develop minimum property requirements.

For further details of definitions see *Aluminum Standards and Data* and *Tempers for Aluminum and Aluminum Alloy Products* published by the Aluminum Association.

Alloy 1060 is a high-purity grade with a 99.6% minimum aluminum content. Typical applications include chemical and food-handling equipment, and containers for food, pharmaceutical, and liquids.

Alloy 1100 shares some of the same applications as alloy 1060, plus fin stock, spun hollowware, impacted fire extinguisher bottles, and tubing. This alloy contains slight additions of silicon, iron, and copper for strength.

Alloy 1350 is used primarily for electrical conductors. This alloy, when ordered in the H111 temper, exhibits the highest electrical conductivity of all extruded aluminum conductor grades, meeting or exceeding 61.0% IACS.

Alloy 1060 has a 99.6% minimum aluminum content, 1100 has a 99.0% minimum aluminum content, and 1350 has a 99.5% minimum aluminum content.

Product Forms Available:

Alcoa produces the alloys in standard architectural shapes, particularly rod and plate.

Applications:

Typical market applications for 1*xxx* series include heat exchanger tubing, impact stock, cable sheathing, electrical conductors, and medical and chemical instrumentation.

Producer:

Alcoa Engineered Products
Cressona, PA 17929
(800) 233-3165
(800) 252-4646 (fax)
www.alcoa.com

ISSN: 002-614X AI-395B

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Cer-1
Ceramic

MARCH 1989

ZIRCAR ZIRCONIA POWDER TYPE ZYP-4.5

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ZIRCAR ZIRCONIA POWDER TYPE ZYP-4.5

(Yttria Stabilized Zirconia Powder)

ZIRCAR* ZIRCONIA POWDER TYPE ZYP-4.5 is a highly reactive form of zirconium oxide stabilized in the tetragonal crystal state with added yttrium oxide. It is an excellent raw material for producing dense structural and wear resistant parts.

*ZIRCAR is a registered trademark of ZIRCAR Products Inc.

Composition (Nominal, weight %):

ZrO_2	95.5*
Y_2O_3	4.5± 10%
Cl	0.03
Impurities;	
SO_4	0.1
SiO_2	0.2
TiC_2	0.05
Loss on ignition	<2.0

*ZrO_2 typically contains 1.5-2.0% HfO_2

Powder Characteristics:

Color	White
Crystallite size, m x 10^{-6}	0.02-0.03
Surface area, m^2/g	30-45
Bulk density, g/cu cm	0.58
Tap density, g/cu cm	0.83
Agglomerate size distribution	
<0.1m x 10^{-6}	30%
<0.3m x 10^{-6}	50%
<0.5m x 10^{-6}	72%
<0.7m x 10^{-6}	85%
<1.0m x 10^{-6}	97%

PROPERTIES

Table 1 -- TYPICAL CHARACTERISTICS OF DENSE PARTS FABRICATED FROM ZYP-4.5 POWDER

Consolidation, uniaxial dry press, psi	20000
Green density, g/cu cm	2.56
Sintered density, 3h at 1500°C (2732°F), g/cu cm	5.97
Grain size, m x 10^{-6}	0.4-0.7
Principal phase	Tetragonal
Thermal coef. expansion/°C (At 25°C)	8 x 10^{-6}
(At 1000°C)	10 x 10^{-6}
Thermal conductivity, cal/cm/sec/°C	0.007*
Elastic modulus, psi	17 x 10^6
MPa	117 x 10^3
Flexural strength, psi	175000±15%
MPa	1200±15%
Fracture toughness, MPa$\sqrt{m}$	8*
Vickers hardness, kg/mm^2	1300*

*Typical values for the range of partially stabilized ZrO2 materials
All other tabulated values are specific to parts from ZYP-4.5 powder.

Processing:

Compaction: Press Without lubricant at about 20000 psi (uniaxial press).
Sintering: 3h at 1500°C (2732°F)

Handling:

Provide ventilation protection as prescribed by OSHA Standard 29CFR 1910.94. Avoid breathing dust: use respirator in compliance with OSHA standard 29CFR 1910.134. Use protective gloves and eye protection (goggles/face shield). Wear long sleeve, loose fitting clothing when handling in a manner that generates respirable dust. Remove spilled material or work –generated dust with vacuum fitted with HEPA filter. Use a dust suppressant. Dispose of waste by routine housekeeping procedures.

General Characteristics:

ZIRCAR zirconia powder has an extremely fine crystallite size giving it broad applicability . Pressed and sintered parts develop high strength. They have a use temperature of up to 2200°C (3990°F). The powder is white and odorless. Common precautions should be taken to minimize inhalation, ingestion and skin contact.

Forms Available:

In addition to the 4.5 % Y_2O_3 stabilized type powder described here, 8 and 12% Y_2O_3 stabilized powders are regularly available as is also unstabilized zirconia powder. Powders with other levels of yttria stabilization may be made available by special request in lots as small as 10lbs

Applications:

Presses and sintered thread guides, ;cutting tools, engine components and others.

Manufacturer:

Zircar Products Inc.
Florida, New York 10921

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

ALUMINA SILICATE 902

Filing Code: Cer-2
Ceramic

APRIL 1989

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ALUMINA SILICATE 902*
(Machinable Ceramic)

ALUMINA SILICATE 902 is a machinable ceramic with a limiting continuous service temperature of 2100°F (1150°C).

*902 is the Cotronics Corporation's identification number.

Chemical Characterization:

High purity alumina silicate.

Physical Constants:

Melting point, °F	3200
°C	1760
Density, lb/cu in.	0.083
g/cu cm	2.30
Thermal coef. expansion/°F	1.8×10^{-6}
°C	3.24×10^{-6}
Thermal conductivity, Btu/h/ft2/in.//°F	7.5
Electrical resistivity, ohm-cm	10^{14}
Dielectric strength, volts/mil	100
Dielectric constant (100kc)	5.3
Loss factor	0.04

PROPERTIES

Table 1 -- MECHANICAL PROPERTIES

Compressive strength, psi	38000
MPa	262
Flexural strength, psi	14000
MPa	96
Hardness, mohs scale	6

Firing:

Material as supplied is machinable and usable to temperatures up to 1100°F (593°C). Air firing at 1900-2000°F (1038-1093°C) develops full hardness and extends the usable temperature to 2100°F (1150°C). Material should be placed in a cold furnace without protective atmosphere. Protect work from direct flame impingement or contact with heating elements. Heat at 200°F/hour, maximum to 1900-2000°F (1038-1093°C). Hold at temperature 1/2 hour for 1/4 inch thickness; 1 hour for 1/2 inch thickness; 1 1/2 hour for 3/4 inch thickness, etc. Cool in the furnace to below 200°F before removing. Parts should be designed to have gradual transition from thick to thin sections. Consult the producer for more specific firing details.

Machining:

Material as supplied is machinable using conventional equipment. Carbide tipped tools should be used if available. Tools must be maintained sharp to minimize chipping of the work. Cutting, turning, drilling, tapping, milling, slotting, grinding are among the operations which may be performed. Machine 2% under size to allow for expansion that occurs on final firing. Machine dry, no lubricants or coolants. Machinist should take the normal precautions to guard against airborne dust such as wearing a face mask. For ultra precision, wet grind using silicon carbide wheels.

General Characteristics:

ALUMINA SILICATE 902 machinable ceramic may be machined as supplied using conventional equipment and tooling. Allow for 2% expansion in final firing after machining. After final firing, material is usable to 2100°F (1150°C) in continuous service in oxidizing, reducing or vacuum environments. The material has excellent thermal shock resistance. Porosity of final fired material is 2.9%.

Forms Available:

Stock size, inches:

Flats

Thickness	Area
1/4, 1/2, 3/4, 1, 1 1/2, 2	4 x 12 or 6 x 6
1/4, 1/2, 1	12 x 12

Rods

Diameter	Length
1/4	6
1/2, 3/4, 1, 1 1/2, 2, 3, 4	12

Special sizes and custom machined parts upon request.

Applications:

Prototype hardware; brazing, soldering, RF heating and vacuum fixtures; supports; electrical components; insulators.

Manufacturer:

Cotronics Corporation
Brooklyn New York 11235

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

ALSIMAG® 222

Filing Code: Cer-3
Ceramic

MAY 1989

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ALSIMAG 222

(Machinable Ceramic)

AlSiMag® 222 is a porous ceramic material. It has excellent electrical insulating properties at elevated temperatures. For high frequency applications as an insulator, impregnation with a moisture repellant substance is required. AlSiMag 222® is well suited to prototype model making.

AlSiMag® is a registered trademark of AlSiMag® Technical Ceramics, Inc.

Composition:

AlSiMag® 222 is a magnesium silicate ceramic.

Physical Constants:

Property	Unit	ASTM test number	Value
Water absorption	%	C373	14 to 18
Specific gravity	--	--	2.0
Density	lb/cu in.	--	0.072
Volume	cu in./lb	--	13.85
Color	--	--	light brown
Hardness	Mohs's scale	--	6
Softening temperature	°C (°F)	C24-26 C24-35	1625 (2957)
Resistance to heat (safe limit, constant temp.)	°C(°F)	--	1300 (2372)
Thermal coef. expansion	per °C	--	
25-100°C			8.9×10^{-6}
25-600°C			10×10^{-6}
Thermal conductivity	W/m°K	C408	
25°C			5.8
300°C			3.9
500°C			2.9
800°C			2.4
Volume resistivity	Ohm-cm	--	
25°C (770°F)			$>10^{14}$
100°C (212°F)			$>10^{14}$
300°C (572°F)			6.0×10^{11}
500°C (932°F)			4.6×10^{9}
700°C (1292°F)			1.7×10^{8}
900°C (1652°F)			1.1×10^{7}
Dielectric strength*	volt/mil(kV/mm)	D149	50 (2.0)
Dielectric constant, 25°C			
1 to 100Hz		D667-42T	5.5
1MHz to 100MHz		D150	5.5
Dissipation factor, 25°C		D150	
1MHz to 100MHz			0.0002
Loss factor, 25°C		667-42T	
1Hz to 100MHz			0.001

*60 Hz AC, test disc 1/4 in. thick.

PROPERTIES

Table 1 -- ROOM TEMPERATURE MECHANICAL PROPERTIES

Property	ASTM Test Number	Unit	Value
Tensile strength	--	psi (MPa)	2500 (17.3)
Compressive strength	C528	psi (MPa)	1000 (6.9)
Flexural strength	C369	psi (MPa)	5000 (35)
Impact resistance	Charpy D256	in.-lb (Nm)	1.9 (0.21)

Shaping:

Conventional pressing or hydrostatic pressing or extrusion may be used.

Firing:

AlSiMag® 222 is ready for use directly after shaping. Firing is not required. This eliminates cracking problems.

Machining:

Almost any conventional machining process can be used with AlSiMag® 222. The material is quite abrasive, however and tungsten carbide tipped tools are used for turning and milling. When only a small number of pieces are to be drilled or tapped, steel tools can be used with frequent grinding as necessary. Slow drilling and tapping speeds reduce tool wear and yield smoother finishes. Cutting of plates and rods can be done with thin abrasive wheels. Surfacing can be done with abrasive paper or grinding wheels. Filing is not practical. Machining and surfacing should be done without the use of liquid lubricants or coolants.

General Characteristics:

AlSiMag® 222 is machinable. This ceramic is porous and if it is to be used under high-frequency ac conditions, it must be impregnated. This can be easily accomplished by immersion in molten wax of high dielectric quality or by impregnation with solutions of wax or suitable organic resins.

Forms Available:

Consult with the producer.

Applications:

Insulators, furnace parts for high-temperature service, prototype modelling.

Producer:

AlSiMag Technical Ceramics, Inc.
Division of Ceramx
P.O. Box 89
Laurens, South Carolina 29360

Alloy DIGEST
SILICON NITRIDE SN-220
Filing Code: Cer-4
Ceramic
JULY 1990
DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

SILICON NITRIDE SN-220

(Engineering Ceramic)

SILICON NITRIDE SN-220 has found its niche in industrial applications in engine and gas turbine components. It has excellent high-temperature strength and thermal shock resistance.

Chemical Characterization:

SILICON NITRIDE SN-220 is a sintered Si_3N_4 silicon nitride ceramic.

PROPERTIES

Physical Properties:

Color	Black
Specific gravity	3.2
Water abscrption, %	0
Thermal coef. expansion (40-400°C)/°C	2.6×10^{-6}
(40-800°C)/°C	3.2×10^{-6}
Thermal conductivity (At room temperature)	
cal/cm•sec•°C	0.05
W/m•K	21
Specific heat (At room temperature), cal/g•°C	0.16
Heat shock resistance*, °C (°F)	550(1022)
Volume resistivity (at room temperature), ohm-cm	10^{14}

*Flexural strength unaffected by quench up through this temperature.

Mechanical Properties:

Flexural strength (4-point bending)	
ksi (MPa) At room temperature	86(590)
At 800°C (1472°F)	87(600)
At 1000°C (1832°F)	74(510)
At 1200°C (2192°F)	47(323)
At 1300°C (2372°F)	17(117)
Fracture toughness, K_{ic}, MPa•$m^{1/2}$	5.7
Modulus of elasticity*, psi	43×10^6
MPa	294×10^3
Poisson's ratio (Room temperature)	0.28

*Average of compression and tension modulii. Compression modulus is about 2% greater than tension modulus.

General Characteristics:

Silicon Nitride SN-220 has excellent mechanical strength at high temperatures. It possesses high heat shock resistance. It has excellent resistance to wear and chemical corrosion. It has low specific gravity.

Applications:

Ceramic glow plugs, swirl chambers and turbo rotor diesel and gasoline engine components are in commercial production. Automotive pistons, cylinder liners and fuel injectors fabricated from silicon nitride are being evaluated. Silicon nitride is widely used in fixtures, spindles and ball screws for machine tools and welding nozzles where heat shock resistance, fracture toughness and wear resistance are requirements.

This engineering ceramic is ideal for foundry use in processing molten aluminum and zinc and their alloys whose melt temperatures are in the range of 1200°F and 800°F (650 and 425°C) respectively.

Producer:

Kyocera America, Inc.
San Diego, California 92123.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

SILICON CARBIDE SC-221

Filing Code: Cer-5
Ceramic

JULY 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

SILICON CARBIDE SC-221
(Engineering Ceramic)

SILICON CARBIDE SC-221 is a beta-phase silicon carbide made from the pressureless sintering method. It possesses excellent mechanical strength at high temperature (4-point bending strength of 71ksi [490 MPa] at 1400°C [2552°F]).

Chemical Characterization:

SILICON CARBIDE SC-221 is a sintered beta SiC ceramic.

PROPERTIES

Table 1 – PHYSICAL PROPERTIES

Color	Black
Specific gravity	>3.0
Water absorption, %	0
Thermal coef. expansion/°C (40-400°C)	3.9×10^{-6}
(40-800°C)	4.4×10^{-6}
Thermal conductivity (@ room temperature),	
cal/cm•sec•°C	0.17
W/m•K	71
Specific heat (@ room temperature), cal/g•°C	0.16
Heat shock resistance, °C (°F)*	350 (662)
Volume resistivity (@ room temperature), ohm-cm	10^3

*Flexural strength unaffected by quench up through this temperature.

Table 2 – MECHANICAL PROPERTIES

Hardness, Rockwell A	94
Vickers/500g load, GPa	20
Flexural strength, ksi (MPa) @ room temperature*	71 (490)
@ 1400°C	71 (490)
Fracture toughness, MPa $\sqrt{m}$	3.4
Young's modulus of elasticity, psi x 10^6 (GPa)	54 (372)
Poisson's ratio (@ room temperature)	0.16

*4-point bending (JIS R 1601)

General Characteristics:

Silicon Carbide SC221, a beta phase ceramic, is made by pressureless sintering. It maintains its room-temperature flexural strength of 71ksi (490MPa) to 1400°C (2552°F). Its Vickers hardness 500 g load) is just over 20 GPa, slightly greater than that of silicon nitride and approaching that of single crystal sapphire (22.5 GPa). It has high thermal conductivity at room temperature. Its corrosion resistance is excellent.

Applications:

Mechanical seals, plungers and cylinders for pumps; gas turbine components and measuring equipment fixtures at service temperatures above 1300°C (2372°F).

Producers:

Kyocera American, Inc.
San Diego, California 92123.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: CI–40
Cast Iron

MAY 1973

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

ALMANITE WSH

ALMANITE* WSH
(Abrasion-Resistant Austenitic Cast Iron)

ALMANITE WSH is an austenitic nodular iron possessing superior tensile strength, toughness and ability to work harden under conditions of severe pounding impact. It is recommended for crusher liners, hammers, grinding balls, etc.

*ALMANITE is a registered trademark of the Meehanite Metal Corporation.

Composition:

	Nominal
Carbon	3.4-3.6
Manganese	5.0-9.0*
Phosphorus	0.06 max.
Sulfur	0.02 max.
Silicon	1.8-2.0
Aluminum	1.5-2.0
Nickel	Optional**
Iron	Remainder

*Manganese varies with section thickness.
**Nickel may replace manganese up to 50% on a weight basis, especially in heavy sections.

Physical Constants: (Approximate)

Density, lb/cu in.	0.275-0.282
Specific gravity	7.6-7.8
Melting point, °F	2200
Specific heat, Btu/lb/°F (300°F)	0.13
(1560°F)	0.16
Thermal coef. expansion/°F (70-800°F)	9.75×10^{-6}
Modulus of elasticity, psi (Tension)	24×10^{6}
Modulus of rigidity, psi (Torsion)	10×10^{6}

PROPERTIES

Table 1 – TYPICAL MECHANICAL PROPERTIES – Castings (As-Cast Condition)

Tensile strength, min, psi	100000
Yield strength (0.2% Offset), psi	75000
Elongation (2 in.), %	4-10
Brinell hardness	350-500
Izod impact, ft-lb (1.2-in. bar, smooth, no notch)	Up to 120

Heat Treatment:

As-cast ALMANITE WSH, before the following heat treatment (anneal), may be partially martensitic and will often contain a relatively large proportion of free carbide.

Annealing: Heat to 1250°F, soak 1 hour per inch of thickness, transfer to a furnace at 1900°F and hold until entire casting has reached this temperature, then quench in brine. The structure is now austenitic with nodular graphite but no carbides and is used in this condition.

Machinability:

Machining of ALMANITE WSH is extremely difficult and follows the procedure used for austenitic manganese steels. The customary practice is to finish grind wherever possible.

Castability:

ALMANITE WSH has very good castability. Because it is generally heat treated before being placed in service, it can be cast without chilling and this allows substantial economies in the foundry.

Cleaning:

Mold materials and scale can be removed by blasting. Acid pickling is not employed for cleaning.

General Characteristics:

ALMANITE WSH is an abrasion-resistant austenitic nodular cast iron possessing superior tensile strength, toughness and ability to work harden under conditions of severe pounding impact. It has the same basic characteristics as austenitic manganese steel, but it has a much higher yield point and lower elongation. It has good castability and poor machinability, but can be finish ground readily. It is recommended and used where shock and stresses in service are unusually severe.

The outstanding feature of ALMANITE WSH is its excellent combination of properties, namely: Izod impact value of 120 ft-lb, minimum tensile strength of 100,000 psi, yield strength of 75,000 psi, and elongation as high as 10%. A maximum Brinell hardness of 500 can be developed by work hardening.

Forms Available:

Castings.

Applications:

Rock crusher liners, impact hammers, crusher jaws, wearing blades, dredge buckets, dipper teeth caps for teeth of land-clearing rakes, pulverizers and all types of rock-handling equipment.

Manufacturer:

Meehanite Metal Corporation
White Plains, New York 10604.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Co-15
Cobalt Alloy

FEBRUARY 1959

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

UNITEMP L-605

UNITEMP L-605

(High Temperature Alloy)

UNITEMP L-605 is a cobalt-base alloy having the highest strength at high temperatures above about 1600°F. It is used only where high stresses exist at the upper end of the temperature range of 1700° to 2000°F.

Composition:

Carbon	0.05 - 0.15
Manganese	1.00 - 2.00
Silicon	1.00 max.
Sulphur	0.030 max.
Phosphorus	0.040 max.
Chromium	19.00 - 21.00
Nickel	9.00 - 11.00
Tungsten	14.00 - 16.00
Iron	3.00 max.
Cobalt	Remainder

Physical Constants:

Specific gravity	9.20
Density, lb./cu. in.	0.333
Melting point, °F.	2570-2620
Thermal coef. expansion, in/in/°F. x 10^{-6}	
70-600°F.	7.61
70-1000°F.	8.31
70-1500°F.	9.08
Thermal conductivity, BTU/ft²/in/hr/°F.	
at 70°F.	88
800°F.	134
1200°F.	153
Specific heat, BTU/lb/°F. (70-212°F.)	0.090
Modulus of elasticity, psi x 10^6	
at 70°F.	35.3
at 1000°F.	28.5
at 1800°F.	21.45

PROPERTIES

(All data developed on specimens heat treated prior to testing by annealing at 2150-2250°F. followed by rapid cooling. Specimens held at temperature a minimum of 30 minutes prior to start of test.)

Table 1 — IMPACT STRENGTH

Test Temperature °F.	Impact Strength ft. lbs.	Type Test
-58	120+	Izod — unnotched
-58	114	Izod — notched
70	120+	Izod — unnotched
70	120+	Izod — notched
1000	198	Charpy — V notch
1400	145	Charpy — V notch
1600	120	Charpy — V notch
1800	105	Charpy — V notch

Table 2 — HOT HARDNESS

Test Temperature °F.	Rockwell Hardness
70	C21
800	B79
1000	B77
1200	B76

Table 3 — TENSILE PROPERTIES*

Test Temperature °F.	Ultimate Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Rockwell Hardness
70	160700	85800	47	C24
1000	130600	53900	40	
1200	94000	54900	29	
1400	73000	49000	12	
1500	55300	44900	16	
1600	40000	37000	25	
1800	29200	27500	37	

* Test specimens taken from 0.062" sheet product.

Table 4 — STRESS TO RUPTURE STRENGTH*

Test Temperature °F.	Stress, psi to Produce Rupture in 10 hrs.	100 hrs.	1000 hrs.	10000 hrs.
1200	58000	47500	39000	32000
1500	28000	21000	16000	12000
1600	25000	15500	9800	6000
1700	17000	10000	6000	3600
1800	9700	6500	3600	—

* Test specimens taken from 0.040" and 0.062" sheet product.

Table 5 — SECONDARY CREEP RATES*

Test Temperature °F.	Stress, psi for Minimum Creep Rate of 0.0001%/hr.	0.00001%/hr.
1500	13000	9000
1600	7100	5300
1700	4300	3000
1800	2900	2000

* Specimens taken from 0.040" sheet product.

Table 6 — FATIGUE STRENGTH

Test Temperature °F.	Endurance Limit, psi 10^8 Cycles
1200	63500
1400	60500
1600	47000
1800	20000

Table 7 — STRESS RELAXATION

Test Temperature °F.	Initial Stress psi	Residual Stress, psi after 100 hrs.	1000 hrs.
1050	70000	42000	39000
1200	45000	19400	17200
1350	25000	14000	12500

Heat Treatment:

Solution Anneal: Heat at 2200-2250°F., cool rapidly in air to approximately 230 Brinell.

Aging Treatment: Age-hardening tendencies are noted after exposure to temperatures in the 1600-1900°F. range, accompanied by some loss in ductility.

Machinability:*

Machinable with high-speed tools using low speeds and small depth of cut, and easily machined with tipped-carbide tools. Suggested tool angles for single point high speed steel cutters are 4-5 deg. front and side relief, 0-8 deg. back rake, 8 deg. side rake, 15-30 deg. side cutting-edge angle, 10-15 deg. end cutting-edge angle, and 1/32 - 1/16 in. nose radius. Carbide-tipped tools may have a nose radius of 1/32 in. or less.

In drilling, high speed steel drills ground to an included angle of 135-140 deg., a clearance angle of 10 deg., and a web thinned to about 1/3 of the web thickness of the standard drill are recommended. It is advisable to keep as much pressure as possible on the drill at all times and to make certain the drill is kept sharp. Cutting fluids are required for all machining operations. Coolant should also have a lubricant included.

Best results are realized in the annealed condition. The techniques and equipment used for austenitic stainless steels can be used, however, machining is more difficult. Sharp tools, positive cuts, slower feeds and speeds, and a rigid tool setup are necessary requisites because of the strong tendency of this alloy to strain harden during machining. (Universal Cyclops)

* Woldman & Gibbons: Machinability and Machining of Metals.

Workability:

Due to its high alloy content, it is "stiffer" at forging temperatures than the 300 series stainless steels. Recommended hot working range is 2250°F. (furnace setting) start and 1850°F. finish. Below 1850°F. it is difficult to work. Neutral or slightly oxidizing atmospheres should be used and heating cycles adjusted to allow for sufficient soak prior to forging. Rate of cooling from the forging operation is not critical and an air cool is most generally used. It has excellent ductility at room temperature, and sheets can be readily formed in bending, stamping, drawing, and spinning. It work hardens very rapidly. Frequent "in process" anneals are generally required to restore ductility lost by cold working. In some severe forming operations it has been found expedient to preheat the material to around 450°F.

Weldability:

This alloy has good welding characteristics and weldments can be made by conventional metallic arc and resistance methods. Restraint during welding should be kept to a minimum to avoid strain cracking in the weld area. Annealing after welding is recommended. Brazing can also be carried out satisfactorily.

Corrosion Resistance:

High resistance to scaling and oxidation at elevated temperatures. Alloy shows particularly good qualities under extreme oxidizing conditions. Excellent resistance to chemical oxidizing agents. Extraordinary resistance to hydrochloric and nitric acids at certain concentrations and temperatures. Resistance to salt spray corrosion is very good.

L-605 has excellent resistance to the hot corrosive atmospheres encountered in jet engine operation. Resistance to oxidation is good for intermittent service up to 1600°F. and continuous service up to 2000°F.

Specification Equivalents:

AMS 5537 and 5759

General Characteristics:

Unitemp L-605 is a cobalt-base high-temperature alloy which was developed to provide good oxidation and corrosion resistance as well as high strength properties under service conditions at elevated temperatures. Considered primarily a "solution hardened" material, its cobalt base is alloyed with chromium, nickel and tungsten. In most applications it is used in the fully annealed condition. Its structure is austenitic under all conditions. It has high resistance against mechanical and thermal stresses, and has excellent hot ductility.

Forms Available:

Sheet, strip, bar, and forging stock.

Applications:

Parts in the afterburner and other hot sections of the jet engine. Support rings, burner liners, exhaust cone assemblies, nozzle diaphragm valves, high temperature valves and springs, gas turbine rotors and buckets. Highly stressed parts that must operate at high temperatures.

Manufacturer:

Universal Cyclops Steel Corporation
Bridgeville and Titusville, Pennsylvania

Alloy DIGEST

ULTIMET™ ALLOY

Filing Code: Co-89
Cobalt Alloy

MARCH 1993

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ULTIMET™ ALLOY
(Improved Co-Cr-Mo Cobalt-Base Alloy)

ULTIMET alloy is a cobalt-base "corrosion-wear" alloy that compares with HASTELLOY® alloys in corrosion and resistance to STELLITE® alloys in its wear resistance. It is available as both wrought and cast products.

ULTIMET is a trademark of Haynes International, Inc.

Composition, Nominal Wt., %:

Chromium	26
Nickel	9
Molybdenum	5
Iron	3
Tungsten	2
Carbon	0.06
N	0.08
Si	0.3
Mn	0.8
Cobalt	Bal.

Physical Properties:

Density	0.306 lbs/in³
Coefficient of expansion	See Table 1
Modulus of elasticity	See Table 2

PROPERTIES

Table 1 – MEAN COEFFICIENT OF THERMAL EXPANSION

Temperature Range °C	°F	Coefficient µm/m.-°C	µin/in.-°F
26-38	78-100	12.8	7.1
26-93	78-200	13.0	7.2
26-149	78-300	13.2	7.3
26-204	78-400	13.5	7.5
26-260	78-500	13.8	7.7
26-427	78-800	14.5	8.0
26-593	78-1100	14.9	8.3
26-760	78-1400	15.9	8.8
26-927	78-1700	16.7	9.3

Table 2 – MODULUS OF ELASTICITY

Temperature °C	°F	Modulus of Elasticity* 10^6 psi	GPa
RT		33.2	229
38	100	33.1	228
93	200	32.6	225
149	300	31.9	220
204	400	31.2	215
260	500	30.6	211
427	800	28.6	197
593	1100	26.8	185

*Bar 12.7 mm, 0.5 in.

Table 3 – MECHANICAL PROPERTIES

Condition	Tensile Properties UTS (Ksi)	YS (Ksi)	Elongation (%)
Annealed	149	82	35.5
Annealed + 1000°F*	151	77	44.2
Annealed + 1200°F	152	76	45.1
Annealed + 1400°F	144	75	26.6
Annealed + 1600°F	144	75	29.5
Annealed + 1800°F	149	74	39.8

*100 hours aging time at temperature prior to room temperature tensile test

HARDNESS

Condition	Rockwell
Mill annealed	C-30
+ 10% cold reduction	C-40
+ 20% cold reduction	C-43
+ 30% cold reduction	C-47
+ 40% cold reduction	C-49

Table 4 – ROOM TEMPERATURE TENSILE PROPERTIES

Condition	0.2% YS Offset MPa	(ksi)	UTS MPa	(ksi)	Elongation %
Mill Annealed Plate	547	(79.3)	1019	(147.8)	36.0
Investment Cast	392	(56.9)	773	(112.1)	34.7
All Weld Metal					
As Welded (GTA)	652	(94.6)	917	(133.0)	10.3
Annealed (GTA)	487	(70.6)	831	(120.5)	12.9
As Welded (GMA-S*)	584	(84.7)	851	(123.4)	17.9
Annealed (GMA-S)	464	(67.3)	827	(119.9)	21.5

*Spray mode

Table 5 – LOCALIZED CORROSION: PITTING

Critical Pitting Temperature
11.5% H_2SO_4 + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$
24 Hours

Alloy	Temperature* °C	°F
C-22™ alloy	120	248
ULTIMET alloy	120	248
alloy C-276	110	230
alloy 625	75	167
alloy 6B™	45	113
20CB-3® alloy	30	86
316L Stainless	25	77

*Temperature at which pitting is initiated

Machinability:

ULTIMET alloy can be successfully turned, drilled and milled providing appropriate tooling and parameters are employed. The alloy possesses high strength, and therefore resists metal removal. It also work hardens rapidly from a hardness of approximately 30 HRC, in the solution annealed condition, to approximately 40 HRC, after 10% cold reduction. The alloy is most easily machined in the solution annealed condition.

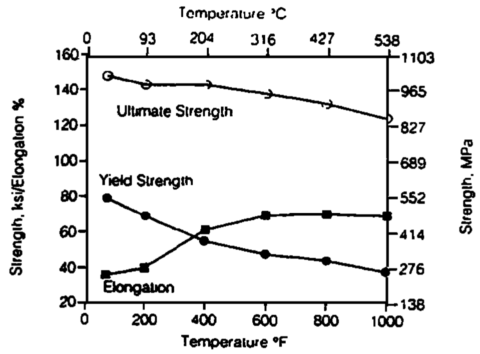
Consult producer for additional advice on machines and tooling practice.

The following machine parameters are recommended for ULTIMET alloy:

Turning:
° Carbide (not high speed steel) tools are recommended
° Surface Speed: 0.30 to 0.35 m/s (60 to 70 ft/min)
° Feed Rate: 0.13 to 0.25 mm (0.005 to 0.010 in) per revolution
° Depth of cut for roughing: 1.3 to 2.5 mm (0.05 to 0.10 in)
° Depth of cut for finishing: 0.25 to 0.38 mm (0.010 to 0.015 in)

Drilling:
° Carbide tipped or high speed steel drills are recommended
° Surface Speed:
-High Speed Steel Drills: 0.04 to 0.05 m/s (8 to 10 ft/min)
-Carbide Tipped Drills: 0.15 to 0.18 m/s (30 to 35 ft /min)

Elevated Temperature Tensile Properties



Figue 1

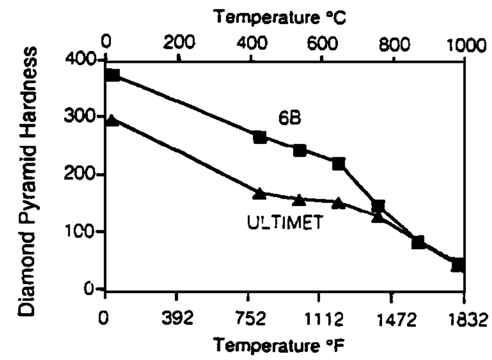


Figure 2

Industrial Test

Phosphoric Acid Slurry

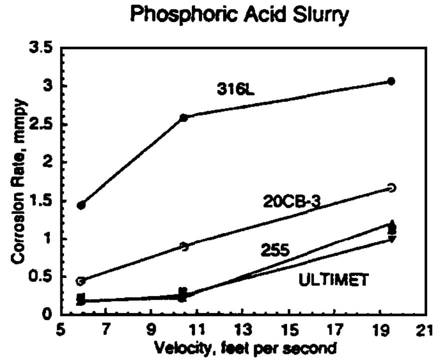


Figure 3

30% $MgCl_2$, 118°C (244°F)

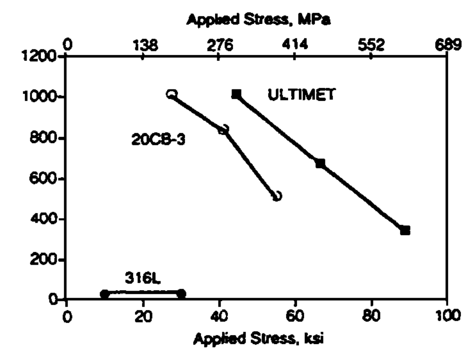


Figure 4

- Feed Rate: 0.1 mm (0.004 in) per revolution for drills of 6.4 mm (0.25 in) diameter and greater
- 135° included angle on point
- Web can be thinned to reduce thrust

Milling:

- Carbide (not high speed steel) end mills are recommended
- Carbide End Mill Surface Speed: 0.12 to 0.15 m/s (25 to 30 ft/min)
- Feed Per tooth
  - -Cutter diameter below 19 mm (0.75 in): 0.05 mm (0.002 in) feed
  - -Cutter diameter above 19 mm (0.75 in): 0.08 mm (0.003 in) feed

Weldability:

ULTIMET alloy possesses excellent weldability, is resistant to hot cracking, and is fabricated using standard welding procedures. Sound welds are readily achieved when good welding practices are observed. These include joint preparation and cleaning prior to welding. Preheating is not required. Weld interpass temperatures should be kept below 93°C (200°F) when possible. All other established practices for welding solid solution strengthened cobalt-base alloys such as HAYNES 25 and 188 alloy should be followed. These include avoiding contamination of the area to be welded with copper, either from copper jigs and fixtures, or from the use of copper-wire cleaning brushes. Stainless steel-wire brushes are recommended for interpass cleaning. ULTIMET weld metal possesses limited room temperature ductility. For weld procedure development, however, a 3T longitudinal bend test should produce acceptable results. Furthermore, if cold forming of a weldment is necessary, where the bend radius will be equivalent to less than 4T, solution annealing at 1120°C (2050°F) followed by water quenching is recommended prior to forming.

General Characteristics:

The alloy was designed to resist erosion-corrosion (combined mechanical and chemical degradation). It is rich in cobalt and shares many of the wear characteristics of the STELLITE alloys. At the same time, by control of carbon and careful selection of chromium, molybdenum, and tungsten levels, many of the most corrosion resistant nickel-base properties have been attained. The alloy performs well under most wear conditions, particularly to cavitation erosion, slurry erosion, and galling.

Forms Available:

Bar, billet, plate, sheet, wire, weld products, casting, and powder.

Applications:

Agitator in fertilizer manufacturing, baghouse straps and filter screens and impact plates in waste treatment; blower shafts, bolts, burner tips, fan shaft and blades, nozzle, pump bushing, pump spool, screw conveyor, valve body, and wiper blades in chemical processing; cam and bolts in pulp and paper bleaching; galvanizing rolls in metal finishing; grinder wear inserts in sewage treatment; mixer shafts in food and pharmaceutical; mold and plunger in glass manufacturing; nozzles and pump wear plates in flue gas desulfurization; scraper blades in glass processing; shredder inserts in nuclear waste treatment; valves in marine; valve stem overlays in oil and gas; wear shields-fans in fiberglass manufacture and weirs in incinerator scrubbers.

Specification Equivalents:

UNS R31233
DIN CoCr26Ni9Mo5W
Werkstoffe Nr.2.4681
ASTM B815, B818
ASME Code Case 2121
Note: C-22, 6B, HAYNES and HASTELLOY are trademarks of Haynes International, Inc. STELLITE is a trademark of Thermadyne Deloro Stellite, Inc. 20 CB-3 is a trademark of Carpenter Technology Corporation.

Producer:

Haynes International, Inc.
Kokomo, IN 46904-9013
800-354-0806

Alloy DIGEST™
DATA ON WORLDWIDE METALS AND ALLOYS

INCONEL® ALLOY 783

Filing Code: Co-95
Cobalt

Revised February 2004

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 Mem-Serv@asminternational.org
Fax 440-338-4634 www.asminternational.org

INCONEL® ALLOY 783
(Age-Hardening Nickel-Iron-Cobalt Superalloy)

Inconel Alloy 783 is an oxidation-resistant, low-expansion, Ni-Co-Fe alloy with other additions. The alloy is a three-phase aging alloy that is of interest for close-clearance control components in the aerospace industry.

Inconel is a registered trademark of the Special Metals Corporation group of companies.

Chemical Composition, wt.%:

Nickel	26.0–30.0
Chromium	2.5–3.5
Iron	24.0–27.0
Niobium	2.5–3.5
Boron	0.003–0.012
Titanium	0.1–0.4
Aluminum	5.0–6.0
Carbon	0.03 max
Manganese	0.50 max
Silicon	0.50 max
Phosphorus	0.015 max
Sulfur	0.005 max
Copper	0.50 max
Cobalt	bal

Physical Properties:

(Age-Hardened Condition)

Density, kg/m^3 (lb/in.^{3})	7810 (0.282)
Melting range, °C (°F)	1336–1407 (2437–2565)
Specific heat capacity, 25 °C (77 °F), J/kg · K (Btu/lb · °F)	455 (0.109)

See also Table 1.

Mechanical Properties:

See Tables 2 and 3. In the age-hardened condition, this alloy has high mechanical properties at room temperature and retains much of its strength at temperatures to about 704 °C (1300 °F). All mechanical properties given here are for the standard heat treatment given below.

Heat Treatment:

Solution anneal at 1121 °C (2050 °F) for 1 h, air cool, beta age at 845 °C (1550 °F) for 4 h, air cool to room temperature, age harden at 720 °C (1325 °F) for 8 h, furnace cool at 55 °C/h (100 °F/h) to 620 °C (1150 °F), and air cool.

Fabricability:

This alloy has good fabricability and can be formed, machined, and welded by convention procedures used for nickel alloys. It behaves similarly to Inconel alloy 718.

Table 1 Mean Coefficient of Linear Expansion (Age Hardened)

Temperature		Coefficient of thermal expansion between 21 °C (70 °F) and temperature	
°C	°F	10^{-6}/K	10^{-6}/°F
93	200	10.08	5.60
149	300	10.19	5.66
260	500	10.33	5.74
371	700	10.51	5.84
427	800	10.94	6.08
538	1000	11.83	6.57
649	1200	12.87	7.15

Inflection point equals 416 °C (780 °F).

Table 2 Dynamic Modulus of Elasticity, Shear Modulus, and Poisson's Ratio (Age Hardened)

Temperature		Young's modulus		Shear modulus		
°C	°F	GPa	10^6 psi	GPa	10^6 psi	Poisson's ratio
21	72	177.3	25.72	67.8	9.83	0.31
260	500	172.4	25.01	65.4	9.49	0.32
538	1000	163.8	23.76	62.8	9.11	0.30
816	1500	142.2	20.62	55.9	8.11	0.27
927	1700	128.7	18.67	49.8	7.22	0.29

Table 3 Mechanical Properties (Age Hardened)

Temperature		Yield strength		Tensile strength			
°C	°F	MPa	ksi	MPa	ksi	Elongation, %	Reduction of area, %
21	70	779	113.0	1194	171.0	24	44
427	800	717	104.0	1076	156.0	25	42
538	1000	686	99.5	1034	150.0	25	46
649	1200	683	99.0	979	142.0	28	39
704	1300	607	88.0	807	117.0	39	64

Hot Forming. The temperature range for hot forming Inconel alloy 783 is 927–1121 °C (1700–2050 °F). Alloy 783 works like alloy 718, but is a bit softer at high temperatures and begins to stiffen quickly as temperature drops below 927 °C (1700 °F).

Forging. For initial forging ingots are heated to 1121 °C (2050 °F) and finished to 8 in. diam billet at 1038–1066 °C (1900–1950 °F). For intermediate forging, heat billets to 1038 °C (1900 °F) with a final reheat from 982–1010 °C (1800–1850 °F).

Machinability:

This alloy is machined by conventional practices for high-strength nickel alloys. Rough machining should be done with the material in the annealed condition.

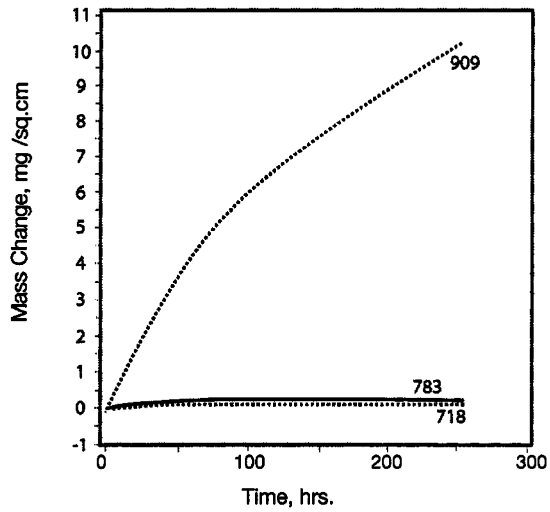


Fig. 1 Cyclic oxidation. Weight loss for Inconel alloys 783, 718, and Incoloy alloy 909 after 704 °C (1300 °F) cyclic oxidation tests (60 min in, 20 min out)

Corrosion Resistance:

Figure 1 provides a comparison of the cyclic oxidation resistance of various Inconel and Incoloy alloys. The oxidation rate of alloy 783 is slightly greater than alloy 718 at 704 °C (1300 °F). The results of salt fog testing to ASTM B 117-85 for duplicate tests shows the alloy with a corrosion rate approaching those of alloy 718 and superior to alloy 909. The end-grain pitting observed on one alloy 783 specimen, but not the other, indicates marginal resistance to pitting on surfaces perpendicular to the worked direction.

Specification Equivalents:

UNS R30783

AMS 5940 (forging billet)

General Characteristics:

Inconel alloy 783 is covered under Patent 5,478,417 and is an oxidation-resistant, low-expansion Ni-Co-Fe alloy with other additions. The alloy has excellent resistance to oxidation, as demonstrated in cyclic tests, at temperatures up to and beyond 704 °C (1300 °F). It has resistance to SAGBO (stress-accelerated grain-boundary oxidation) comparable to that of alloy 718. Inconel alloy 783 has a density of 7810 kg/m^3 (0.282 lb/$in.^3$), which is 5% less than 718 and contributes to an important potential improvement in strength to weight ratios. The alloy has better impact resistance and stability than alloy 909 at up to 704 °C (1300 °F). Manufacturing and processing characteristics are comparable to those of alloy 718 and less limiting than those of alloy 909.

Inconel alloy 783 is a low coefficient of thermal expansion superalloy strengthened by precipitation of γ' (ordered FCC) and β (BCC) aluminide phases in a Ni-Co-Fe-based austenitic matrix. The low-expansion characteristics arise from the ferromagnetic nature of bonding between nickel, cobalt, and iron atoms. Low-expansion alloys of this type are limited in their capacity to contain chromium for oxidation resistance because increasing chromium lowers the Curie temperature, thus raising thermal expansion over a range. Alloy 783 achieves resistance to general cyclic oxidation and stress-accelerated grain-boundary oxygen embrittlement primarily through an aluminum addition sufficient to produce a three phase (γ, γ', β) microstructure. The formation of β during processing enables fine grain sizes to be achieved with relative ease. Proper heat treatment partially re-solutions β at a relatively high temperature, then reprecipitates β intergranularly prior to the final aging step. The aging treatment produces intergranular γ' for strength. The resulting microstructure provides high strength, good notch ductility, and slow static crack growth rates at elevated temperatures in air. The unique microstructure and overall high aluminum content impart excellent overall oxidation resistance to the alloy. Stability, after long time exposure at elevated temperatures, is good.

Product Forms Available:

This alloy is available as forging billet to AMS 5940 and as rod and bar for machining. Extruded sections and wire rod are available, and sheet is under development.

Applications:

This alloy is of interest to aircraft gas turbine engine designers and materials engineers for containment and clearance control components such as rings, casings, shrouds and seals for compressors, turbines, and exhaust systems.

Producer:

USA:

Special Metals Corporation
Huntington, WV 25705 -1771
(304) 526-5100
(800) 334-4626
(304) 526-5643 (fax)

United Kingdom:

Special Metals Wiggin Ltd.
Hereford HR4 9SL England
+44-1432-382200
+44-1432-264030 (fax)

ISSN: 002-614X

Alloy DIGEST

CALCARB

Filing Code: Cp-1
Composite

JULY 1989

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

CALCARB®

(High-Temperature Carbon Fiber-Carbonized Resin Composite)

CALCARB* is a rigid, high-temperature composite made from discontinuous lengths of carbon fibers, vacuum formed and bonded by a carbonized resin. It is a relatively strong, high-purity carbon material with low bulk density that is readily machinable.

*CALCARB® is a registered trademark of Calcarb, Inc.

Composition (Typical):

	Processed at 1800°C	Processed at 2000°C
Carbon	99.997%	99.998%
Ash	0.3%	0.11%

Spectrographic analysis of ash, ppm.

Silicon	310	60
Iron	260	<1
Nickel	<2	<2
Aluminum	200	125
Lithium	<1	<1
Sodium	<4	<4
Zinc	<1	<1
Titanium	<4	<4
Potassium	<1	<1
Chromium	<3	<3
Boron	<1	<1
Magnesium	13	18
Vanadium	<1	<1
Copper	<1	<1
Calcium	140	315
Strontium	<4	<4
Barium	<1	<1

Physical Constants:

Density, g/cc, standard		0.18
per customer requirements		0.13-0.25
Thermal conductivity*, W/cm/°K	(At 100°C)	0.00096
(See also Fig. 1)	(At 1000°C)	0.00172
	(At 2000°C)	0.00359
Thermal expansion, in./in. x 10^{-3}	(At 500°C) (Approximate)	1.2
	(At 1000°C)	2.2
	(At 1500°C)	4.3
	(At 2000°C)	16.0
	(At 2500°C)	26.0
	(At 2750°C)	22.0

*For heat loss data see Fig. 2

PROPERTIES

Mechanical Properties:

Compressive strength, longitudinal (At room temperature), psi	179
transverse (At room temperature), psi	83
Compressive stress-strain data	See Table 1
Flexural strength, psi	>115

Table 1 -- APPROXIMATE STRESS-STRAIN TEST RESULTS, COMPRESSION

	At room temperature				
Stress, psi	25	50	75	100	125
Strain, in./in. x 10^{-3}	10	30	65	170	260
	At 2600°C				
Stress, psi	25	50	75	100	
Strain, in./in. x 10^{-3}	48	130	208	255	

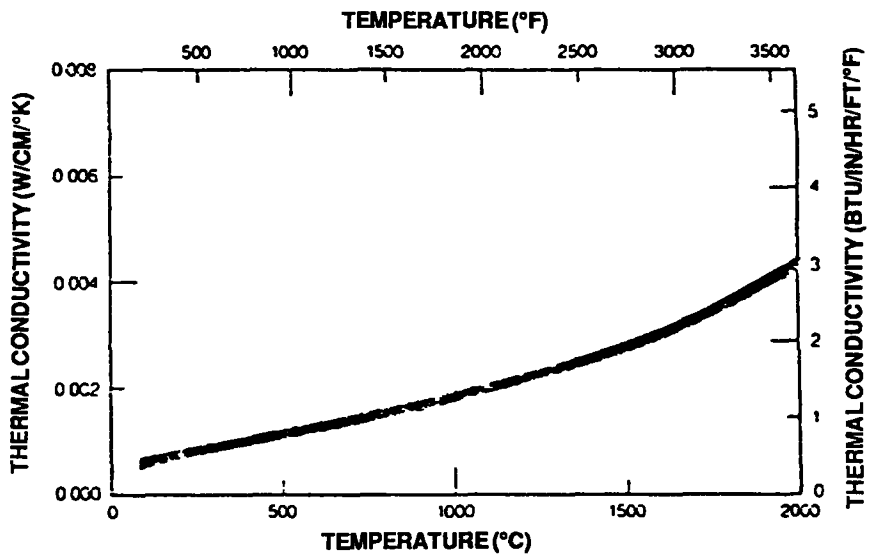


Fig. 1 – Thermal conductivity

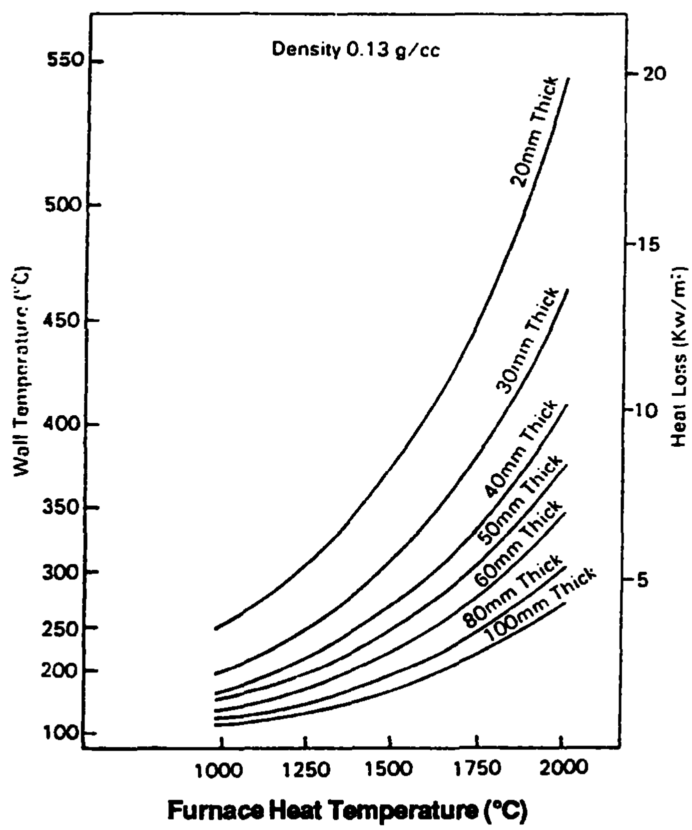


Fig. 2 – Heat loss of various thicknesses

Machinability:

CALCARB can be readily shaped by sawing, drilling or machining. Standard machining and sawing tolerances are ± 0.100 inches.

Chemical Resistance:

CALCARB has excellent chemical resistance. It exhibits low wettability by most liquid metals. In reducing or inert atmospheres, CALCARB is capable of operating at 3000°C.

Protective Treatments:

CALCARB composites can be treated with Calcoat*, a protective coating that prevents erosion during gas quenching processes. Calcoat can be used to touch up faces or to make repairs. Its reflective character makes it specially suited for hot-face insulation surfaces.

Calfoil*, a shiny, graphite finish may be bonded to rigid CALCARB material for even greater insulation efficiency. It also effectively reduces erosion and dusting during furnace operation. Calfoil is available in various widths, lengths and thicknesses. It is a totally non-toxic, 99% carbon material and has no respirable fibers. It has excellent thermal shock resistance and low coefficient of friction. In oxidizing atmospheres it is usable from cryogenic temperatures to 500°C; in reducing or inert atmospheres to temperatures as high as 3000°C.

**Calcoat and Calfoil are tradenames of Calcarb Inc.*

General Characteristics:

CALCARB exhibits low out-gassing in temperatures >1500°C. It has low vapor pressure at high temperatures. It has excellent chemical resistance and low wettability by most liquid metals. CALCARB is light weight and rigid. It possesses resilience and toughness providing for good service under vibration and shock. It will give many years of reliable operation up to 1500°C. In inert atmospheres it is capable of operating at 3000°C. It has low water absorbtion characteristics which means shorter pump-down times for vacuum furnaces and freedom from oxidation of processed parts in both vacuum and inert atmosphere equipment.

Forms Available:

CALCARB is offered in two basic forms; flat board up to 6 inches thick and hollow cylinders to 70 inch OD x 30 inch high to 3 inch thick. It may be supplied uncoated, Calcoated or Calfoiled.

A wide variety of shapes and configurations can be molded to suit customer specifications. Design assistance is available where required.

Applications:

Insulation for sintering, heat treating and crystal growing furnaces; furnace fixtures.

Producer:

Calcarb Inc.
Willingboro, New Jersey 08046

Alloy DIGEST

KEVLAR®49 ARAMID FABRIC AND FABRIC REINFORCED COMPOSITES

Filing Code: Cp-10
Composite

AUGUST 1990

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

KEVLAR®49 Fabric and Fabric Reinforced Composites*

(Data involving 1 light weight and 4 medium weight fabric styles)

KEVLAR®49 is a high-modulus para-aramid reinforcing fiber. It is the dominant organic reinforcing fiber in advanced composites today. It has exceptional strength and stiffness and is a low density material.

KEVLAR is the registered trademark of E I DuPont de Nemours & Co., Inc. for its high strength aramid fiber.

Chemical Characterization:

Aramid is the approved generic designation for an aromatic polyamide polymer. KEVLAR® is a para-phenyleneterpthtalamide.

Physical Properties:

Density (fiber) @ room temperature, lb/cu in. (g/cu cm)	0.052(1.44)
Specific heat @ 32°F(0°C), Btu/lb•°F(J/kg•°C)	0.292(1220)
@ 122°F(50°C)	0.383(1600)
@ 212°F(100°C)	0.476(1990)
@ 302°F(150°C)	0.565(2360)
@ 392°F(200°C)	0.626(2620)
@ 482°F(250°C)	0.654(2740)
@ 572°F(300°C)	0.679(2840)

*For Unidirectional KEVLAR®49 reinforced composites see Alloy Digest Cp-7, April 1990.

PROPERTIES

Table 1 — CHARACTERISTICS OF SOME COMMONLY USED KEVLAR®49 ARAMID FABRIC STYLES

duPont Style No.	Weave*	Basis Weight oz/yd²(g/m²)	Fabric Construction ends/"(ends/cm)	Yarn Denier	Fabric Thickness 10^{-3}"(mm)	Air Permeability ft³/ft²•min.**
120	Plain	1.8 (61.1)	34 x 34 (13 x 13)	195	4.5(0.11)	213
181	8-harness satin	5.0 (169.8)	50 x 50 (20 x 20)	380	9 (0.23)	36
281	Plain	5.0 (169.8)	17 x 17 (7 x 7)	1140	10 (0.25)	39
285	Crowfoot	5.0 (169.8)	17 x 17 (7 x 7)	1140	10 (0.25)	—
328	Plain	6.8 (230.9)	17 x 17 (7 x 7)	1420	13 (0.33)	18

*Plain weave: 1 over, 1 under
8-harness satin: 1 over, 7 under
Crowfoot (a 4-harness satin): 1 over, 3 under
**Frazier Precision Instrument Co. No. 248 High Pressure Permeability Machine.

Table 2 — STATIC ROOM-TEMPERATURE STRENGTHS OF KEVLAR®49 FABRICS

duPont Style No.	Tensile Strength lb/in. (kN/m)	Tongue Tear Strength lb (N)	Trap Tear Strength lb (N)
120	250 (44)	60 (267)	22 (98)
181	700 (123)	110 (489)	56 (249)
281	650 (114)	105 (407)	43 (191)
285	650 (114)	* *	40 (178)
328	700 (123)	120 (534)	65 (289)

*Construction too loose for testing.

Table 3 — ROOM-TEMPERATURE COMPOSITE FLEXURAL PROPERTIES REINFORCED WITH FABRICS OF KEVLAR®49

duPont style No.	Fiber Volume Fraction	Flexural Modulus		Flexural Strength	
		Warp 10^6psi (GPa)	Fill 10^6psi (GPa)	Warp 10^3psi (MPa)	Fill 10^3psi (MPa)
120	0.45	4.0 (27.6)	4.0 (27.6)	50 (345)	50 (345)
181	0.40	3.8 (26.2)	3.2 (22.1)	50 (345)	50 (345)
281	0.40	3.3 (22.8)	3.3 (22.8)	50 (345)	50 (345)
285	0.40	3.6 (24.8)	3.1 (21.4)	50 (345)	50 (345)
328	0.45	3.3 (22.8)	3.3 (22.8)	45 (310)	45 (310)

Table 4 — ROOM-TEMPERATURE PROPERTIES DUPONT STYLE 181 FABRIC OF KEVLAR®49 REINFORCED COMPOSITE*

Property	Test Direction: Warp	Test Direction: Bias (45°)
Tensile modulus, 10^6psi (GPa)	4.5 (31.0)	1.1 (7.58)
Compressive modulus, 10^6psi(GPa)	4.5 (31.0)	1.0(6.89)
Shear modulus, 1-2 plane, 10^6psi(GPa)	0.3 (2.07)	3.0(20.7
Tensile strength, 10^3psi(MPa)	75 (517)	30(207)
Compressive strength, 10^3psi(MPa)	25 (172)	18(124)
Shear strength, 1-2 plane, 10^3psi(MPa)	16 (110)	32(221)
Flexural modulus, 10^6psi(GPa)	4.0 (27.6)	— —
Flexural strength, 10^3psi(MPa)	50.0 (345)	— —
0.2% offset compressive stress, 10^3psi(MPa)	12 (82.7)	6.5 (44.8)
0.2% offset flexural stress, 10^3psi(MPa)	25 (172)	— —

*Fiber volume fraction = 0.50
Density = 0.048lb/cu in(1.33 g/cu cm)

Table 5 — ELEVATED TEMPERATURE WARP PROPERTIES DUPONT STYLE 181 FABRIC OF KEVLAR®49 REINFORCED COMPOSITE

Fiber Volume Fraction	Matrix	Test Temp. °F	Property	
0.50	350°F cure epoxy	300	Tensile modulus, 10^6psi(GPa)	3.5 (24.1)
		350	Compressive modulus, 10^6psi(GPa)	4.0 (27.6)
		300	Tensile strength, 10^3psi(MPa)	50 (345)
		350	Compressive strength, 10^3psi(MPa)	15 (103)
		350	Flexural modulus, 10^6psi(GPa)	3.0 (20.7)
		350	Flexural strength, 10^3psi(MPa)	30 (207)
0.55	Polymide	450	Tensile modulus, 10^6psi(GPa)	3.6 (24.8)
		485	Flexural modulus, 10^6psi(GPa)	3.4 (23.4)
		450	Flexural strength, 10^3psi (MPa)	28 (193)
		550	Flexural strength, 10^3(MPa)	18 (124)

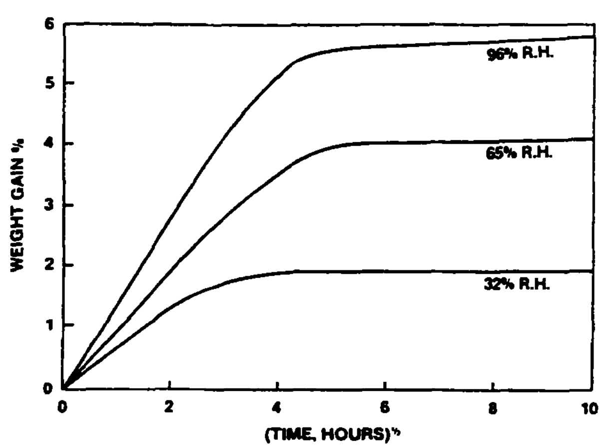


Figure 1 – Equilibrium moisture content of KEVLAR®49 from dry condition.

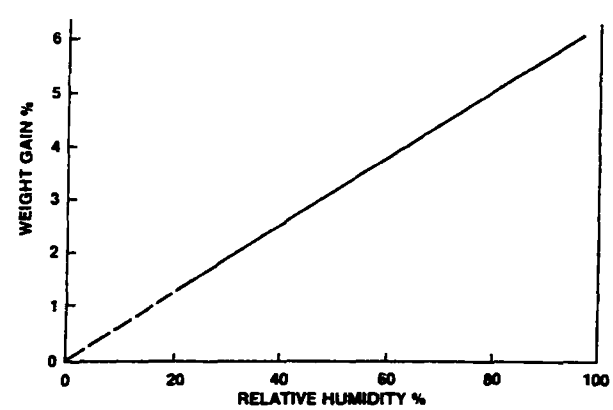


Figure 2 – Moisture absorption rate of KEVLAR®49 from dry condition.

Style Description:

Weave, basis weight, fabric construction, denier, fabric thickness and fabric air permeability for 1 light weight and 4 medium weight fabric styles are summarized in Table 1. Other characteristics are as follows:
Style 120: A light weight fabric (1.8 oz/yd²) designed as the volume equivalent to Style 120 in fiberglass. It is for use where thin laminate with a smooth surface is desired.
Style 181: An 8-harness satin that conforms well to molds. Designed as the volume equivalent to Style 181 in fiberglas.
Styles 281 and 285: Designed to be more economical versions of Style 181, taking advantage of a heavier denier yarn (1140 vs 380). The 4-harness satin weave has better mold conformability than the plain weave Style 281.
Style 328: A plane weave 1420 denier KEVLAR® 49 fabric used primarily in the boating industry.

Ultraviolet Light Stability:

DuPont Style 220 (Plain weave light weight 380 denier fabric) exposed bare for 5 weeks in Hialeah, Florida sun retained 51% of its break strength.

Handling:

KEVLAR® 49 should be dried at 250°F (121°C) and resin impregnation should be carried out within 1 hour after drying. Atmospheres of fine particles of KEVLAR® 49 are not explosive. The material is not biodegradable and contains no significant water extractable components. Skin irritation potential of the material is minimal but even so, exposure to inhalable material should be avoided.

Machining:

Use sharp tools kept free from resin build-up. Avoid overheating to minimize resin matrix deterioration. High-speed tools give adequate service life and this may be extended by titanium carbide or nitride coatings.

Applications:

Aerospace, marine and sporting goods.

Producers:

DuPont
Wilmington, Delaware 19898

Alloy DIGEST
DATA ON WORLD WIDE METALS AND ALLOYS

ELECTRAFIL® G-50/SS/5

Filing Code: Cp-13
Composite

JANUARY 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ELECTRAFIL G-50/SS/5
(Conductive Thermoplastic)

ELECTRAFIL® G-50/SS/5 provides good electrical conductivity at a low loading of stainless steel fibers. It is useful as a shielding material and for current carrying parts.

ELECTRAFIL® is a registered trademark of AKZO Engineering Plastics.

Chemical Characterization:

Matrix resin; thermoplastic polycarbonate.
Conductive fiber; long stainless steel, 5% by weight.

PROPERTIES

Table 1 — PHYSICAL PROPERTIES (ASTM TEST METHOD)

Specific gravity (D792)	1.27
Water absorption in 24 hrs, %(D570)	0.12
Linear mold shrinkage, % 1/8" (3mm)	0.4

Table 2 — THERMAL PROPERTIES (ASTM TEST METHOD)

Deflection temperature under load (D648), °F (°C)	
66psi (0.45MPa)	295(146)
264psi (1.82MPa)	285(141)
Flammability, min. thickness (UL94)	V-0

Table 3 — ELECTRICAL PROPERTIES (ASTM TEST METHOD)

Volume resistivity, ohm-cm (D257)	10
Shielding effectiveness, attenuation at 1000 MHz, 1/8" (3mm) section, decibels	40

Table 4 — MECHANICAL PROPERTIES (ASTM TEST METHOD)

Tensile strength, psi (MPa) (D638)	10000(68)
Elongation, % (D638)	5.0
Tensile modulus, 10^5 psi (GPa) (D638)	4.5(3.1)
Flexural strength, psi (MPa) (D790)	16000(110)
Flexural modulus, 10^5 psi (GPa) (D790)	4.5(3.1)
Izod impact strength, notched (D256) 1/4" x 1/2" (6.35mm x 12.7mm), ft-lb/in. (J/m)	1.3(69.4)

General Characteristics:

Stainless steel fiber is the newest and most efficient conductive additive for plastics on the market today. The 5 weight percent long stainless steel fiber loading in the polycarbonate matrix of G-50/SS/5 has a log ohm-cm volume resistivity of about 1. This compares to –4 to –6 for metals and 12 to 16 for insulating plastics. The 10 ohm-cm conductivity of G-50-SS/5 is sufficient to dissipate electrostatic discharge and also function well in shielding. The low fiber loading level of this composite allows the user to meet most color specifications.

The polycarbonate matrix of G-50/SS/5 composite is a tough thermoplastic resin and its basic properties are not greatly affected by the 5% stainless steel fiber loading.

Applications:

Electronic enclosure housings for medical equipment, bezels for business machines, electronic module housings.

Manufacturer:

AKZO Engineering Plastics
PO Box 3333
Evansville, Indiana 47732

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

KEVLAR®/ J-2

Filing Code: Cp-14
Composite

MARCH 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

KEVLAR® / J-2
(Thermoplastic Composite Material)

KEVLAR®/J-2 is an advanced thermoplastic composite material based on J-2 copolymer reinforced with continuous KEVLAR® fiber. The inherent fiber/matrix compatability of this composite provides attractive mechanical properties.

Chemical Characterization:

J-2 is an amorphous polyamide copolymer. KEVLAR® is an aramid fiber (aramid is the approved generic designation for an aromatic polyamide polymer).

PROPERTIES

Table 1 — COMPARATIVE THERMOPLASTIC MATRIX PROPERTIES

Property	Polymer			
	J-2	Nylon 6/6	Ryton*PPS	Ultem**PEI
Density, g/cc	1.15	1.14	1.36	1.27
G_{IC} (interlaminar fracture toughness) kJ/m²	2	2	1.4	1 to 2
T_g (glass transition temperature) (dynamic mechanical analysis), °C	160	50	88	210
Modulus (tensile), GPa	3.2	2.7	3.2	3.5
Heat distortion temperature, °C	138	75	135	200
Processing temperature, °C	290 to 305	275 to 290	200 to 240	340 to 380

*Ryton, registered trademark of Philips Petroleum Co. (PPS = polyphenylene sulfide).
**Ultem is a registered trademark of General Electric Co. (PEI = polyether imide).

Table 2 — ROOM-TEMPERATURE MECHANICAL PROPERTIES OF UNIDIRECTIONAL KEVLAR® / J-2 COMPOSITE (60% volume fraction fiber)

		ASTM	Value	
Tensile Properties	Unit	Test	Axial	Transverse
Modulus	GPa(10^6psi)	D3039	73-79(10.5-11.5)	5.1-5.8(0.75-0.85)
Strength	MPa(10^3psi)		1300-1400(180-200)	20-24(3-3.5)
Strength	%		1.5-1.8	0.4-0.6
Poisson's Ratio			0.32-0.35	0.02-0.03
Flexural Properties				
Modulus	GPa(10^6psi)	D790/D2344	70-73(10-10.5	40(6)
Strength	MPa(10^3psi)		675-700(98-103)	21(3)
Short beam shear strength	MPa(10^3psi)		55-62(8-9)	—
Compressive Props.				
Strength	MPa(10^3psi)	D695	248-276 (36-40)	—
Inplane Shear Properties (±45)2s				
Modulus	GPa(10^6psi)	D3518	2.1(0.3)	—
Strength	MPa(10^3psi)		45-55(6.5-8.0)	—

Processing:

Using a melt impregnation technology where the resin, in this instance J-2, is metered throughout a fiber (KEVLAR®) bundle, an impregnated tow is formed. This impregnated tow may then be woven into formable fabric or consolidated into rigid sheets. This technique, a building block approach, leads to easier and more economical consolidation than comingling or film stacking. Flexible woven fabric and rigid consolidated sheets can be reheated for subsequent shape forming.

Table 3 — ROOM-TEMPERATURE MECHANICAL PROPERTIES OF KEVLAR® / J–2 COMPOSITE FABRIC*

			Value	
Tensile Properties	Unit	ASTM Test	Axial	Transverse
Modulus	GPa(10^6psi)	D3039	35-40(5.2-6)	35-40(5.2-6)
Strength	MPa(10^3psi)		530-570(77-83)	530-570(77-83)
Failure strain	%		1.6-1.8	1.6-1.8
Flexural Properties				
Modulus	GPa(10^6psi)	D790/D2344	34-37(4.9-5.4)	34-37(4.9-5.4))
Strength	MPa(10^3psi)		425-470(62-68)	425-470(62-68)
Short beam shear strength	MPa(10^3psi)		35-40(5-6)	— —
$[\pm45]_{2S}$ Properties				
Modulus	GPa(10^6psi)	D3518	6.9(1.0)	— —
Strength	MPa(10^3psi)		159(23)	— —

*60% volume fraction fiber,
8 harness satin weave (a one-over, seven-under configuration).

Table 4 — FLEXURAL STRENGTH RETENTION OF KEVLAR® / J–2 COMPOSITE WOVEN FABRIC
(60% volume fraction fabric, 8 harness satin weave)

	Flexural Properties		
Test Temperature °C	Modulus (10^6psi) GPa*	Strength (10^3psi)MPa*	SBS Strength (10^3psiMPa)*
	As-is Specimens		
24	(5.2)35.6±0.99	(6.1)428±18.0	(5.0)34.6±1.50
38	—	—	—
66	(4.7)32.7±1.48	(60)411±12.6	(4.8)32.8±1.97
93	(4.5)30.8±0.89	(55)382±6.21	(4.8)33.4±1.85
121	(4.1)28.0±0.12	(47)327	(4.8)32.8±2.07
135	(4.0)27.3±1.82	(49)336±46.6	(4.8)32.9±2.4
	Conditioned Specimens**		
24	(5.3)36.6±2.08	(65)447±24.3	(5.1)35.2±1.21
38	—	(61)421±19.3	(5.2)36.9±1.37
66	(5.6)38.6±0.68	(59)408±7.91	(5.8)40.0±1.01
93	(5.3)36.6±0.06	(43)297±0.8	(5.1)34.9±1.76
121	(3.3)22.6±1.32	—	—
135	(1.9)13.4±0.4	—	—

*Range of mean value of 5 to 10 specimens at 95% confidence level.
**Exposed to 82°C and 80% relative humidity for 500 hours prior to testing.

Consolidation conditions for laminates of KEVLAR® / J–2 composites of 300°C(570°F) at 1.4-1.7MPa(200-250psi) for dwell times of 10-20 minutes provide excellent results. Laminates so processed had less than 1% void content. When necessary, drying to less than 0.2% moisture can be accomplished in 16 hours at 105°C or 4 hours at 150°C (in vacuum in both cases).

Effects of Heat and Humidity:

Effects of dry heat and hot humid aging on flexural modulus, flexural strength and flexural short beam shear strength are summarized in Table 4. Above 93°C test temperature, retention of flexural modulus was more adversely affected by hot and humid aging (conditioning), than by dry heat aging.

Chemical Resistance:

Solvent exposure tests (14 day exposure) at 23 and 71°C in hydraulic fluid showed excellent resistance in the as-consolidated condition. Specimens with machined surfaces lost 36% of their flexural strength under the same exposure conditions. For other solvents including methyl ethyl ketone, deicing fluid, isopropanol, jet fuel and trichloroethylene, flexural strength of samples with machined surfaces lost 6% or less of their flexural strength after exposure at 23°C.

General Characteristics:

The excellent properties, good environmental stability and low density of J–2 make it an attractive thermoplastic matrix for high-performance composites reinforced with KEVLAR®. A variety of composite forms, including unidirectional prepreg tape and woven fabric constructions exhibit attractive properties. The composite is well suited to the building block approach using melt impregnated tow.

Reference:

High Performance Composites of J–2 Thermoplastic Matrix. Reinforced with KEVLAR® Aramid Fiber; Subhotosh Khan, Robert B. Croman, Ike Y. Chang, William H. Krueger. 33rd International SAMPE Symposium, March 7-10, 1988.

Producer:

DuPont
Wilmington, Delaware 19898

Alloy DIGEST

SXA®

Filing Code: Cp-15
Composite

MAY 1990

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

SXA®

(Discontinuously Reinforced Aluminum Alloys)

SXA® is a unique group of alloy composites that provide a superior balance of strength, stiffness and fatigue resistance with low density. They are produced by powder metallurgy.

Chemical Characterization:

Matrices of SXA® composites are heat treatable aluminum alloys such as 2009, 6061, 6013 and 7475 (Aluminum Association registered alloys, see Table 1).

The discontinuous reinforcing component is silicon carbide, usually in the form of fine powder (approximately 3.5 x 10^{-6} m in diam.) or whiskers (approximately 0.5 x 10^{-6} m diam. x 10 to 80 x 10^{-6} m long). Volume fraction of silicon carbide powder is up to 55%; whiskers up to 30%.

PROPERTIES

Table 1 – COMPOSITION LIMITS OF SOME MATRIX ALLOYS IN SXA® COMPOSITES*

Alloy Number	Partial Composition, Weight Percent: Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc
2009	0.25	0.25	3.2-4.4	–	1.0-1.6	–	0.10
6061**	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25
6013**	0.6-1.0	0.07	0.6-1.1	–	0.8-1.2	–	0.25
7475**	0.10	0.12	1.2-1.9	–	1.9-2.6	–	5.2-6.2
7075*	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.18-0.28	5.1-6.1
2024*	0.50	0.50	3.8-4.9	0.30-0.9	1.2-1.8	0.10	0.25

*Alloys 2024 and 7075 are unreinforced wrought alloys included in the table for comparative purposes.
**Off-specification alloys which contain no dispersoid forming elements which are deleterious to composite properties.

Table 2 – SOME COMPARATIVE MECHANICAL PROPERTIES, T6 TEMPER

Material	Tensile Strength ksi	Yield Strength ksi	Compressive Yield Str. ksi	Elongation %	Modulus Tens. ksi x 10^3	Modulus Comp. ksi x 10^3
Forgings						
7075-T6	83	73	–	11	10.4	–
6061-T6	45	40	–	12	10.0	–
2009SiC/20P*	80	61	63	5	16.3	16.4
2009SiC/25P	87	70	–	4	16.7	–
2009SiC/15W*	93	58	70	3	15.4	16.1
6061SiC/40P	75	60	–	2	20.5	–
Extrusions						
2024-T6	69	57	–	10	10.6	–
7075-T6	83	73	–	6	10.4	–
6013SiC/15P	72	59	–	6	14.4	–
6013SiC/20P	80	65	–	6	16.3	–
6013SiC/25P	82	67	66	5	17.8	–
6013-T6	57	53	–	11	9.9	–
2009SiC/15P	78	62	–	5	15.4	–
2009SiC/20P	95	67	–	4	16.3	–
2009SiC/25P	97	–	–	3	17.6	–

*20P=20 volume percent SiC powder reinforcement
15W=15 volume percent SiC whisker reinforcement

Table 3 – TYPICAL PROPERTIES OF 2009/SiC/15W* SHEET

Property	Direction	T6	T3X1	T8X1	T8X2	
					15W	20P
TUS (ksi)	L	92	98	96	92	86
	LT	75	82	80	80	83
TYS (ksi)	L	58	74	79	70	66
	LT	52	55	61	58	61
CYS (ksi)	L	65	61	70	62	61
	LT	–	–	–	62	63
BUS (ksi)	e/D=2.0	–	–	152	154	172
BYS (ksi)	e/D=2.0	–	–	132	126	116
SUS (ksi)	ST	–	–	–	51	–
e (%)	L	5.2	5.2	4.5	6.4	5.2
	LT	8.2	7.8	6.4	8.8	5.3
Kc (ksi $\sqrt{in}$)	L-T	–	–	49	52	41
E (Msi)	L	15.2	15.5	15.4	15.3	15.8
	LT	13.5	13.7	13.7	14.3	15.8
Ec (Msi)	L	15.0	15.4	15.5	15.2	–
	LT	–	–	–	13.9	–
Density		0.102				
Thermal coef. expansion (ppm/°F)	L	8.3				
	LT	10.0				

*Properties also given for T8 x 2/20P.

Processing:

Powders of the matrix aluminum alloy and the silicon carbide reinforcing material (powder or whisker) are blended and consolidated into billet form in a vacuum hot press. The billets are thermally treated, machined and sonically inspected before extruding, forging or rolling into finished product.

General Characteristics:

SXA® discontinuously reinforced aluminum alloys are significantly stronger and stiffer (higher modulus of elasticity) than conventional aluminum alloys with equal density. These enhanced properties allow a reduction in material weight (as much as 30%) per part resulting in marked improvement in performance. SXA® composites also offer superior dimensional stability, wear resistance and fatigue resistance compared to conventional aluminum alloys. They have similar longitudinal and transverse (isotropic) properties. Corrosion resistance when compared to high-strength alloys like 7075-T6, is also very good. SXA® materials can be fabricated, bonded, joined, anodized and plated using conventional equipment and techniques.

Applications:

Nearly unlimited variety of applications, particularly where improved strength, stiffness and weight savings are important.

Forms Available:

Billet, plate, sheet, forgings, near-net shapes, extrusions, tubing.

Producer:

Advanced Composite Materials Corporation
Greer, South Carolina 29651

Alloy DIGEST
DATA ON WORLD WIDE METALS AND ALLOYS

AKULOY™ RM M-1915

Filing Code: Cp-17
Composite

SEPTEMBER 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

AKULOY™ RM M-1915

(30% Fiberglass-Reinforced Modified Polyamide Alloy)

AKULOY RM M-1915 is a thermoplastic composite that can be used in many types of injection molded applications where polypropylene or nylon are used.

Chemical Characterization:

AKULOY RM M-1915 is based on nylon 6 modified with a functionalized polyolefin and reinforced with 30% fiberglass.

PROPERTIES

Table 1 – PHYSICAL AND THERMAL PROPERTIES

Property	ASTM Test	Unit	Value
Specific gravity	D-792	–	1.26
Water absorption	D-570		
24 hours		%	0.35
At saturation		%	4.85
Linear mold shrinkage	D-955		
(1/8" average section)		"/"	0.003
Delection temperature under load @ 264psi	D-648	°F	330

Table 2 – MECHANICAL PROPERTIES, PROVISIONAL DATA (TESTS CONDUCTED AT 73°F)

Property	ASTM Test	Unit	Value
Tensile strength	D-638	psi	17500
Elongation	D-638	%	4.3
Flexural strength	D-790	psi	23000
Flexural modulus	D-790	psi x 10^5	11.0
Izopd impact (1/8")	D-256		
Notched		ft-lb/in.	1.60
Unnotched		ft-lb/in.	10

Table 3 – COMPARATIVE PROPERTIES OF FOUR 30% FIBERGLASS-FILLED COMPOSITES

Property	ASTM Test	Unit	Homopolymer Polypropylene J-60/30/E8	Polyamide Alloy M-1915	Polyamide 6 J-3/30	Polyamide 66 J-1/30
Specific gravity	D-792	–	1.13	1.26	1.4	1.39
Moisture absorption	D-570	%	0.04	0.35	1.30	0.90
Mold shrinkage	D-955	"/"	0.002	0.003	0.003	0.002
Hedat deflection temperature @ 264 psi	D-648	°F	300	330	410	485
Tensile strength	D-638	psi	13000	17200	24500	25000
Elongation	D-638	%	3.5	4.3	2.2	2.5
Flexcural strength	D-790	psi	16000	23000	35500	35000
Flexural modulus	D-790	psi x 10^3	1100	1100	1330	1300
Izod impact	D-256					
Notched		ft-lb/in.	1.6	1.6	2.5	2.0
Unnotched		ft-lb/in.	10	10	20	17

Production:

AKULOY RM M-1915 can be injection molded for many types of applications where polypropylene or nylon are employed. AKULOY RM M-1915 processes at lower temperatures than 30% fiberglass-filled nylon 6. Mold shrinkage is nearly identical to that of 30% glass-filled nylon 6 and 30% glass-filled chemically coupled polypropylene. This affords a change to AKULOY RM M-1915 with no mold dimension modifications in most cases. AKULOY M-1915 produces superior surface finish and improved cycle times compared to glass-reinforced polypropylene. Its flatness directly from the mold is generally superior to glass-reinforced polypropylene.

General Characteristics:

Compared with 30% glass-filled polypropylene, AKULOY RM M-1915 exhibits greater tensile strength, greater stiffness (higher flexural modulus) and higher heat resistance. Compared with 30% glass-filled nylon, AKULOY M-1915 has about 2/3 less moisture absorption and 10% lower specific gravity. AKULOY M-1915 has excellent chemical resistance and its cost is between that of glass-filled nylon and glass-filled polypropylene.

Availability:

AKULOY RM M-1915 can be supplied in various custom colors.

Applications:

AKULOY RM M-1915 is used in under-the-hood automotive components, consumer durable parts, pump and electronics housings, impellers, fans, materials handling equipment (conveyors, bushings, bearing retainers).

Producer:

Akzo Engineering Plastics, Inc.
Evansville, Indiana 47732

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

ZYMAXX

Filing Code: Cp-18
Composite

OCTOBER 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ZYMAXX

(Chemical and Creep Resistant Parts)

ZYMAXX* provides outstanding compressive creep resistance, toughness and chemical inertness at high temperatures and pressures and under adverse conditions. They have a wide range of uses beyond chemical processing, including aerospace and automotive applications, general industrial equipment, home appliances, farm and construction equipment.

*ZYMAXX is a trademark of DuPont for chemical and creep resistant parts.

Chemical Characterization:

ZYMAXX is comprised of resins made from fluorocarbons. They are reinforced with carbon fibers.

Physical Properties:

Specific gravity	2.07
Thermal conductivity, Btu•in/hr•ft²•°F	2.02
W/m•K	0.291
Thermal coef. expansion/°F x 10^{-5} (–40 to 81°F)*	0.94
(82 to 428°F)	0.44
(–40 to 284°F)	17.0
(302 to 464°F)	29.0

*ASTM method E228, perpendicular to fiber direction.

PROPERTIES

Table 1 – MECHANICAL PROPERTIES

Property	Test Condition	ASTM Method	Orientation, Test vs Fiber	Unit	Value
Compressive creep	2ksi,24h, 73°F	D621	—	%	0.3
	500°F		—	%	1.4
Compressive strength	73°F	D695	Perpendicular	ksi	22
	500°F		Perpendicular	ksi	8.6
	73°F		Parallel	ksi	12
	500°F		Parallel	ksi	2.4
Max. compressive strain	73°F	D695	Perpendicular	%	7.8
	73°F		Parallel	%	1.6
Tensile strength	73°F	D1708	Parallel	ksi	13
Elongation	73°F	D1708	Parallel	%	2
Flexural modulus	73°F	D790	Perpendicular	ksi	1280
Hardness Durometer	73°F	D2240	Perpendicular	—	D74
Izod impact, notched	73°F	D256	Perpendicular	ft•lb/in.	7.2
	73°F		Perpendicular	J/m	387
unnotched	73°F		Perpendicular	ft•lb/in.	9.9
	73°F		Perpendicular	J/m	528
notched	73°F		Parallel	ft•lb/in.	5.4
	73°F		Parallel	J/m	288
unnotched	73°F		Parallel	ft•lb/in.	10.5
	73°F		Parallel	J/m	560

Table 2 – COMPARATIVE MECHANICAL PROPERTIES

Property	ASTM Method	Corrosion-Resistant Composite Components	PTFE 15% Graphite Filled	PTFE 25% Glass Filled
Compressive strength, ksi	D695	22.0/12.0[1]	5.0/5.2[1]	5.6/4.5[1]
Tensile strength, ksi	D1708	13[2]	1.3/2.7[1]	2.1/2.7[1]
Tensile elongation, %	D1708	2-10[2]	130/240[1]	300/270[1]
Flexural modulus, ksi	D790	1280[3]	203[3]	239[3]
Izod impact (notched), ft•lb/"	D256	7.2/5.4[1]	2.6	2.2
Compressive creep deformation, %	D621			
24h, 2ksi, 78°F		0.2	8.1/9.5[1]	7.1/7.5[1]

[1] perpendicular/parallel to fiber direction
[2] parallel to fiber direction
[3] perpendicular to fiber direction.

Table 3 – WEAR PROPERTIES, UNLUBRICATED THRUST WASHER TEST*

Wear factor** in air vs steel, cu in•min/ft•lb•hr	29×10^{-10}
Critical PV, ksi•ft/min	50
Coefficient of friction in air	
PV = 20ksi•ft/min; P = 0.5 ksi	0.36

*Test perpendicular to fiber direction
**Wear factor = wear rate/PV

Table 4 – CHEMICAL RESISTANCE TO IMMERSION EXPOSURE

Media	Immersion Conditions Temperature °F (°C)	Time Days	Swelling, Weight Gain %	Compressive Strength Loss %
96% sulfuric acid	212 (100)	30	0.3	6
	392 (200)	7	3.9	36
85% phosphoric acid	212 (100)	30	<0.1	0
Glacial acetic acid	223 (106)	30	0.6	0
Xylene	284 (140)	30	0.9	3
Mineral oil	212 (100)	30	<0.1	0
Aniline	212 (100)	30	0.1	0
Tetrahydrofuran	149 (65)	30	0.8	0
Methyl ethyl ketone	174 (79)	30	0.6	7
Dimethyl terephthalate	212 (100)	30	<0.1	0
Methylene chloride	104 (40)	30	0.9	3
Dimethyl sulfoxide	212 (100)	30	<0.1	0
25% aqueous ferric chloride	212 (100)	30	<0.1	0
25% aqueous zinc chloride	212 (100)	30	<0.1	1
Steam	500 (260)	7	0.4	–
Iodine	302 (150)	35	–	0

Safety Precautions:

A well ventilated work area should be adequate protection when machining Zymaxx. The part being machined should be maintained at a temperature below the composite's normal melting point, 572°F (300°C). Care should be taken to avoid the contamination of smoking materials with process dust and cuttings. In the event of fire, temperatures may rise above the decomposition temperature of the resin, thus liberating volatile fluorocarbons and hydrogen fluoride. Personnel entering the storage or use area under these conditions should use a fresh air supply or respirator effective against acid fumes and finely divided particulate matter. Protective clothing is also recommended to minimize contact with the skin. All types of chemical fire extinguishers and large amounts of water may be used.

Waste Disposal:

The preferred method of waste disposal of Zymaxx is sanitary landfill. The material is non-biodegradable and contains no extractable ingredient.

General Characteristics:

Zymaxx chemical and creep resistant parts have been developed to provide industry with a material which has outstanding compressive creep resistance and toughness combined with chemical inertness at high temperatures and pressures. Izod impact strength is in the range of super tough materials. These properties resulting from preferred fiber orientation provide dimensional stability suitable for engineering applications. Parts made of this material contribute to increased reliability and reduced operating costs.

Applications:

Zymaxx has a wide range of uses beyond chemical processing, including parts for aerospace and automotive applications, general industrial equipment, home appliances, farm and construction equipment. Specific parts include valve seats, washers, gaskets, compressor seals and pump parts.

Producer:

Du Pont, Wilmington, Delaware 19898

Alloy DIGEST

REFRACTORY SHEET TYPE 100

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Cp-19
Composite

OCTOBER 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

REFRACTORY SHEET TYPE 100

(Ceramic Fiber Reinforced Alumina Composite)

Refractory Sheet Type 100 is an engineered ceramic, fiber reinforced structural alumina composite with useful properties in thermal, structural and electrical insulation applications; as well as the transport of molten nonferrous metals to 1260° C (2300°F).

Composition (Typical):

Al_2O_3	75
SiO_2	16
Other metal oxides	9
Organics	0

Physical Properties:

Density, gm/cu cm	2.1
lb/cu ft	130
Melting point, °C	1500
°F	2732
Maximum temperature, °C	1300
°F	2372
Color	White or tan

PROPERTIES

Table 1 — MECHANICAL AND ELECTRICAL PROPERTIES

Compressive strength, MPa	69
psi	10000
Flexural strength, MPa	55.1
psi	8000
Volume resistivity (ASTM D-257), ohm-cm	4.6×10^9
Dielectric strength (ASTM D-149 volts/mil	71
Breakdown voltage (1/8" thick), kv	7.3

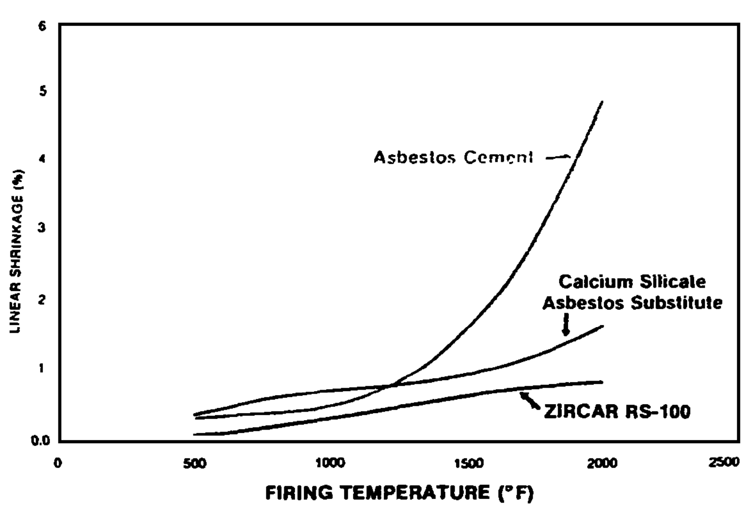


Fig. 1 – Linear shrinkage vs firing tempereature (1 hour soak at temperature)

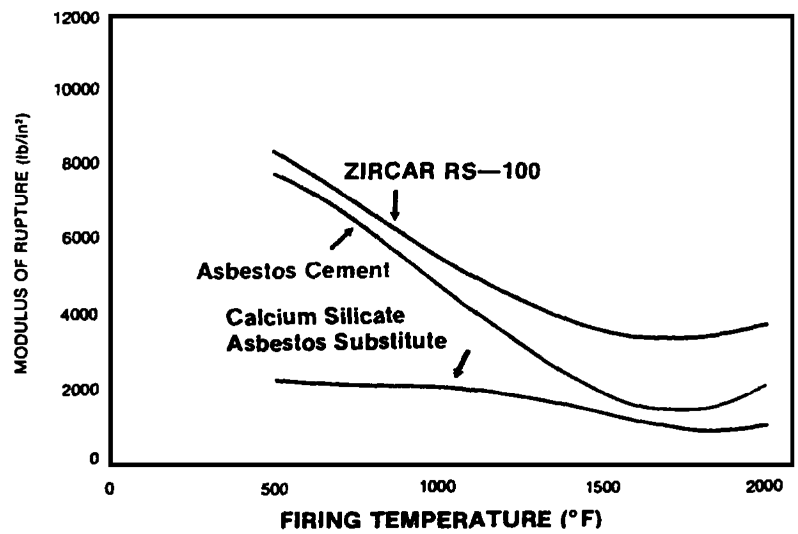


Fig. 2 – Room-temperature modulus of rupture vs firing temperature (1 hour soak at temperature)

Machinability:

Refractory Sheet Type 100 may be cut and machined with standard tooling.

Corrosion Resistance:

The high alumina content (75%) of Refractory Sheet Type 100 makes the material highly resistant to corrosion in many environments, including molten aluminum.

General Characteristics:

Refractory Sheet Type 100 has flexural and compressive strengths in the range of high-temperature, reinforced plastics such as G-7 and G-10 laminates but Type 100 retains its strength and utility to temperature levels far exceeding the maximum use temperature of plastics. Mechanical properties of Refractory Sheet Type 100 exceed those of Tansite and other asbestos-cement materials over all temperature ranges. Type 100 Sheet is 100% inorganic, non-flammable and contains no asbestos. The composite undergoes little or no outgassing on heating. It is not brittle; has high impact properties.

Forms Available:

Sheets, 610 x 1220 mm (24 x 48 in.) in thicknesses from 0.79 to 25.4 mm (1/32 to 1 in.)
Cylinders (contact the producer concerning user requirements).

Applications:

Induction coil liners, melting furnace structural parts, high-temperature insulation, hearth plates, glass-bottle forming machine wear parts, transport of molten nonferrous metals, high-temperature press platens, terminal boards.

Producer:

Zircar Products, Inc.
Florida, New York 10921

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

ULTEM 2100, 2200, 2300 & 2400

Filing Code: Cp-5
Composite

FEBRUARY 1990

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ULTEM 2100, 2200, 2300 & 2400

(Glass Reinforced Amorphous Thermoplastic Polytherimides)

ULTEM resins have high heat resistance, inherent flame resistance with low smoke evolution, broad chemical resistance and outstanding processability. Glass reinforcment provides increased rigidity and dimensional stability while maintaining good processing features. The ULTEM 2000 series is available in both low viscosity and mold release grades in addition to the standard grades. Mold release grades (designated with the suffix "R") reduce the risk of parts sticking in the mold, and hence permits molding at higher pressures to obtain improved melt flow. The mold release agent contains no silicone, is not conductive and is non-corrosive.

Chemical Characterization:

The Ultem 2100, 2200, 2300, & 2400 resins are amorphous thermoplastic polytherimides reinforced with 10, 20, 30, and 40% glass, respectively.

PROPERTIES

Table 1 — TYPICAL PHYSICAL PROPERTIES

Property	ASTM Test Method	ULTEM Resin 2100	2200	2300	2400
Specific gravity	D792	1.34	1.42	1.51	1.61
Mold shrinkage, in/in	D955	0.005-0.006	0.003-0.005	0.002-0.004	0.001-0.003
Water absorption	D570				
24hr, 73°F, %		0.21	0.19	0.16	0.13
Equilibrium, 73°F, %		1.20	1.10	0.90	0.90

Table 2 — TYPICAL THERMAL PROPERTIES

Property	Test Method	Units	ULTEM Resin 2100	2200	2300	2400
Deflection temperature (unannealed)	ASTM D648	°F(°C)				
@ 66 psi, 1/4in.			410(210)	410(210)	414(212)	420(216)
@ 264 psi 1/4in.			405(207)	408(209)	410(210)	415(213)
Vicat softening point (method B)	ASTM D1525	°F(°C)	434(223)	428(226)	442(228)	454(234)
Thermal index, UL Bulletin 746B	UL 476B	°F(°C)	338(170)	338(170)	356(180)*	—
Thermal coef. expansion (0-300°F)		"/"/°F				
(mold direction)		x 10^{-5}	1.8	1.4	1.1	0.8
		"/"°C				
		x 10^{-5}	3.2	2.5	2.0	1.4

*Applies to electrical and mechanical properties without impact.

Table 3 — TYPICAL FLAMMABILITY CHARACTERISTICS

Property	Test Method	ULTEM Resin 2100	2200	2300	2400
Vertical burn, UL Bulletin 94*	UL94				
@0.016"		V-0	V-0	—	—
@0.010"		—	—	V-0	V-0
NBS smoke, flaming mode, 0.060"	ASTM E662				
D_s @ 4 min		1.8	1.3	1.6	1.0
D_{max} @ 20 min		27	27	20	20
Oxygen index, %	ASTM D2863	47	50	50	54

*Rating not intended to reflect hazards presented by this or any other material under actual fire conditions.

Table 4 — TYPICAL ELECTRICAL PROPERTIES

Property	ASTM Test Method	Units	ULTEM Resin 2100	2200	2300	2400
Dielectric strength, 1/16"	D149	V/mil(kV/mm)				
in oil			700(27.5)	670(26.5)	630(24.8)	610(24.0)
in air			—	—	770(30)	—
Dielectric const. @1kHz, 50%RH*	D150	—	3.5	3.5	3.7	3.7
Dissipation factor	D150	—				
1kHz, 50%RH, 73°F			0.0014	0.0015	0.0015	0.0020
2450MHz, 50%RH, 73°F			0.0046	0.0049	0.0053	—
Volume resistivity, 1/16"	D257	ohm-cmx10^{16}	10.0	7.0	3.0	1.5
Arc resistance	D495	seconds	85	85	85	125

*RH = relative humidity

Table 5 — TYPICAL MECHANICAL PROPERTIES

Property	ASTM Test Method	Units	ULTEM Resin 2100	2200	2300	2400
Tensile strength, yield	D638	ksi(MPa)	16.6(120)	20.1(140)	24.5(160)	27.0(186)
Tensile modulus, 1% secant	D638	ksi(MPa)	650(4500)	1000(6900)	1300(9000)	1700(11700)
Tensile elongation, yield	D638	%	5	—	—	—
, ultimate	D638	%	6	3	3	2.5
Flexural strength	D790	ksi(MPa)	28(200)	30(210)	33(230)	36(250)
Flexural modulus, tangent	D790	ksi(MPa)	650(4500)	900(6200)	1300(9000)	1700(11700)
Compressive strength	D695	ksi(MPa)	22(150)	28.7(200)	30.7(210)	31.8(220)
Compressive modulus	D695	ksi(MPa)	541(3700)	809(5600)	938(6500)	1060(7300)
Izod impact strength	D256	ft-lb/"(J/m)				
notched, 1/8"			1.1(60)	1.6(90)	2.0(110)	2.1(110)
unnotched, 1/8"			9.0(480)	9.0(480)	8.0(430)	8.0(430)
Shear strength, ultimate	—	ksi(MPa)	13(90)	13.5(95)	14(100)	15(105)
Rockwell hardness	D785	M scale	114	114	114	114

Processing Characteristics:

Processability of ULTEM 2000 grades is very good. Glass reinforcing does not adversely affect processing. For specific help in processing, mold and part design, consult the producer.

General Characteristics:

Various strength properties of the ULTEM 2000 series increase as the amount of glass reinforcement increases. Specific gravity also increases but to a lesser extent and therefore the strength/weight ratio is significantly improved as glass reinforcement is increased from 10 to 40%. Mold shrinkage, water absorption and thermal coef. of expansion decrease as glass reinforcement is increased.

Applications:

Transportation: automotive underhood parts, structural applications requiring minimal thermal expansion, high heat lamp sockets.
Industrial: pressure vessels, filter bowls, various threaded components, hardware, fasteners.
Electrical: switches and controls, circuit boards, connectors, disc drives.

Producer:

G E Plastics
Plastics Group
One Plastics Avenue
Pittsfield, Massachusetts 01201

Alloy DIGEST

UNIDIRECTIONAL KEVLAR® 49
ARAMID REINFORCED EPOXY COMPOSITES

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Cp-7
Composite

APRIL 1990

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

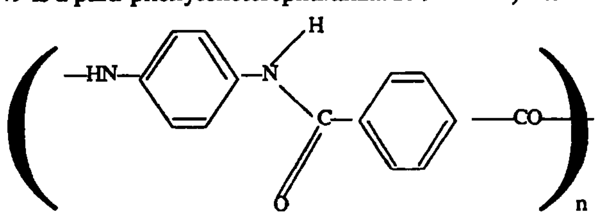
UNIDIRECTIONAL KEVLAR® 49 ARAMID REINFORCED EPOXY COMPOSITES

(Fiber volume fraction 55-60%; ply thickness approximately 5 mill)

KEVLAR® 49 is a high-modulus para-aramid reinforcing fiber. It is the dominant organic reinforcing fiber in advanced composites today. It has exceptional strength and stiffness and it is a low density material.

Chemical Characterization:

KEVLAR® 49 is a para-phenyleneterephthalamide 9PPD-T). Its chemical structure may be represented as follows:



PROPERTIES

Table 1 – STATIC DATA, DENSITY AND SPECIFIC HEAT, KEVLAR® 49 FIBERS

Property		Test Temperature: Room Temp.	Test Temperature: 250°F (121°C)
Axial modulus*, psi x 10^6 (MPa x 10^3)		18 (124)	15.4 (114)
Transverse modulus*, psi x 10^6 (MPa x 10^3)		1 (6.9)	0.95 (6.6)
Axial shear modulus*, psi x 10^6 (MPa x 10^3)		0.4 (2.8)	0.38 (2.6)
Axial Poisson's ratio*		0.36	0.36
Transverse shear modulus*, psi x 10^6 (MPa x 10^3)		0.4 (2.8)	0.35 (2.4)
Axial tensile strength**, psi x 10^3 (MPa x 10^3)		525 (3.62)	460 (3.17)
Axial elongation to break**, %		2.9	2.8
Axial coef. thermal expansion*, in/in/°F x 10^{-6}		–2.9	–2.9
m/m/°C x 10^{-6}		–5.2	–5.2
Transverse coef. thermal expansion*, in/in/°F x 10^{-6}		23.0	23.0
m/m/°C x 10^{-6}		41.4	41.4
Density, lb/cu in. (g/cu cm)		0.052 (1.44)	0.052 (1.44)
Specific heat, C_p, Btu/lb/°F (J/kg/°C)	At 0°C	0.292 (1220)	
	At 100°C	0.476 (1990)	
	At 200°C	0.626 (2620)	
	At 300°C	0.679 (2840)	

*Determined from unidirectional composite data.
**Resin impregnated strand test (ASTM D2343).

Table 2 – COMPARATIVE REINFORCING FIBER DATA*

Property		KEVLAR® 49 Aramid	E-Glass	T-300 Carbon	AS-4 Carbon	S-Glass
Tensile strength, 10^3 psi		525	450	470	520	600
	MPa	3620	3100	3240	3590	4140
Tensile modulus, 10^6 psi		18.0	10.5	33.5	34.0	12.4
	10^3 MPa	124	72	231	234	85
Elongation to break, %		2.5	4.3	1.4	1.5	4.8
Density, lb/cu in.		0.052	0.092	0.064	0.065	0.090
	g/cu cm	1.44	2.55	1.77	1.80	2.49

*Resin impregnated strand test ASTM D2343.

Table 3 – TYPICAL STATIC DATA FOR UNIDIRECTIONAL KEVLAR® 49 REINFORCED EPOXY*

Property	Test Orientation	Test Temperature R.T.	Test Temperature 250°F (121°C)
Tensile and compressive moduli of elasticity, 10^6 psi (GPa)	Fiber direct.	11 (78.5)	9.4 (64.8)
	90° to f. dir.	0.8 (5.52)	0.7 (4.83)
Shear modulus, 10^6 psi (GPa)	In fiber plane	0.3 (2.07)	0.26 (1.79)
Major Poisson's ratio	Comp. loaded in fiber direct.	0.34	0.34
Thermal coef. expans., in/in/°F x 10^{-6}	Fiber direct.	−2.24 (−4)	−2.2 (−4)
(mm/mm/°C x 10^{-6})	90° to f. dir.	32 (57)	32 (57)
Tensile strength, psi x 10^3 (MPa)	Fiber direct.	200 (1379)	170 (1172)
Compressive strength, psi x 10^3 (MPa)	Fiber direct.	40 (276)	32 (221)
Tensile strength, psi x 10^3 (MPa)	90° to f. dir.	4.3 (29.6)	2.9 (20.0)
Compressive strength, psi x 10^3 (MPa)	90° to f. dir.	20 (137.9)	15.5 (107)
Shear strength, psi x 10^3 (MPa)	In fiber plane	6.3 (43.4)	4.8 (33.1)
Density, lb/cu in. (g/cu cm)		0.050 (1.38)	0.050 (1.38)

*60% fiber volume fraction.

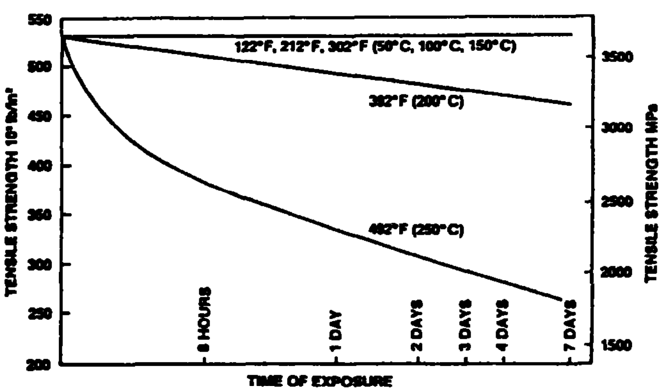


Fig. 1 – Elevated temperature aging of KEVLAR® 49 resin impregnated strands.

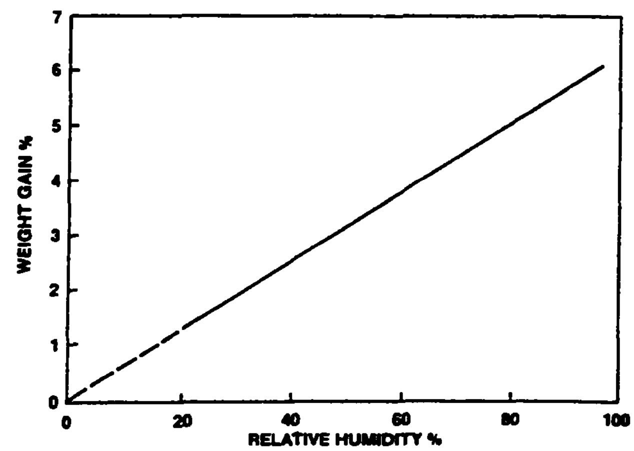


Fig. 2 – Moisture absorption rate of KEVLAR® 49 from dry condition.

Table 4 – ROOM-TEMPERATURE CREEP BEHAVIOR OF KEVLAR® 49 FIBER*

Stress, % of Tensile Strength	Approximate % Creep Strain in 100 Min.	Approximate % Creep Strain in 300 Min.
50	1.175	1.20
60	1.425	1.45
70	1.675	1.70
80	1.875	1.90
90	2.125	2.175

*Resin impregnated strands, 60-70% fiber volume fraction.

Table 5 – ROOM-TEMPERATURE STRESS-RUPTURE BEHAVIOR OF KEVLAR® 49 AND S-GLASS FIBERS*

	Approximate Stress (% of T.S.) at which there is					
	5% Failure Probability in			50% Failure Probability in		
Fiber	10hr	100hr	1000hr	10hr	100hr	1000hr
KEVLAR® 49	84	80	75	87	84	80
S-Glass	75	69	64	68	64	59

*Resin impregnated strands, 60-70% fiber volume fraction.

Handling of KEVLAR® 49 Fiber:

Storage: Avoid exposure to UV light. Storage in the shipping containers is satisfactory. Typical storage life of preimpregnated fiber is typically 6 months at 0°F.

Drying: Good practice involves drying KEVLAR® 49 fiber at 250°F prior to use. Resin impregnation should be carried out within 1 hour after drying.

Product Safety: Spark ignition tests indicate that atmospheres of fine fiber particles do not explode. KEVLAR® 49 yarn is not readily biodegradable and contains no significant water extractable material so its effect on ground water in case of landfill disposal is negligible. Skin contact tests show minimal potential for irritation. Rat inhalation tests at respirable fiber concentrations 100 times that encountered in fiber processing operations were typical of nuisance dust exposures. Even so, exposure to inhalable material should be minimized by adequate ventilation, effective containment and personal cleanliness. In handling this unusually strong fiber, there is a possibility of cuts to hands or fingers caught in loops or tangles.

Machining:

Machine tool performance in terms of quantity of work per tool and quality of finished part will be enhanced by use of very sharp tools kept free of resin build-up. Overheating must be avoided to minimize resin matrix deterioration. The generally low thermal conductivity of the composite means that most of the heat generated in machining must be conducted away by the tool. The impact of fluid absorption on material properties has not been studied in detail. High thermal coefficient of expansion of composites makes maintenance of dimensional accuracy more difficult than in the case of metals. High-speed steel tools will typically provide adequate but limited service life. Coating tools with titanium carbide or titanium nitride will economically provide much improved service, particularly where more than one type of reinforcing fiber is encountered (hybrid composites).

Applications:

Aerospace, marine and sporting goods.

Producer:

E.I. duPont deNemours & Co., Inc.
Wilmington, Delaware 19898

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Cu-2
Copper Alloy
Revised 1/1/66

OCTOBER 1952

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

RESISTAC No. 1

RESISTAC No. 1
(HEAT TREATABLE ALUMINUM BRONZE)

Resistac No. 1 is a high strength, corrosion resistant aluminum bronze capable of responding to heat treatment for increased strength and hardness. It has exceptionally good fatigue resisting qualities and will retain its strength and hardness at relatively high temperatures.

Composition:

	Typical	Range
Copper	89	86.0 min
Aluminum	10	9.00-11.00
Iron	1	0.75-1.50
Total named elements		99.00 min.

Physical Constants:

Specific gravity, g/cc	7.57
Density, lb/cu. in.	0.270
Coefficient of expansion, in/°F	0.000009
Electrical conductivity, % Cu	12.8
Thermal conductivity, cgs	0.21
Modulus of elasticity, psi	17,500,000

PROPERTIES:

Table 1

	As-Cast	Heat Treated	As-Forged
Tensile strength, psi	65000-85000	80000-90000	72000-92000
Yield strength, psi	28000-35000	35000-55000	33000-42000
Proportional limit, psi	16000-19000	24000-35000	20000-25000
Elongation, % in 2"	35-20	20-5	25-15
Reduction of area, %	35-20	20-5	25-15
Brinell hardness	120-160	160-245	130-170
Shear strength, psi	45000	50000	46000-49000
Fatigue strength., psi	24000	30000	26000-28000
Charpy impact, ft. lbs.	18	—	14
Izod impact, ft. lbs.	20	—	18
Ultimate in compression, psi	110000	—	123000
Elastic limit in compression, psi	18000	—	30000

Table 2

HARDNESS VERSUS TEMPERING TEMPERATURE
(Water quenched from 1620°F and tempered as indicated)

Tempering Temperature, °F	Brinell Hardness
as-quenched	224
350	226
750	240
850	210
925	193
975	183
1025	180
1075	175
1125	173
1275	173

Heat Treatment:

Solution Treatment: Heat to 1600°F, quench in water.
Aging Treatment: Reheat to 1000-1150°F, depending on desired hardness, and water quench.

(The maximum hardness is obtained on the solution treatment and the hardness drops on aging or tempering below 1200°F. Heating to the high temperature should be slow and uniform to avoid high temperature gradient and consequent excessive grain growth at the metal surface.)

Castability:

Controlled foundry technique is necessary to accommodate the high shrinkage, short freezing range, and necessity for accurate chemical composition. Precautions in melting is to use oxidizing or neutral atmosphere and minimum stirring. This alloy is subject to gas absorption during melting with subsequent porosity. No deoxidizer and no flux is generally used. Highly oxidizing conditions or excessive agitation of molten metal in mildly oxidizing conditions will substantially reduce gas pick-up, but will result in high loss of aluminum content and consequent change in composition of the alloy.

Pouring temperatures will vary from 2000°F for heavy castings to 2250°F for light sections and long runs. Heavy risers are mandatory. They should be about 1¼ to 1½ times the thickness of the section they are expected to feed.

Workability:

Good forging properties. Physical properties are improved lending itself more easily to machining and fabrication. Hot working temperature range is critical and should be kept in the range 1500-1650°F.

It is possible to cold-work the duplex aluminum bronze only to a limited extent, and in general it should not be subjected to severe cold-working operations.

Machinability:

Its machinability rating is 20% of that of free-cutting brass. With high speed steel cutters use 75-150 sfpm cutting speed with 0.015-0.040 inch roughing feed and 0.005-0.020 inch finishing feed. Such cutting tools should be ground for 15° lead angle, 20-30° side rake, 10-20° back rake, 10-20° side clearance, and 10-15° front clearance. Carbide-tipped tools should be ground 8-15° end cutting-edge angle, 10-15° lead angle, 15-25° side rake, 4-8° back rake, 7-10° side clearance and front clearances. A cutting fluid of mineral base oil with 10-20 percent lard oil is recommended.

With tungsten-carbide cutting tools rough machining of castings may be performed at 250 sfpm with 1/32 inch feed per revolution and ¼ inch depth of cut, while finish machining may be performed at 500 sfpm with 1/64 inch feed per revolution and 0.015 inch depth of cut.

Parting tools should be given ample side clearance and back relief to prevent binding in the work. Forming tools may be similar in design to those employed in steel practice, though additional front clearance is advocated to prevent the tool from riding the surface of the work.

Drilling is done best with standard twist drills. At the higher hardness of heat treated stock it may be to advantage to reduce the rake angle by grinding flats in the cutting edges. Alternatively drills having a steeper helix angle than standard may be used.

Weldability:

Good weldability. Use welding rod of similar composition. In metal-arc welding use reverse (positive) polarity direct current; while in carbon-arc welding use straight (negative) polarity direct current. It is advantageous to preheat to 300°F before welding.

It can be brazed, hard soldered and also soft soldered with some difficulty. Soft soldering can be done using any standard grade of tinsmith's solder with orthophosphoric flux.

Corrosion Resistance:

High resistance to corrosion. Resists sulphuric acid solutions, salt solutions and vapors, many organic acids and ammonium salts. It is corrosion resistant to mild, but not strong, alkalis.

General Characteristics:

Resistac No. 1 has about the same strength and ductility as ordinary cast carbon steel. It has a rich gold color, is 10% lighter in weight than the tin-bronzes, and requires experience, careful control and special technique in molding and pouring to produce sound castings.

In the soft condition it has high elongation and low hardness suitable for light members subject to shock and plastic flow under heavy loads. In the heat treated condition the increased mechanical properties with retained good elongation make it suitable for highly stressed parts where deformation rather than breakage is essential in cases of heavy loading, and also for high abrasive conditions.

The principle application is in the field of chemical corrosion where strength and corrosion resisting properties are required. It is also heat resistant, that is, it retains its strength and hardness at elevated temperatures. It also has exceptionally good fatigue resisting properties which recommends it for parts and equipment subject to oscillating or repetitive stresses. Also applicable where good bearing and resistant characteristics are required.

This alloy is generally used for thin or moderate sections, and is not used for very heavy wall sections as its low iron content permits large grain growth and a tendency towards brittleness. For very heavy wall sections the higher iron content type of aluminum bronze is recommended.

Forms Available:

Sand castings and hammered forgings.

Applications:

Hot-mill guides, valve guides in internal combustion engines, gears, worm wheels, propellers, shafting, valve seats for super-heated steam and similar service, bearing liners, thrust pads, machine and tool bearings, valve stems and spindles, wear plates, and marine equipment and parts.

Manufacturer:

American Manganese Bronze Company
Phila delphia, Pennsylvania

Alloy DIGEST™

ALLOY 390™

DATA ON WORLDWIDE METALS AND ALLOYS

Filing Code: Cu-712
Copper

March 2004

ASM INTERNATIONAL® The Materials Information Society

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 Mem-Serv@asminternational.org
Fax 440-338-4634 www.asminternational.org

ALLOY 390™
(Copper-Nickel-Beryllium Alloy)

Alloy 390 was specifically designed for high-power applications and provides a combination of high strength and high conductivity. Increasing power requirements drive the need for lower conductor resistance to reduce joule heating. This alloy has a high thermal conductivity that is critical to thermal management. Higher power requirements create harsh environments and higher operating temperatures. Alloy 390 provides excellent stress-relaxation resistance at elevated temperatures, which increases electrical contact reliability.

Alloy 390 is a trademark and Brush 60 is a registered trademark of Brush Wellman Inc.

Chemical Composition, wt.%:

Nickel	1.0–1.4
Beryllium	0.15–0.50
Aluminum	0.20 max
Iron	0.20 max
Silicon	0.20 max
Tin	0.25 max
Zirconium	0.50 max
Copper including silver	bal
Copper + sum of named elements	99.5 min

Physical Properties:

Density, kg/m^3 (lb/in.^{3})	8800 (0.318)

See also Table 1.

Mechanical Properties:

Yield strength, min, MPa (ksi)	930–1055 (135–153)
Tensile strength, min, MPa (ksi)	950–1090 (138–158)
Elongation, min, %	1
Bend radius in 90°, longitudinal and transverse, *R*/*t*	2.0
Modulus of elasticity, GPa (10^6 psi)	138 (20)

See also Table 1.

Specification Equivalents:

UNS C17460

General Characteristics:

The producer used Lean Six Sigma methodologies to make process breakthroughs, making it possible to produce an alloy that has both high strength and high conductivity. Alloy 390 combines the best attributes of two separate families of commercial copper-beryllium alloys: the strength of the "high-strength" alloy C17200 with the conductivity of "high-conductivity" alloys C17410 and C17510. Alloy 390 has excellent stress-relaxation resistance at elevated temperatures. In applications where durability is important, such as in burn-in and test sockets, battery contacts, SIM (subscriber identity module) card contacts, and relays, the excellent fatigue strength of this alloy extends the product life, providing better utility that translates into cost savings.

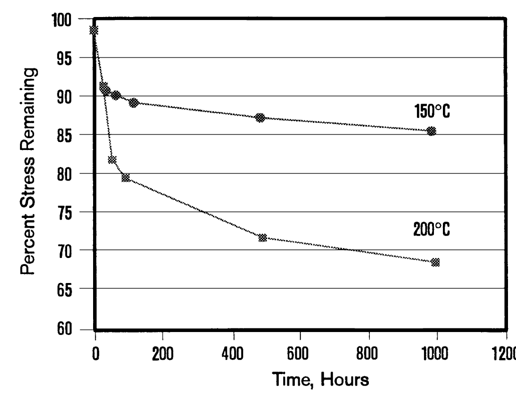


Fig. 1 Stress-relaxation behavior

Alloy 390 has a high conductivity so that it maintains flow of electrical or thermal energy, reducing device operating temperatures and improving device battery life. The alloy has excellent stress-relaxation performance so that it retains contact force at elevated temperatures for high reliability (see Fig. 1). Its excellent resilience means that the alloy tolerates large displacements without permanently deforming, and its excellent fatigue strength enables high cycle life without degradation in contact force (see Fig. 2).

Handling copper-beryllium strip products in solid form poses no special health risk. Like many industrial materials, beryllium-

Table 1 Alloy Comparisons

Alloy	Temper	Yield strength MPa	Yield strength ksi	Electrical conductivity, %IACS	Elongation, min, %	Bend radius, 90° bend, *R*/*t* Longitudinal	Bend radius, 90° bend, *R*/*t* Transverse	Modulus of elasticity GPa	Modulus of elasticity 10^6 psi
Alloy 390	HT	931–1055	135–153	44	1	2.0	2.0	138	20
Alloy 190	XHM	931–1172	135–170	17	4	4.0	5.0	131	19
Brush 60	HT	720–860	105–125	50	10	1.5	1.5	138	20

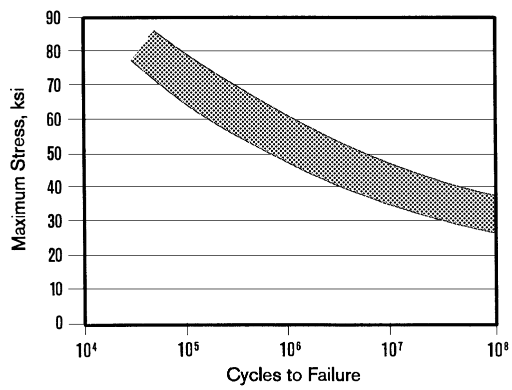


Fig. 2 Flexural fatigue strength in fully reversed bending, $R = -1$

containing materials may pose a health risk if recommended safe-handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) from the producer before working with this material.

Product Forms Available:

Strip

Applications:

Potential uses include computer burn-in and test sockets (BiTS), production sockets, power connectors, switches, relays, automotive power applications, and other handheld and portable electronic contact applications.

Producer:

Brush Wellman, Inc.
17876 St. Clair Ave.
Cleveland, OH 44110
(216) 486-4200
(216) 383-6868 (fax)

ISSN: 002-614X Cu-712B

Alloy DIGEST™

PERMENDUR 49

DATA ON WORLDWIDE METALS AND ALLOYS

ASM INTERNATIONAL® The Materials Information Society

Filing Code: Fe-126
Iron

February 2004

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 Mem-Serv@asminternational.org
Fax 440-338-4634 www.asminternational.org

PERMENDUR 49
(Cobalt Iron Soft Magnetic Alloy)

Permendur 49 is an alloy with nominal composition 49% Co, 49% Fe, and 2% V that combines high saturation with high permeability. It can be supplied as forged section or strip normally in the range 0.1–1.0 mm (0.004–0.04 in.) thickness.

Chemical Composition, wt.%:

Cobalt	49
Vanadium	2
Iron	49

Physical Properties:

Density, kg/m^3 ($lb/in.^3$)	8150 (0.295)
Resistivity, $\mu\Omega \cdot m$ (Ω circular-mil/ft)	0.40 (241)
Coefficient of linear thermal expansion, 10^{-6}/K (10^{-6}/°F)	9.5 (5.3)
Thermal conductivity, W/m · K (Btu/(ft · h · °F))	25 (14.4)
Specific heat capacity, J/kg · K (Btu/lb · °F)	420 (0.10)
Curie temperature, °C (°F)	940 (1724)
Magnetic peak inductance, saturation induction at 40,000 A/m (500 Oe), T (G)	2.34 (23,400)
Magnetic permeability, max dc permeability for strip	7000
Magnetic residual induction, remanence from saturation, T (G)	1.62 (16,200)
Coercivity, H_c dc for strip, A/m (Oe)	80 (1.0)

See also Fig. 1.

Mechanical Properties:

Yield strength, strip heated at 760 °C (1400 °F), MPa (ksi)	340 (49)
Tensile strength, strip heated at 760 °C (1400 °F), MPa (ksi)	700 (102)
Elongation in 50 mm (2 in.), strip heated at 760 °C (1400 °F), %	6
Young's modulus, GPa (10^6 psi)	230 (33)

Heat Treatment:

Alloys are supplied in the hard rolled condition for fabrication by stamping, turning, or milling. After these operations have been completed, the material requires heat treatment to develop its magnetic properties. Parts are degreased, if necessary, and heat treated in accordance with the following recommendations.

Parts should be heated to 350 °C (660 °F) and held at this temperature until the exit dew point is better than –35 °C (–31 °F).

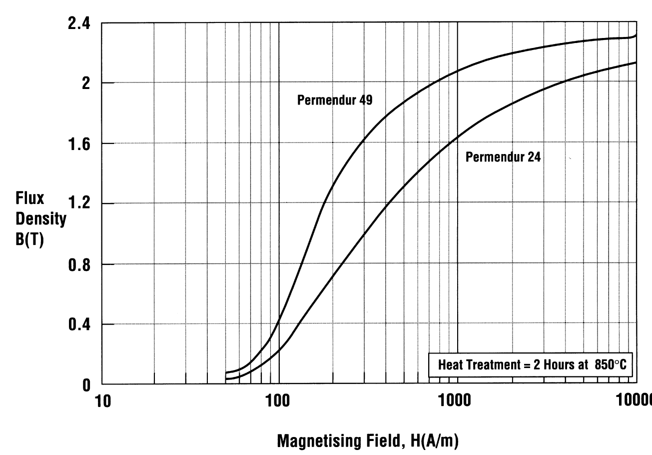


Fig. 1 Typical dc normal induction curves

When this is achieved, the temperature can then be raised to 500 °C (930 °F) and held again until the dew point reaches –35 °C (–31 °F). This procedure also removes traces of oil from the parts. The furnace temperature can then be slowly raised until the load reaches 760 °C (1400 °F). The temperature should be held within ±10 °C (±18 °F) for 2 h before cooling at a rate between 1–3 °C/min (1.8–5.4 °F/min) down to 300° C (570 °F) and removing from the furnace.

The heat treatment temperature of 760 °C (1400 °F) is specified for all cobalt-iron alloys to obtain a balance of good magnetic and mechanical properties. Where optimum magnetic properties such as lowest loss or highest permeability are required, or alternatively where better mechanical properties are a prime consideration, then alternative temperatures are needed. For optimum magnetic properties use 850 °C (1562 °F). For optimal mechanical properties use 720 °C (1328 °F).

Some small increase in dimensions can be expected following heat treatment and an allowance of approximately 0.1% should be made for this where very tight tolerances on finished parts are needed.

Machinability:

Permendur is readily machined, but requires different techniques than those used on conventional steels and brasses. The most significant features are the tendency to brittleness and the need to

Table 1 Drilling

Depth of cut		Cut per revolution	
mm	in.	mm	in.
0.8–3.175	1/32–1/8	0.025	0.001
3.175–11.10	1/8–7/16	0.10	0.004
11.1–25.4	7/16–1.0	0.15	0.006
25.4–50.8	1.0–2.0	0.25	0.010

Table 2 Setup for Turning with High-Speed Steel (HSS) Tools

Detail	Roughing value	Finishing value
Top rake angle, degrees	10–15	25–30
Nose radius, mm (in.)	0.5–0.75 (0.02–0.03)	0.5–0.75 (0.02–0.03)
Speed, continuous cuts, sfpm (smpm)	200 (61)	200 (61)
Speed, interrupted cuts, sfpm (smpm)	120 (37)	120 (37)
Feed, where practical, mm/rev (ipr)	0.125 (0.005)	0.125 (0.005)
Depth of cut, initial cuts, mm (in.)	up to 9.5 (0.375) to within 3 (0.125) of finish size	
Depth of cut, mm (in.)	up to 1.6 (0.062) to within 0.25 (0.010) of finish size	

Table 3 Recommended Rates for Milling Operations with Cobalt-Iron Alloys

Roughing, m/min (ft/min)	61 (200)
Maximum finishing, m/min (ft/min)	132 (435)

avoid overheating, which can lead to surface cracking. Care should be taken to ensure pressure is not unduly localized when the material is held in a chuck, or clamped. A fairly high approach angle (approximately 30°) should be used to prevent breakup on run out of cuts. Generally, maximum rigidity of tool and workpiece is required to ensure smooth cutting. Machine speed needs to be low, ensuring sufficient torque or force at the cutting edge to prevent deceleration. Tools must be well maintained, with a high degree of surface finish on the rake face. The tool material may be either high-speed steel or tungsten carbide.

Cutting Fluids. Because heat is generated during cutting operations, machining is made easier by using a good cutting fluid. For general machine work, a flow of soluble oil is recommended, while a neat chlorinated oil is favored for use on automatic or semiautomatic machines. A flow rate of approximately 5 L/min/hp used is normally sufficient. For tapping and reaming with standard tools, Rocol RTD or a similar compound is recommended.

Drilling. Use quick spiral drills. Drills should be reground as soon as they show signs of dulling. Flow a large amount of cutting fluid onto the cutting edge of the drill and use a speed of 9–12 mpm (30–40 fpms).

Grinding. Wheel grade WA 60 JV and lubricant Houghtogrind 4 are recommended for cobalt-iron alloys. Grinding after annealing should be avoided if possible to avoid degradation in magnetic performance. If annealing is essential, the following cuts are recommended.

Final cut, mm (in.)	0.005 (0.0002)
Final cut but one, mm (in.)	0.005 (0.0002)
Final cut but two, mm (in.)	0.010 (0.0004)
Final cut but three, mm (in.)	0.025 (0.001)
Final cut but four, mm (in.)	0.050 (0.002)

See also Tables 1–3.

General Characteristics:

Cobalt-iron alloys containing 24–50% Co provide a range of properties with the highest known saturation magnetization at room temperature. This combined with high strength makes them a natural choice for the design engineer where considerations of weight and space are of prime importance.

Product Forms Available:

Cold-rolled strip is available in thicknesses ranging from 0.1–1.0 mm (0.004–0.04 in.). Widths range from 6.0–225 mm (0.24–8.9 in.). The material is available in coils typically 300–500 mm (12–20 in.) internal diameter or cut lengths. The cold-rolled condition has a hardness of 315 HV.

Hot-worked products are available. They may be forged as hot worked, rolled rod as hot worked or centerless ground, forged squares as hot worked, rolled rectangles as hot worked, and rolled squares as hot worked. Contact the producer for sizes available.

Applications:

Permendur 49 is used to maximize flux concentration in high field devices such as mass spectrometers, magnetrons, traveling wave tubes, NMR medical equipment, solenoids and valves for aircraft and missiles, and for high-performance loud speakers.

Producer:

Carpenter Technology, Ltd.
Napier Way
Crawley, West Sussex, RH10 2RB
England
+44 1293 55 1190
+44 1293 53 7313 (fax)

USA:
Carpenter Technology Corporation
Wyomissing, PA 19610
(800) 654-6543

ISSN: 002-614X

Alloy DIGEST

ARMCO TRAN-COR ELECTRICAL STEEL, GRADE H-0

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Fe-92
IronAlloy

SEPTEMBER 1990

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

Armco Tran-Cor Electrical Steel, Grade H-0

("Super Oriented" Electrical Steel)

Armco Tran-Cor Electrical steel offers an outstanding degree of grain orientation with resultant far lower core loss than possible with conventional grain-oriented electrical steels.

Composition:

An iron silicon alloy.

Physical Constants:

Density, gm/cu cm	7.65
Volume resistivity, microhm-cm	45
Ferric induction, saturation value (effective value, coated specimen), B-H, kilogausses	19.9
Curie Temperature, °F (°C)	1380(749)

PROPERTIES

Table 1 — MAXIMUM CORE LOSS* LIMITS, ARMCO TRAN-COR GRADE H-0

Thickness", (mm)	0.009(0.23)
Core loss @ 60 Hertz, 17kG induction, watts/lb(watts/kg)	0.60(1.32)
Core loss @ 50 Hertz, 17kG induction, watts/lb(watts/kg)	0.46(1.01)

*Equivalent to ASTM Core Loss Type 23 P 060.

Table 2 — REPRESENTATIVE MECHANICAL PROPERTIES

Tensile strength in the rolling direction, psi(MPa)	48000(331)
Yield strength in the rolling direction, psi(MPa)	45000(310)
Elongation in the rolling direction (2"), %	12
Rockwell hardness, 15T Scale	85
Equivalent B Scale	76
Modulus of elasticity in the rolling direction, ksi (MPa)*	16500(113800)
20° to the rolling direction	20000(138000)
45° to the rolling direction	35000(241000)
55° to the rolling direction	40000(276000)
90° to the rolling direction	29500(203000)

*Values may vary as much as ±5%.

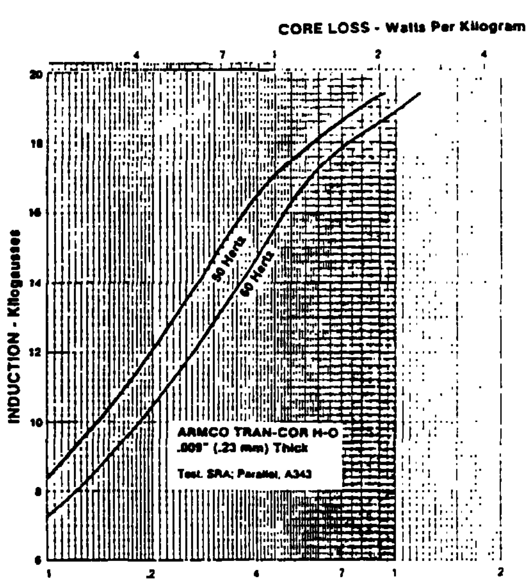


Figure 1-a — Core loss at various inductions for 50 and 60 Hertz.

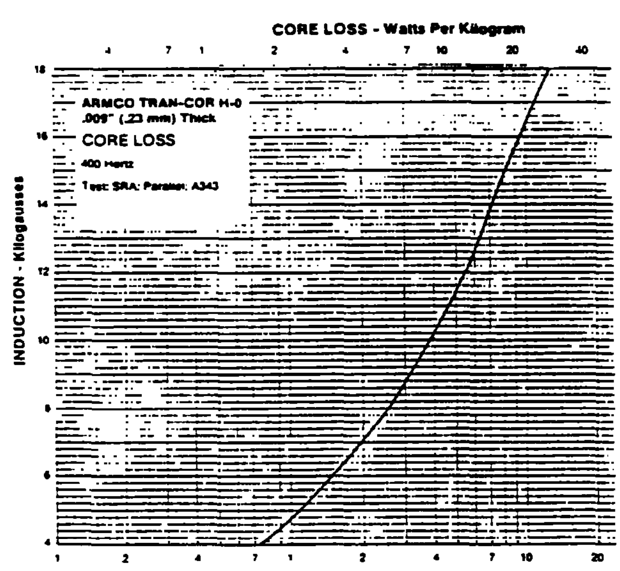


Figure 1-b — Core loss at various inductions for 400 Hertz

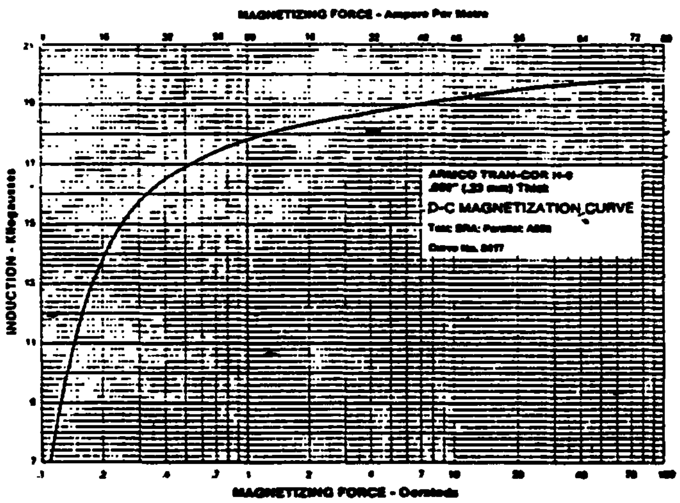


Figure 2

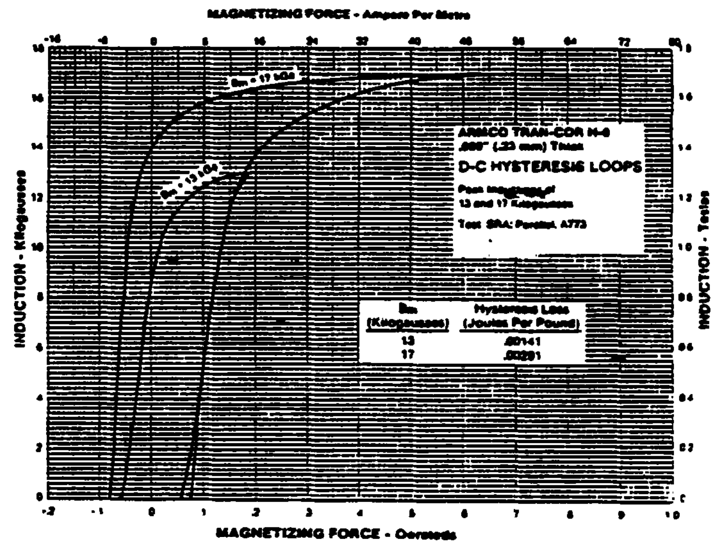


Figure 3

Magnetic Characteristics:

Core loss at various inductions for 50, 60 and 400 Hertz; D-C magnetization curve; and D-C hysteresis loops for peak inductions of 13 and 17 kilogausses are shown in figures 1a, 1b, 2 and 3. For additional curves of magnetic characteristics, consult the producer.

Coating:

Armco-developed inorganic Carlite*3 insulative coating applied over the mill annealed finish is intended for materials that will be used in the form of sheared laminations for power transformers. It corresponds to AISI C-5 insulation. In addition to its excellent insulation qualities, the coating supplies a beneficial tensile stress and contributes to better magnetic properties and decreased stress sensitivity. The smooth surface of Carlite 3 allows for easy assembly of laminations.

*Carlite is a registered trademark of Armco Inc.

Heat Treatment:

Full magnetic properties are developed by closely controlled mill annealing. To stress relieve after fabrication, heat to 1400-1550°F (760-845°C) and cool to room temperature maintaining atmosphere protection to 600-700°F (315-370°C). Stress relieving may be done in box furnaces with inner protective covers. It is essential that atmospheres free from carbon and oxygen be used.

General Characteristics:

Like other Armco oriented steels, TRAN-COR H-O steel has exceptionally high lamination factors. The steel exhibits an outstanding degree of grain orientation, high permeability particularly at higher operating inductions, improved resistance to magnetic damage resulting from elastic strain incurred in core construction and reduced magnetostriction with a potential for less noisy core structures.

Forms Available:

Armco TRAN-COR H-O is available in coils 0.009" (0.23mm) thickness 34" wide or narrower.

Applications:

Transformer cores.

Producers:

Armco Advanced Materials Company
Butler, Pennsylvania 16001-1609

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Mg-4
Magnesium Alloy

MARCH 1953

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

ELEKTRON ZT1

ELEKTRON ZT1

(MAGNESIUM CASTING ALLOY, CREEP-RESISTANT UP TO 660°F.)

ELEKTRON ZT1 is distinguished by the best combination of properties at temperatures of and above 600°F of any magnesium casting alloy; also by excellent room temperature properties, by freedom from microporosity, and exceptionally good founding characteristics. Very suitable for jet engine parts.

Composition:

Thorium	3.0
Zinc	2.3
Zirconium	0.7
Impurities	
Manganese	0.15 max.
Copper	0.03 max.
Silicon	0.01 max.
Iron	0.01 max.
Nickel	0.005 max.
Rare earth metals	0.10 max.
Magnesium	balance

Physical Constants:

Specific gravity, g/cc	1.83
Density, lb/cu. in.	0.0657
Modulus of elasticity, psi	6,500,000
Modulus of rigidity, psi	2,500,000
Poisson's ratio	0.3

PROPERTIES

Table 1
TYPICAL MECHANICAL PROPERTIES

Tensile strength, psi	27,000-31,500
Yield strength, psi	12,500-15,000
Elongation, % in 2"	5-10
Brinell hardness, 500/30/10	50-60

Table 2
ELEVATED TEMPERATURE PROPERTIES

Temperature °F	Tensile Strength psi	Elongation % in 2"
527	12,100	50
572	10,750	45
617	10,080	40
662	9,630	35

Table 3
FATIGUE PROPERTIES
(Single point loading alternating bending fatigue)

Temperature °F	Fatigue limit for $5x10^7$ reversals in psi. NOTCHED	Fatigue limit for specified reversals in psi. UNNOTCHED		
		10^7	$5x10^7$	10^8
68	±10,080	—	±10,080	—
392	—	±7,170	—	±7,170
482	—	±6,050	—	±6,050
600	—	±4,700	—	±3,360
662	—	±3,470	—	±2,350

Table 4
CREEP PROPERTIES

Temperature °F	Stress psi	Rate 10^{-7} in./in./hr.	Total plastic strain %
600	1,680	12 (200/1,000 hrs.)	0.10 (200 hrs.)
	2,240	15 (200/1,000 hrs.)	0.15 (200 hrs.)
	3,360	15 (500/1,000 hrs.)	0.28 (500 hrs.)
662	1,120	9 (200/1,000 hrs.)	0.04 (200 hrs.)
	1,680	>35 (500/ 700 hrs.)	0.90 (700 hrs.)
	2,240	430 (800/1,000 hrs.)	1.50 (800 hrs.)

Castability:

The alloy is completely free from microporosity and possesses exceptionally good founding properties.

Heat-Treatment:

Elektron ZT1 requires no high temperature solution heat-treatment for the development of the maximum creep resistance and mechanical properties. A simple stabilizing anneal at the maximum service temperature of the casting is the only heat-treatment required.

Machinability:

Like all magnesium-base alloys, Elektron ZT1 has excellent machining qualities. The power required per cubic inch of metal removed is about one-sixth that required for steel and about half that needed for aluminum. In general the higher the cutting speed the better the results, the limiting factor being the power of the machine rather than the quality of the tool material.

High-speed tools are normally suitable but tipped tools are preferred. Very good finish cuts are obtained with diamond tools. Tools must be kept sharp; they must always take off a definite cut; they must have a definite clearance to avoid rubbing; and they must not be allowed to dwell in the cut. Dry machining is recommended; compressed air is sometimes used for cooling. If liquid coolants are indispensable, then mineral oil base fluids are recommended. Water base coolants should not be used.

High speed steel lathe tools for rough cutting should have a 15-20° top rake, 5-10° side rake, 8-10° front clearance, 3-6° side clearance, and a cutting edge-angle of about 35°. Finishing tools should be designed as for rough cutting tools except for a round nose of 0.040" diameter. Tipped-carbide cutting tools should have smaller rake angles to provide more support for the cutting edge. Forming tools usually have the back rake angle reduced to 4-8° to eliminate possible chatter. Parting tools should have clearance angle of about 6-8°, except the side face clearance angle which could be about 3-5°. A 15-20° back rake is recommended for parting tools.

Moderate feeds and depth of cut, high cutting speeds, large rake angles, and ample chip clearance are desirable. Cutting speeds of 2500-5000 sfpm with 0.010-0.030 inch per revolution feed and 0.150 inch maximum depth of cut can be used for roughing, while cutting speeds of 2500-5000 sfpm with 0.003-0.015 inch maximum depth of cut can be used for finishing, when using high speed steel turning tools.

Joining:

This alloy can be joined by the usual methods — riveting, bolting and screwing; also it is particularly easy to weld by the argonarc or heliarc method. Gas welding is not feasible.

Surface Treatment:

The normal methods of protecting magnesium alloys by chromate baths apply equally to this alloy; in particular the chrome-manganese bath will give a deep brown or black finish. Whenever possible painting should follow immediately. There are numerous suitable primers and enamels (air-drying and stoving types) available. The priming coat should contain preferably a chromate only as an inhibitor. Exceptionally good adhesion and abrasion resistance can be obtained by the application of Araldite or its equivalent for use in special conditions.

General Characteristics:

Elektron ZT1 is the magnesium alloy with the best combination of properties at temperatures of and above 600°F. In addition it has excellent room temperature properties and its general characteristics are similar to those of the magnesium-base alloys containing zirconium and rare earths.

Corrosion Resistance:

The alloy is perfectly stable in normal atmospheric conditions, but it should not be used unprotected in marine applications. Galvanic corrosion does not occur except in the presence of an electrolyte, and it can be prevented by suitable methods of insulation.

Resistance to Oxidation:

Undue oxidation of Elektron ZT1 is not likely to occur in service. Exposure to normal atmosphere at temperatures up to 660°F for periods of up to 1,000 hrs. results in only superficial tarnishing; no serious exfoliation has been observed up to 750°F.

Forms Available:

Sand castings and permanent mold castings.

Applications:

Mainly for components (such as jet engine parts) which must be creep-resistant up to about 660°F.

Manufacturer:

Magnesium Elektron Ltd., Manchester, England

Licensees:

Howard Foundry Company, Chicago, Illinois
Rolle Manufacturing Co., Inc., Lansdale, Pennsylvania
Aluminium Laboratories Limited, Montreal, Canada
The Robert Mitchell Co. Limited, Montreal, Canada

Alloy DIGEST™

ELEKTRON MSR-B

DATA ON WORLDWIDE METALS AND ALLOYS

ASM INTERNATIONAL® The Materials Information Society

Filing Code: Mg-74
Magnesium

January 2009

Published by: ASM International,
Materials Park, OH 44073-0002, 440-338-5151
CustomerService@asminternational.org
Fax 440-338-4634 www.asminternational.org

ELEKTRON MSR-B
(Heat Treatable Magnesium Casting Alloy)

ELEKTRON Alloy Elektron MSR-B is a magnesium casting alloy developed to offer good properties while retaining good foundry characteristics. The alloy is used in aerospace and military applications.

Elektron is a registered trademark of Magnesium Elektron Limited.

Chemical Composition, wt.%:

(Nominal)

Silver	2.0–3.0
Rare earths	2.0–3.0
Zirconium	0.4–1.0
Magnesium	bal

Physical Properties:

Specific gravity	1.82
Coefficient of thermal expansion, at 25.3 °C (77.5 °F), 10^{-6}/K (10^{-6}/°F)	26.7 (14.8)
Thermal conductivity, W/m · K (Btu/lb · h · °F)	113 (65.3)
Specific heat, J/kg · K (Btu/lb · °F)	1000 (0.24)
Electrical resistivity, nΩ · m (Ω circular-mil/ft)	68 (40.9)
Melting temperature range, °C (°F)	550–640 (1022–1184)

Mechanical Properties:

Design data; minimum specification tensile properties:

0.2% proof stress, MPa (ksi)	185 (26.8)
Tensile strength, MPa (ksi)	240 (34.8)
Elongation, %	2%
Modulus of elasticity, GPa (10^6 psi)	44 (6.4)
Poisson's ratio	0.3
Vickers hardness	80–105
Damping index	0.4

See also Tables 1 to 3.

Heat Treatment:

Castings are given the following T6 heat treatment to obtain optimum mechanical properties: (i) Solution treat for 8 h at 525 °C (977 °F). (ii) Hot water quench using water at 60–80 °C (140–175 °F) or polymer quench. (iii) Age for 16 h at 200 °C (400 °F), air cool.

Table 1 Mechanical properties at ambient temperature

Typical tensile properties	
0.2% proof stress, MPa (ksi)	205 (29.7)
Tensile strength, MPa (ksi)	266 (38.6)
Elongation, %	4
Typical compressive properties	
0.2% proof stress, MPa (ksi)	165–200 (23.9–29.0)
Ultimate strength, MPa (ksi)	310–385 (45.0–55.8)
Typical shear; ultimate stress, MPa (ksi)	152 (22.0)
Fracture toughness (K_{Ic}), MPa $\sqrt{m}$ (ksi) $\sqrt{in.}$	14.9 (13.6)
Fatigue strength, rotating bend fatigue test, unnotched, at 5×10^7 cycles, MPa (ksi)	100 (14.5)

Castability:

Excellent castability. Fine-grained microstructure and pressure tight. Pattern makers shrinkage factor is 1.3%.

Weldability:

Weldable by the tungsten arc inert gas (TIG) process with a filler rod of a similar composition. Castings should be heat treated after welding to obtain optimum properties.

Machinability:

Electron MSR-B castings, like all magnesium alloy castings, machine faster than any other metal. If the geometry of the part allows, the limiting factor is the power and speed of the machine rather than the quality of the tool material. The power required per cubic centimeter of metal removed varies from 9 to 14 watts per minute depending on the operation.

Surface Treatment:

All the normal chromating, anodizing, and finishing treatments are applicable.

Table 2 Typical elevated-temperature tensile properties

Temperature, °C (°F)	0.2% proof stress		Tensile strength		Elongation,
	MPa	ksi	MPa	ksi	%
100 (212)	195	28.3	230	33.4	15
150 (300)	182	26.4	208	30.2	19
200 (390)	165	23.9	185	26.8	24
250 (480)	122	17.7	160	23.2	30

Corrosion Resistance:

ASTM B117 Salt Spray test
Corrosion rate for base metal: 5.6 mg/cm^2/day (430 mpy)

This alloy is perfectly stable in normal atmospheric conditions, but it should not be used unprotected in marine applications. Galvanic corrosion does not occur except in the presence of an electrolyte and can be prevented by suitable methods of insulation. The alloy is not susceptible to stress-corrosion failure in salt solutions.

Specification Equivalents:

UNS M18220
AECMA MG-C-51
AFNOR G-Ag2.5TR
MOD DTD 5035A

General Characteristics:

This alloy is a high-strength magnesium casting alloy developed by Magnesium Elektron to have good ambient and elevated-temperature properties while retaining good foundry characteristics. It is a fully heat treatable magnesium alloy containing silver and rare earth metals. It is pressure tight, weldable, and may be used up to temperatures of 200 °C (390°F).

Applications:

The alloy will be of interest to designers requiring good retention of properties at elevated temperatures for aerospace, automotive, and military applications.

Producer:

Magnesium Elektron Wrought Products, North America
Madison, IL 62060
Tel: 618-452-5190
Fax: 618-452-7929

In United Kingdom:
Magnesium Elektron UK Operations
Swinton, Manchester England M27 8DD
Tel: +44 (0) 161 911 1000
Fax: +44 (0) 161 911 1010

Table 3 Creep strength

	Stress to produce specific creep strains					
	0.1% creep strain		0.2% creep strain		0.3% creep strain	
Time at temperature	MPa	ksi	MPa	ksi	MPa	ksi
150 °C (300 °F)						
10 h	...	...	...	...	...	...
100 h	...	...	...	...	...	...
500 h	...	...	135	19.6	160	23.2
1000 h	...	...	123	17.8	151	21.9
150 °C (300 °F)						
10 h	102	14.8	...	...	...	...
100 h	74	10.7	86	12.5	103	14.9
500 h	54	7.8	65	9.4	83	12
1000 h	46	6.7	56	8.1	72	10.4
250 °C (480 °F)						
10 h	43	6.2	...	...	...	...
100 h	26	3.8	34	4.9	41	5.9
500 h	14	2	22	3.2	27	3.9
1000 h	10	1.5	16	2.3	21	3

Alloy DIGEST

C.D.C. Manganese Alloy No. 772

Filing Code: Mn-1
Manganese Alloy

Revised—2/23/60

JULY 1953

DATA ON WORLD WIDE METALS AND ALLOYS

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

C. D. C. MANGANESE ALLOY No. 772

C. D. C. MANGANESE ALLOY No. 772 offers a combination of high strength and ductility. It has a high temperature coefficent of expansion, high electrical resistivity, low thermal conductivity, and high vibration damping constant.

Composition:

	Nominal	Range
Manganese	72	71.75-72.25
Copper	18	17.90-18.10
Nickel	10	9.90-10.10

Physical Constants:

Specific gravity, g/cc	7.21
Density, lb./cu.in.	0.26
Electrical resistivity, ohms per cir mil ft.	1050
Temperature coefficient of expansion/°C (25-150°C)	0.0000275
Temperature coefficient of resistance/°C (25-150°C)	0.000141
Thermal conductivity, cal/sec/cm/°C/cm	0.02
Emissivity, as rolled, %	26
Specific heat, cal/g/°C(15-35°C)	0.126
Vibrating damping constant, %	2.3
Magnetic characteristic	nonmagnetic
Modulus of elasticity, psi	18,000,000

PROPERTIES

Table 1
TYPICAL MECHANICAL PROPERTIES

Tensile strength, psi	115000
Yield strength, psi (0.1% set)	95000
Proportional limit, psi	50000
Elongation, % in 2"	6.5
Vickers hardness (50% cold reduction)	220

Table 2
EFFECT OF ELEVATED TEMPERATURES

Temperature °F	Tensile Strength psi	Yield Strength 0.1% set, psi	Proportional Limit psi	Elongation % in 2"
0	115000	92000	48000	6
100	112000	92000	48000	6
200	110000	91000	47000	5.8
300	108000	90000	45000	5.5
400	104000	88000	40000	5.0
500	97000	84000	35000	4.5
600	91000	76000	30000	4.0

Table 3
EFFECT OF ELEVATED TEMPERATURES

Temperature °F	Expansion* Coefficient	Resistivity ohms/cir mil ft.
0	0.0000148	1035
100	0.0000151	1055
200	0.0000154	1062
300	0.0000166	1070
400	0.0000175	1075
500	0.0000188	1080
600	0.0000200	1080

* in/in/°F

Machinability:

C.D.C. MANGANESE ALLOY No. 772 is satisfactorily machinable, and it machines similarly to Monel. Because of its great toughness, cutting speeds are somewhat slower and feeds lighter than those for mild steel. Tools should be of high speed steel, especially the cobalt type, ground with sharper angles than for steel. Sulphurized cutting oil should be used abundantly as a lubricant for boring, drilling, tapping, etc., and is preferred for all work, though water-soluble oils suffice for lathe work. In turning screw machine parts a good finish is obtained by using carbon tetrachloride as a coolant. Below are given some general recommendations of speeds for cutting this alloy:

Operation	Speed sfpm	Depth of Cut, in.	Feed, inch
Turning	45-65	1/8-1/16	1/8-1/16
Drilling	40-60		Same as for steel
Milling	50-65		0.005-0.010 in/tooth
Tapping	20-25		
Thread chasing	20-25		
Reaming	25-35		Twice drill speeds

For high production, carbide-tipped tools should be used. All cutting tools should be ground to sharp cutting edges, and the speeds and feeds should be moderate. Standard twist drills should have polished flutes and must be kept feeding into the work. Spiral-fluted, high speed steel reamers with narrow lands and well polished flutes are used and are kept sharp at all times.

Workability:

This alloy can be readily stamped, drawn, and extruded. Its hot working temperature range is 1600-1650°F.

Weldability:

Can be spot welded, butt welded, or silver brazed to itself or steel. It can be atomic hydrogen welded, electric arc welded, resistance welded, and oxyacetylene torch welded effectively. After welding, no thermal or chemical (passivation) treatments are necessary or recommended to retain or restore corrosion resistance.

General Characteristics:

The exceptionally high electrical resistivity, low temperature coefficient of resistance, and excellent physical properties are a combination which makes the alloy ideally suited for low temperature resistor applications. Also in electrical apparatus, parts located in a varying magnetic field are free from eddy current losses, if made of the No. 772 alloy, due to its high electrical resistivity. The combination of high strength and a high specific damping constant makes the alloy desirable in applications which cannot incorporate rubber or plastics to reduce vibrations. It is especially useful in eliminating sustained resonance of metallic members due to intermittent shock. The damping rate of the alloy is about twenty-five times greater than for hardened steel when compared at low stresses. The electrical resistivity value is not affected by annealing procedure, cold working, or by cooling to minus 100°F. The alloy is nonmagnetic. Low thermal conductivity combined with high strength makes the alloy useful in power transmission where heat flow must be minimized.

Forms Available:

Sheet, strip, hot-rolled round bars, extruded tubing, special shapes.

Applications:

Low temperature resistor applications — rheostats, auxiliary heaters for circuit breakers — electrically heated expansion elements, thermostatic bimetal, electrical appliances, low thermal transmission couplings.

Heat Treatment:

Anneal: Heat in neutral or reducing atmosphere (S-free) at 1400-1425°F, hold at temperature for 20-30 minutes, cool in furnace to 400°F, then air cool.

Stress-Relief: Heat in neutral or reducing atmosphere (S-free) at 675-700°F, hold at temperature for 30 minutes, cool in furnace to 400°F, then air cool.

Pickling:

To remove slight discoloration or heat tint due to high temperature heat treatment, immerse in a 10% nitric acid plus 2% hydrofluoric acid solution at 110-140°F. Can also be pickled in a solution of supersaturated ammonium sulphate containing 5% concentrated nitric acid.

Manufacturer:

Chicago Development Corporation
Riverdale, Maryland

Alloy DIGEST™

KANTHAL® 200/72

DATA ON WORLDWIDE METALS AND ALLOYS

Filing Code: Mn-3
Manganese

February 2008

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 CustomerService@asminternational.org
Fax 440-338-4634 www.asminternational.org

KANTHAL® 200/72 (Thermostatic Bimetal)

Kanthal 200/72, a thermostatic bimetal, is recommended for use in the temperature range −20 to 250 °C (−4 to 480 °F).

Kanthal is a registered trademark of Kanthal AB. Invar is a registered trademark of Imphy Alloys S.A.

Chemical Composition, wt.%:

(Nominal)

	High-expansive component	Low-expansive component
Designation	411	430
Manganese	74.0	0.30
Nickel	11.5	36.5
Copper	14.0	...
Iron	...	bal

Physical Properties:

(Marking on the high expansion side 210TB20220)

Density, kg/m^3 (lb/in.^{3})	7800 (0.282)
Coefficient of linear thermal expansion, 35–120 °C (95–248 °F), 10^{-6}/K (10^{-6}/°F)	
High-expansive component 411	27.3 (15.2)
Low-expansive component, 430	1.0 (0.56)
Specific deflection heat, 10^{-6}/K (10^{-6}/°F)	20.8 (11.6)
Linear thermal curvature, 10^{-6}/K (10^{-6}/°F)	39.0 (21.7)
Linearity range, °C (°F)	−20 to 200 (−4 to 392)
Thermal conductivity, 20 °C (68 °F), W/m · K (Btu/(ft · h · °F))	6 (3.5)
Specific heat capacity, 20 °C (68 °F), J/kg · K (Btu/lb · °F)	460 (0.11)
Temperature range, °C (°F)	−10 to 250 (14 to 482)
Maximum operating temperature, °C (°F)	330 (626)

See also Table 1.

Table 1 Electrical Resistivity

Designation	Temperature °C	Temperature °F	Resistivity µΩ · m	Resistivity Ω circular-mil/ft
Bimetal 200/72	0	32	1.09	656
	20	68	1.10	662
	100	212	1.20	722
	200	392	1.27	764
	300	572	1.33	800
High-expansive component 411	20	68	1.71	1029
Low-expansive component 430	20	68	0.80	481

Mechanical Properties:

Young's modulus, GPa (10^6 psi)	135 (20)

See also Table 2.

General Characteristics:

Kanthal 200/72 is a thermostatic bimetal that is recommended for use in the temperature range −20 to 250 °C (−4 to 480 °F).

Bimetal consists of two or more metallic strips, each with different thermal expansion, bonded together. When heated up, the bimetal bends in a predetermined manner and can be used to monitor, measure, or regulate heat.

The relative thickness of the components is shown below.

	Alloy	Designation	Portion of thickness, %
High-expansive component	72-18-10	411	51.8
Low-expansive component	Invar 145	430	48.2

Applications:

The main applications are in thermostats for room heaters or water mixing, but the material is also used in control devices in automobiles.

Product Forms Available:

Kanthal offers a wide range of manufactured widths ranging between 1.0 and 70 mm (0.039 and 6.63 in.) and in thicknesses between 0.10 and 2.5 mm (0.0039 and 0.097 in.).

Table 2 Mechanical Properties

Designation	Condition	Yield strength, 0.2% MPa	Yield strength, 0.2% ksi	Tensile strength MPa	Tensile strength ksi	Elongation, %	Hardness, HV
High-expansive component 411	Annealed	230	33	470	68	40	110
	Cold worked 35%	...	...	...	...	...	230
Low-expansive component 430	Annealed	270	39	450	65	40	110
	Cold worked 35%	...	...	...	...	...	270

Producer:

Kanthal AB
Kanthal Heating Systems
Amherst, NY 14228-2311
(716) 691-4010
(716) 691-7850 (fax)
www.kanthal.com

ISSN: 002-614X

Mn-3B

Alloy DIGEST

CHLORIMET® 2

DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Ni-12
Nickel Alloy

Revision May 1996

Published by: ASM International
Materials Park, Ohio 44073-0002
216-338-5151 Fax 216-338-4634
Mem-Serv@po.ASM-Intl.org

CHLORIMET® 2
(Corrosion-Resistant Cast Nickel-Base Alloy

CHLORIMET 2 is a nickel-base alloy that provides good resistance to corrosive conditions not normally handled by other types of commercially available alloys. CHLORIMET 2 is a refined equivalent of HASTELLOY® B and is most commonly used in engineered equipment, such as pumps and valves, made by the alloy's manufacturer.

CHLORIMET is a registered trademark of the Duriron Company, Inc. HASTELLOY and B-2 are registered trademarks of HAYNES International, Inc. Stellite is a registered trademark of Deloro Stellite Inc.

Chemical Composition, wt%:

Molybdenum	30.0-33.0
Chromium	1.0 max.
Carbon	0.07 max.(a)
Silicon	1.00 max.
Iron	3.0 max.
Manganese	1.00 max.
Phosphorus	0.040 max.
Sulfur	0.030 max.
Nickel	Balance

(a) Duriron's limit is 0.03 max.

Physical Properties:

Density	
lb/in.^{3}	0.33
kg/m^3	9200
Specific gravity	9.2
Melting point, °F(°C) (approx.)	2400 (1300)
Thermal coefficient of expansion	
10^{-6}/°F (at 70-600°F)	6.4
10^{-6}/°C (at 21-316°C)	11.5
Modulus of elasticity	
10^6 psi	27
GPa	186

Mechanical Properties:

(Solution-annealed, water-quenched condition)

Tensile strength, min, ksi (MPa)	76 (525)
Yield strength (0.2% offset), min, ksi (MPa)	40 (275)
Elongation (2 in. or 51 mm), min, %	20
Brinell hardness	230
Charpy impact (V-notch), ft · lbf (N · m)	20 (27)

Heat Treatment:

Chlorimet 2 castings are provided in the solution-annealed, water-quenched condition, which optimizes corrosion resistance and mechanical properties. They are heated to 2050 to 2150°F, equalized and water quenched.

Machinability:

Chlorimet 2 can be machined readily, in general with slower speeds and lighter feeds than required with the austenitic stainless steels. Turning, facing, and boring with Stellite® cobalt-chromium-tungsten metalcutting tools can be done using a soluble-oil coolant.

Production of Castings:

Chlorimet 2 can be cast successfully with no unusual problems. It exhibits very predictable corrosion resistance because contaminating elements in the alloy are strictly maintained at a minimum. Iron and carbon, which are deleterious to the general corrosion resistance of this type alloy, are closely controlled by using only select raw materials.

Joinability:

Chlorimet 2 can be welded, brazed, and silver soldered by all methods used for stainless steels, that is, all methods of welding except hammer or forge welding. In metal-arc welding direct current with reversed polarity should be used.

Corrosion Resistance:

Because of its excellent resistance to corrosion, Chlorimet 2 is widely used in the manufacture and/or processing of many products.

Hydrochloric Acid. Chlorimet 2 finds its greatest use in the handling of hydrochloric acid: it is suitable for all concentrations to the boiling point. Corrosion rates for Chlorimet 2 in boiling hydrochloric acid are shown in Fig. 1. It must be kept in mind, however, that the corrosion rate for Chlorimet 2 in hydrochloric acid is increased if oxidizing contaminants are present. This would include oxidizing chlorides such as ferric chloride, cupric chloride, hypochlorites, etc., or other oxidizing media such as nitric acid, or even aeration.

Sulfuric Acid. Chlorimet 2 has excellent resistance to all concentrations of sulfuric acid within the temperature limitations shown in Fig. 2. As with hydrochloric acid, the presence of oxidizing contaminants renders Chlorimet 2 unsuitable in sulfuric acid. Less expensive alloys are sufficiently resistant to many conditions of sulfuric acid, and these alloys are naturally selected whenever possible. However, contamination of sulfuric acid with fluorides, chlorides, or other reducing species may necessitate the selection of Chlorimet 2. In nonoxidizing sulfuric acid solutions up to 50% concentration, Chlorimet 2 is the most resistant alloy available next to noble metals (gold, platinum, etc.), high-silicon iron, and refractory metals such as tantalum and zirconium.

Phosphoric Acid. Chlorimet 2 finds use in the handling of phosphoric acid when higher temperatures and/or the presence of

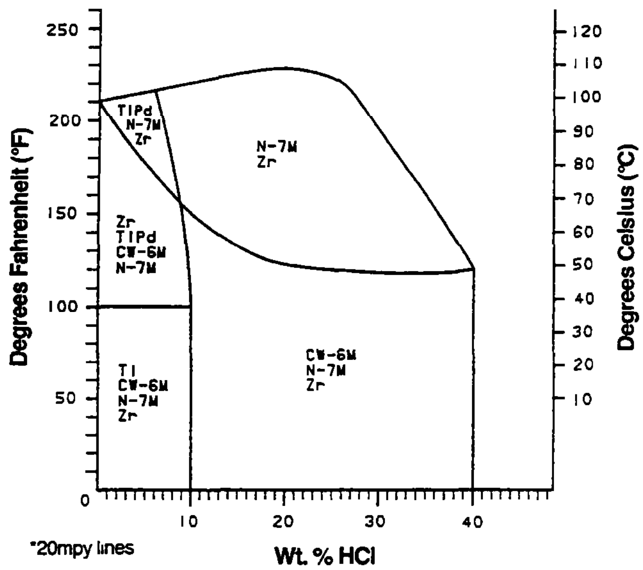


Fig. 1 Hydrochloric acid isocorrosion chart

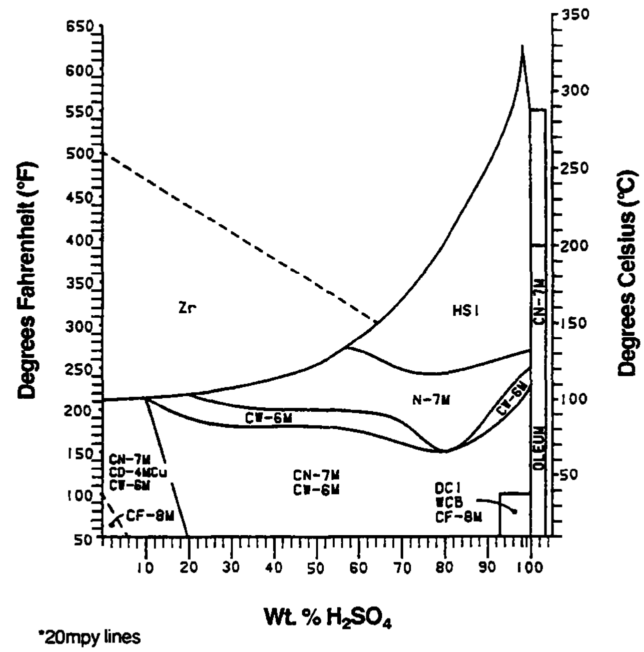


Fig. 2 Sulfuric acid isocorrosion chart

contaminants such as chlorides and fluorides result in conditions too severe for alloys such as cast Type 316 stainless steel. Chlorimet 2 is resistant to all concentrations of pure phosphoric acid up to 300°F (149°C). This temperature limitation can be raised depending on exact concentration of the acid.

Other Media. The manufacturer has data on the resistance of Chlorimet 2 to many commonly handled corrosives and strongly urges the prospective user to ask for these data. The user should furnish a complete description of the corrosive condition (see next paragraph). In this way the manufacturer's staff of engineers can study the problem and make reliable recommendations based on many years of experience in the corrosion field.

Many factors influence the corrosion resistance of any alloy in service. The factors which must be given consideration are temperature, concentration, aeration, influence of recirculation, solids in suspension, velocity, continuity or frequency of use, and equipment design. The influence of contaminants is probably the most important from a commercial standpoint; while the majority of contaminants have no influence on corrosion, those that do generally affect the conditions greatly. Ferric chloride is a good example. Relatively small amounts of ferric chloride can cause destructive crevice corrosion and pitting to take place even though this salt was not added to the solution intentionally. Buildup of the corrosion products in a chloride solution may increase the iron concentration to a sufficient degree to be destructive.

Specification Equivalents:

ASTM A 494, Grade N-7M

(Requires castings with major weld repairs to be given a postweld heat treatment.)

General Characteristics:

Chlorimet 2 is a Duriron-developed Mo-Ni alloy that has been in use since the early 1950s. Although there are many newer, but similar alloys available, most notably the Hastelloys, the Chlorimets have undergone constant refinement over the years so that in most services they are certainly equal if not superior to these newer cast versions.

Chlorimet 2 is a highly corrosion-resistant cast metal-base alloy. It consists primarily of nickel and molybdenum, a combination that provides excellent resistance to nonoxidizing media not equaled by other type alloys. This is particularly true of hot hydrochloric acid of all concentrations; strong, hot phosphoric acid; and various strong chlorides provided they have no oxidizing tendencies. Chlorimet 2 should not be used for corrosives having oxidizing characteristics.

Chlorimet 2 has excellent strength and ductility which allows adaptability to standard equipment designs. The high hardness of Chlorimet 2 provides good erosion-corrosion resistance for handling corrosive media which contain moderately abrasive solids in suspension.

In ASTM A 494 for the cast nickel-base alloys there are two choices of the Mo-Ni alloys. There is the original Hastelloy B (N-12MV) and Chlorimet 2 alloy (N-7M). There is no ASTM cast grade for Hastelloy B-2. Chlorimet 2 has lower levels of critical residual elements, such as carbon and iron, than N-12MV. Also, Chlorimet 2 does not utilize tungsten or vanadium, which along with lower iron and carbon, allows a higher content of nickel and molybdenum, which enhances the corrosion resistance of Chlorimet 2 as well as its ductility. This combination of nickel and molybdenum provides excellent resistance to nonoxidizing media as noted above.

Forms Available:

Castings.

Applications:

Chlorimet 2 is used for engineered equipment, such as pumps and valves, for handling corrosive chemicals. It also is used in many industries for processing and/or handling insecticides, paints and pigments, plastics, pulp and paper, foods, pharmaceuticals, soaps and detergents, organic acids, petroleum, sewage and many other materials.

Manufacturer:

The Duriron Company, Inc.
Dayton, Ohio 45401
(513) 476-6100

Alloy DIGEST™
DATA ON WORLDWIDE METALS AND ALLOYS

HPM® 233

Filing Code: Ni-635
Nickel

April 2006

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 CustomerService@asminternational.org
Fax 440-338-4634 www.asminternational.org

HPM® 233
(High-Purity Nickel Alloy)

HPM 233 is a wrought nickel with low carbon. The alloy is used in electrical and electronic components.

Chemical Composition, wt.%:

(Nominal)

Nickel	99.7
Iron	0.05
Manganese	0.1
Carbon	0.01

Physical Properties:

(Typical values, not a guarantee of minimum or maximum)

Density, kg/m³ (lb/in.³)	8885 (0.321)
Melting point, approximate, °C (°F)	1445 (2633)
Resistivity at room temperature, μΩ · m (Ω circular-mil/ft)	0.077 (46)
Temperature coefficient of resistivity, 20–95 °C (68–203 °F), ppm/°C (ppm/°F)	5500 (3055)
Coefficient of linear thermal expansion, 20–100 °C (68–212 °F), 10^{-6}/K (10^{-6}/°F)	13.3 (7.4)
Thermal conductivity at room temperature, W/m · K (Btu/(ft · h · °F))	80.7
Curie temperature, °C (°F)	350 (662)
Magnetic attraction	Yes

Mechanical Properties:

(Typical)

Tensile strength, MPa (ksi)	
Annealed	379 (55)
Cold rolled	758 (110)
Yield strength, 0.2% offset, MPa (ksi)	
Annealed	103 (15)
Cold rolled	689 (100)
Elongation, in 2 in., %	
Annealed	40
Cold rolled	2
Modulus of elasticity in tension, GPa (10^6 psi)	207 (30)
Poisson's ratio	0.28

The measured elongation will be less as thickness decreases to 0.002 in. and less. Mechanical property values may be adjusted by control of process variables. Consult the producer for desired values.

Heat Treatment:

In annealing, the time-temperature relationship is of prime importance with respect to grain growth. Box annealing is done most satisfactorily at 705 °C (1300 °F), for 2–6 h at temperature. The total time in the furnace will depend on the rate of heating. The range for open annealing is 815 °C (1500 °F) for 2–5 min at temperature, or 925 °C (1700 °F) for ½ to 2 min at temperature when mechanical work is to follow. If manual operations such as spinning are to follow, the annealing time should be about 50% longer in order to soften the material fully.

Annealing should be performed in a reducing atmosphere to retain bright finishes. Dry hydrogen and dissociated ammonia are preferred but less expensive atmospheres such as partially burned natural gas will also provide adequate brightness. Heating in oxidizing atmospheres at high temperatures should be avoided because of the danger of intergranular oxidation. HPM 233 nickel is sensitive to intergranular attack from sulfur and metal such as lead, tin, zinc, and bismuth that have low melting points. Scrupulous care must be exercised to remove all traces of forming lubricants, marking paints, and shop oils prior to heating. Open-annealed material should be water quenched immediately following removal from the furnace. When the material is brought out into the air, an oxide flash may result. This can be reduced by quenching in a solution of 2–3% denatured alcohol in water, and the resulting surface will be clean and bright.

Workability:

This alloy can be hot worked readily. The proper temperature during deformation is the most important factor in achieving hot malleability. The recommended temperature range for hot working is 650–1230 °C (1200–2250 °F). All heavy hot working should be done above 870 °C (1600 °F); the metal stiffens rapidly below this temperature. Light working below 650 °C (1200 °F), however, will produce higher mechanical properties.

HPM 233 can be worked by all conventional cold-forming methods. Generally, the alloy will behave similarly to mild steel except that, because of the higher elastic limit of Nickel 233, greater power will be required to perform the operations. The use of soft-temper material generally will yield the most satisfactory results in drawing and severe forming operation. Cold-rolled (not stretcher-leveled) and annealed strip is in the best condition for pinning and other manual work. Tallow, soap, sulfur-base oil, soluble oil, and similar heavy lubricants are used in connection with cold-working operations.

Machinability:

HPM 233 nickel can be machined satisfactorily. Because of its strength and toughness, cutting speeds should be considerably slower and feeds lighter than used for mild steel. Tools should be either of high-speed steel, (W-Cr-V type) or of super (cobalt-bearing) high-speed steel. Tool clearances should be kept to a minimum so as to give sufficient support for the cutting edge and sufficient bulk of tool material to carry away the heat generated at the edge. Rake angles should be large enough to reduce whip pressure and consequent frictional heat. A good grade of water-soluble oil should be supplied to the cutting edge of the tool in copious quantities.

Weldability:

Electrical resistance welding can be applied successfully to HPM 233 nickel for the small electronic components for which it is used.

Corrosion Resistance:

Atmospheric attack is usually very slow, although the metal may tarnish. It is resistant to marine corrosion, hydrogen sulfide water, and carbonated waters. Nonoxidizing neutral and alkaline salts are not very active on HPM 233 nickel. In general, it is much more susceptible to corrosion in an oxidizing atmosphere or by an oxidizing agent. Sulfurous atmospheres are most active in corrosion, especially above 315 °C (600 °F). Oxidizing mineral acids or those containing oxidizing salts attack the metal violently, while oxidizing alkaline salts and ammonium hydroxide (over 10%) also attack the metal strongly. Molten metals are highly corrosive.

Specification Equivalents:

ASTM B 162
ASTM F 3
UNS N02233

General Characteristics:

This alloy is a commercially pure wrought nickel with low carbon. The material has excellent corrosion resistance with high thermal and electrical conductivities. The alloy can be formed by all conventional cold-forming methods and can be joined by welding, brazing, and soldering. The corrosion resistance is generally very good in most media, although it is subject to intergranular embrittlement by sulfur compounds above 315 °C (600 °F).

Product Forms Available:

HPM 233 Nickel is available as strip product in thicknesses from 0.0005–0.020 in. and in widths up to 12.0 in. It is available as foil as thin as 0.000100 in. with maximum width 4.0 in.

Applications:

A high thermal coefficient of electrical resistance makes the alloy suitable for temperature sensors and electronic components.

Producer:

Hamilton Precision Metals
Lancaster, PA 17601-2334
(800) 476-7065
(717) 569-7061
(717) 569-7642 (fax)
www.hpmetals.com

ISSN: 002-614X

Alloy DIGEST

ISOPLAST 101, UNREINFORCED

Filing Code: P-10
Plastic

OCTOBER 1989

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ISOPLAST 101, Unreinforced

(Rigid Polyurethane Thermoplastic Polymer)

ISOPLAST* 101, unreinforced, is a rigid, amorphous polyurethane thermoplastic polymer. It is opaque and impact modified. It is injection moldable and extrudable. It is characterized by its high impact strength, high abrasion resistance, excellent chemical and solvent resistance and low moisture sensitivity.

*ISOPLAST is a trademark of The Dow Chemical Company.

Chemical Characterization:

Rigid thermoplastic polyurethane amorphous resin.

Physical Constants:

Melt flow rate, g/10 min. (224°C, 500 g. wt., 6 min. preheat)	ASTM D1238	8
Specific gravity	D792	1.2
Water absorption, (24 hrs @ 73°F), %	D570	0.17
Mold shrinkage, in./in. (isotropic)	D955	0.004-0.006
Deflection temperature, °F (°C)	D648	
@ 264psi		158 (70)
@ 66psi		176 (80)

PROPERTIES

MECHANICAL PROPERTIES

Property	ASTM Method	Typical Value
Tensile Strength, psi(MPa)	D638	7200(50)
Yield strength, psi(MPa)	D638	7800(54)
Elongation at yield, %	D638	6
at rupture, %	D638	180
Tensile modulus, psi(MPa)	D638	190000(1300)
Flexural strength, psi(MPa)	D790	10200(70)
Flexural modulus, psi(MPa)	D790	235000(1600)
Izod impact strength (73°F)	D256	
Notched, 1/8 in. thick, ft-lb/in(J/m)		18(960)
Notched, 1/4 in. thick, ft-lb/in(J/m)		16(850
Hardness, Rockwell R	D785	>100
Rockwell M	D785	48
Taber abrasion resistance, mg CS-17 wheel, 1000g wt, 1000 cycles at 73°F	D1044	11

Processability:

ISOPLAST 101 resin must be dried to a moisture content of less than 0.03% prior to molding. This typically requires at least 4 hours in a dehumidifying hopper dryer between 210 and 230°F with an operating dew point below -20°F. Injection molding temperature range, 420-460°F. Extrusion temperature range, 410-450°F. These ranges are given as a guide only.

Handling:

ISOPLAST engineering thermoplastic resins are considered to have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from ingestion or contact with eyes or skin. Dust resulting from sawing, filing and sanding in post-molding operations can be combustible. Adequate ventilation should be provided and dust masks are suggested when necessary.

Material Safety Data (MSD) sheets are available from The Dow Chemical Company and should be requested before handling or using the resin.

Disposal:

ISOPLAST 101 resin may be disposed of in an approved industrial incinerator or other appropriate incineration facility. Disposal in an approved industrial landfill may be appropriate. Because the resin is inert and not readily degradable, it will not contribute to instability of the landfill or evolve gases or leachates known to pollute water resources.

General Characteristics:

ISOPLAST 101 has low moisture sensitivity and excellent chemical and solvent resistance. It has high notched impact and abrasion resistance. It may be injection molded or extruded. It is an amorphous resin with crystalline properties. Outstanding continuous-exposure chemical resistance is a key advantage of this material.

Applications:

Markets include automotive, health care, lawn and garden and sporting goods.
Use for applications demanding toughness and exceptional long-time resistance to chemical exposure.

Producer:

The Dow Chemical Company
Dow Plastics
Midland, Michigan 48674

Alloy DIGEST
DATA ON WORLD WIDE METALS AND ALLOYS

GRILON ELX 23NZ

Filing Code: P-11
Plastic

OCTOBER 1989

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

GRILON ELX23NZ
(Thermoplastic Polyamide Elastomer Alloy)

GRILON ELX23NZ is a thermoplastic polyamide elastomer with both rigid and elastomeric components.

Grilon is a registered trademark of EMS-Chemie AG, Zurich, Switzerland.

Chemical Characterization:

GRILON ELX23NZ is a thermoplastic polyamide elastomer (Nylon 6 based) alloyed with another thermoplastic elastomeric material..

Physical Properties (At 23°C unless otherwise indicated):

Property	Test Method	Unit	Value
Melting point	DSC* max.	°F(°C)	408(209)
Specific gravity	ASTM D792	–	1.03
Water absorption	ASTM D570		
24 hour immersion		%	1.36
In 23°C air at 50% R.H.**		%	1.0-1.5
In 23°C water		%	(Approx.) 5
Linear mold shrinkage	EMS	%	1.5-2.0
Thermal coef. expansion	DIN 52328	per °F	7×10^{-5}
		per °C	12×10^{-5}
Heat deflection temperature	ASTM D648		
@ 66psi(0.46MPa)		°F(°C)	158(70)
@ 264psi(1.82MPa)		°F(°C)	95(35)
Maximum usage temperature	EMS		
Long term in air		°F(°C)	176(80)
Short term in air		°F(°C)	212(100)
Comparative tracking index	ASTM D3638		
Dry[1]		Volts	600+
Conditioned[2]		Volts	600+
Volume resistivity	DIN 53482		
Dry		Ohm-cm	10^{15}
Conditioned		Ohm-cm	10^{12}
Dielectric strength, 3mm spec.	DIN53481		
Dry		kV/mm	50
Conditioned		kV/mm	35

*DSC=Differential scanning calorimetry.
**R.H.=Relative humidity.
[1] Tested dry-as-molded, containing less than 0.1% moisture.
[2] Stored at 23°C/50% R.H. to achieve equilibrium moisture level before testing.

PROPERTIES

Table 1 – MECHANICAL PROPERTIES AT 23°C

Property	Test Method	Unit	Value
Tensile strength	ASTM D638		
Dry[1]		psi(MPa)	5450(38)
Conditioned[2]		psi(MPa)	4400(30)
Elongation	ASTM D638		
Dry		%	390[3]
Conditioned		%	370[3]
Flexural strength, at yield	ASTM D790		
Dry		psi(MPa)	1500(10)
Conditioned		psi(MPa)	1100(8)
Flexural modulus	ASTM D790		
Dry		psi(MPa)	27000(186)
Conditioned		psi(MPa)	20000(138)
Izod impact strength (notched)	ASTM D256		
Dry		ft-lb/in(J/m)	No break
Conditioned		ft-lb/in(J/m)	No break
Hardness	Shore D		
Dry			50
Conditioned			45

[1] Tested dry-as-molded, containing less than 0.1% moisture.
[2] Stored at 23°C/50% R.H. to achieve equilibrium moisture level before testing.
[3] Machine limit, no break.

Processing:

Injection Molding: Typical injection molding temperatures for Grilon ELX23NZ are:

	°F	°C
Barrel	390-410-430	200-210-220
Melt	445	230
Mold	120	50

Variations will occur depending upon part design, machine and mold configuration and production rate requirements.
Extrusion: Typical extrusion temperatures are:

	°F	°C
Barrel	355-375-390-390	180-190-200-200
Die	355	180
Melt	410	210

The above temperatures are for general purpose extrusion of tubing or simple profiles. For special applications such as large diameter tubing, high speed extrusion of thin-wall tubing, stock shapes or complex profiles, contact the resin producer.
GRILON ELX23NZ resin is supplied predried to 0.1% moisture. For optimum processing and parts quality, it should be protected from exposure to a humid environment. If hopper residence times are likely to exceed two hours, use of a hopper dryer operating at 80°C is recommended. If the resin is exposed to a humid environment for more than two hours, drying is recommended to ensure that its moisture content does not exceed 0.1% for processing. Use of a vacuum dryer operating at 110°C for three to four hours is strongly recommended. A desiccant dryer may also be used, but to avoid oxidation of the material and consequent discoloration, temperatures should not exceed 80°C, with drying times between six and ten hours. For longer drying periods, overnight for example, desiccant drying is acceptable at temperatures not exceeding 70°C.

General Characteristics:

GRILON ELX23NZ has excellent strength, toughness and ductility; outstanding abrasion resistance and bearing characteristics; very good resistance to a wide range of chemicals, solvents, oils and greases. It can be easily processed using conventional equipment suitable for use with Nylon. Moisture content should not exceed 0.1% for optimum processing and product quality.

Forms Available:

Free flowing pellets packaged in multi-wall, foil-lined, moisture-proof 25 kg bags. Gaylords can also be made available.

Applications:

Injection molded or extruded parts requiring high strength, toughness and abrasion resistance together with very good resistance to solvents and a wide range of chemicals.

Producer:

EMS-American Grilon, Inc.
P.O. Box 1717
Sumter, South Carolina 29151-1717
Contact: John Mewborn, telephone (803) 481-3172.

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

VALOX®300 FAMILY

(Unreinforced Engineering Thermoplastic Resins)

VALOX®300 Family is comprised of four unreinforced thermoplastic resins; 325, 310-SEO 357 and 365. It is the most complete line of unreinforced thermoplastic polyester resins in the industry.

VALOX® is a registered trademark of GE Plastics.

Chemical Characterization:

VALOX® resins are polyester thermoplastic materials; specifically polybutylene terephthalates (PBT).

PROPERTIES

Table 1 — PHYSICAL PROPERTIES OF VALOX® 300 FAMILY

Property	ASTM test Method	Units	Resin 325	310-SEO	357	365
Specific gravity	D792	—	1.31	1.39	1.34	1.33
Specific volume	—	cu in./lb	21.3	20.0	20.8	20.8
Water absorption, 24 hr.	D570	%	0.08	0.08	0.08	0.14
Mold-shrinkage, flow and cross flow direction	—	in/in x 10^{-3}				
25-50 mil			7-13	6-12	6-10	6-12
50-100 mil			13-17	12-16	10-15	12-16
100-180 mil			17-22	16-21	15-18	16-21

Table 2 — THERMAL AND ELECTRICAL PROPERTIES OF VALOX® 300 FAMILY

Property	ASTM test Method	Units	Resin 325	310-SEO	357	365
Heat deflection temperature	D648	°F(°C)				
@66psi (0.46MPa)			310(154)	325(163)	280(138)	265(129)
@264psi (1.82MPa)			130(54)	160(71)	210(99)	250(121)
Thermal coef. expansion, mold direction x 10^{-5}	D696	in/in/°F(/°C)				
-40 to 100°F (-40 to 40°C)			4.5(8.1)	4.4(7.9)	5.1(9.2)	3.8(6.8)
140 to 280°F (60 to 140°C)			7.7(13.8)	7.3(13.0)	6.9(12.4)	— —
Dielectric strength, 1/16" (1.6mm)	D149	V/mil (kV/mm)	590(23)	560(22)	640(25)	— —
1/8" (3.2"mm)			400(16)	468(18)	470(19)	307(12)
Dielectric constant	D150					
100Hz			3.3	3.1	3.2	8.5
10^6Hz			3.1	3.1	3.2	5.7
Dissipation factor	D150					
100Hz			0.002	0.002	0.003	0.002
10^6Hz			0.02	0.02	0.03	0.03
Volume resistivity	D257	Ohm-cm x 10^{16}	4.0	1.6	1.2	—

Table 3 — UNDERWRITER LABORATORY PROPERTIES OF VALOX® 300 FAMILY

Property	Test Method	Units	Resin 325	310-SEO	357	365
Flammability*		UL94	— HB/0.058"	V-0/0.028" 5V/0.120"	— V.0/0.025"	5V/0.123" V-0/0.031"
Arc resistance	ASTM D495	sec.	184/0.120"	63/0.120"	71/0.120"	74/0.123"
High voltage arc tracking rate	UL 746A	in/min	0.9/0.120"	18/0.120"	8.1/0.120"	5.1/0.123"
High ampere arc ignition	UL 746A	arcs	200+/0.120"	200+/0.120"	28/0.120"	50/0.031"
Hot wire ignition	UL 746A	sec.	27/0.120"	45/0.120"	37/0.120"	19/0.031"
Comparative track index (CTI)	UL 746A	volts	600/0.120"	185/0.058"	275/0.120"	230/0.123"
UL temp. index	UL 746B	°C				
Electrical properties			120/0.058"	120/0.028"	120/0.025"	105/0.031"
Mechanical properties						
with impact			120/0.058"	120/0.028"	120/0.025"	105/0.031"
without impact			140/0.058"	140/0.028"	140/0.025"	105/0.031"

*This rating not intended to reflect hazards presented by this or any other material under actual fire conditions.

Table 4 — MECHANICAL PROPERTIES OF VALOX® 300 FAMILY

Property	Test Method	Units	Resin 325	310-SEO	357	365
Tensile strength [0.125"(3.2mm)]	ASTM D638	ksi (MPa)	7.5(52)	8.5(59)	7.0 (48)	6.0(41)
Elongation at break [0.125"(3.2mm)]	ASTM D638*	%	>200	80	110	120
Flexural strength [0.125"(3.2mm)]	ASTM D790	ksi(MPa)	12(83)	14.7(100)	12(83)	10(69)
Flexural modulus [0.125"(3.2mm)]	ASTM D790	ksi(MPa)	340(2300)	380(2600)	300(2000)	325(2240)
Compressive strength	ASTM D695	ksi(MPa)	13(90)	14.5(100)	5.3(40)	—
Shear strength	ASTM D732	ksi(MPa)	7.7(53)	7.7(53)	6.0(40)	—
Izod impact strength	ASTM D526	ft-lb/in(J/m)				
notched, 1/8in. thick			1.0(53)	0.7(37)	10(530)	12(640)
unnotched, 1/8in. thick			60(3200)	60(3200)	60(3200)	60(3200)
Gardner impact, 1/8in. thick	Falling dart	ft-lb(J)	30(41)	25(34)	32(43)	28(36)
Rockwell hardness	ASTM D785	R scale	117	120	117	115

*Type V @ 0.5 in/min.

Processing:

VALOX® 300 family resins are characterized by fast processing cycles, excellent flow, easy mold release and similar mold shrinkage in flow and cross-flow directions. They process with low tool and machine wear.

General Characteristics:

The VALOX® 300 family comprise the most complete line of unreinforced engineering thermoplastic resins in the industry. They have good dimensional and physical stability in most environments. They resist attack by most oils and greases. They process to a glossy, high-luster finish with good lubricity. They exhibit high notch impact strength. They are available in a wide range of standard or custom-matched, molded-in colors eliminating the need for secondary finishing operations such as priming or painting.

Applications:

Engineering products where dimensional stability, chemical resistance and low moisture absorption, high heat resistance and good electrical properties are important.

Producer:

G.E. Plastics
Plastics Group
One Plastics Avenue
Pittsfield, Massachusetts 01201

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

TACTIX 556

Filing Code: P-26
Plastic

MAY 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

TACTIX 556

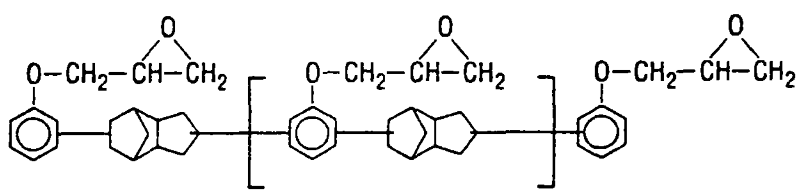
(Low-Moisture, Hydrocarbon Epoxy Novolac Resin)

TACTIX *556 is a multifunctional epoxy novolac resin. Its dicyclopentadiene structure has extremely low average molecular polarity, a feature critical to low moisture absorbance.

*TACTIX is a registered trademark of the Dow Chemical Company.

Chemical Characterization:

TACTIX 556 is based on dicyclopentadiene-phenol (DCPD). Its structure is represented as shown here:



PROPERTIES

Table 1 – TYPICAL RESIN PROPERTIES*

Epoxide equivalent weight	220-240
Viscosity, cps @ 79°C	2250
Resin form	Semi-solid
Average functionality	2.2
Volatiles, wt %, max.	0.5

*These typical properties are not to be construed as specifications.

Table 2 – PROPERTIES OF TACTIX 556 AND BLENDS IN UNREINFORCED RESIN CASTINGS*

Property**	TACTIX 556	TACTIX 556+ 10% Tactix 123	TACTIX 556+ 10% D.E.N.† 431
Tensile strength, ksi	10.5	10.8	9.6
Tensile modulus, ksi	380	410	460
Elongation, %	3.7	3.7	2.7
Flexural strength, ksi	19.7	19.0	20.3
Flexural modulus, ksi	450	460	470
Glass transition temperature, °C	223	230	225
Moisture absorbance (200 hour water boil), wt %	1.9	2.39	2.40

*Resins cured with diaminodiphenysulfone (DDS) (100% stoicheometry) for 3 hours @ 177°C + 2 hours @ 232°C.
**Tensile and flexural properties tested dry at room temperature.
†D.E.N. is a trademark of Dow Chemical Company.

Table 3 – COMPARATIVE PROPERTIES*

Property	Araldite** MY 720	Tactix 742	D.E.N. 438	D.E.N 431	Tactix 556
Moisture absorbance (200 hour water boil)	4.56	4.2	3.35	3.0	1.9
Flexural modulus retention, % (200 hour water boil)	53	44	42	39	77
Dry T_g	250	320	250	185	240
T_g (200 hour water boil)	145	120	135	135	185

*4,4 DDS cured 3 hours @ 177°C + 2 hours @ 232°C.
**Trademark Ciba-Geigy.

Processing:

TACTIX 556 is a semi-solid, multifunctional epoxy resin, It can be used to fabricate prepregs with excellent tack and drape characteristics and is suitable for a variety of applications including structural composites and adhesives. It offers superior hot/wet performance characteristics. TACTIX 556 can be cured with a variety of conventional hardeners to optimize specific properties. Diaminodiphenylsulfone (DDS) appears to give the best balance of glass transition temperature and moisture properties when cured at 100% of stoichiometry for 3 hours at 177°C + 2 hours at 232°C. It has good flow and low shrinkage characteristics. TACTIX 556 can be blended with 10% low viscosity TACTIX 123 or D.E.N. 431 with minimal effect on moisture absorption and glass transition temperature. (See Table 2).

General Characteristics:

TACTIX 556 resin is ideal for end uses requiring intermediate glass transition temperature where retention of properties under moist conditions or hot/wet conditions is critical. It is processable by standard epoxy techniques and it has a 300°F service temperature, low equilibrium moisture absorption and excellent hot/wet performance.,

Applications:

Composite for aerospace primary structures, vertical and horizontal stabilizers and wing skins and for adhesives.

Producer:

The Dow Chemical Company
Dow Plastics
Midland, Michigan 48674

Alloy DIGEST

SUPEC G401 AND G402

Filing Code: P-3
Plastic

MAY 1989

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

SUPEC G401 and G402

(High-Strength, High-Performance Crystalline Polymer)

SUPEC* G401 AND G402 are resins based on polyphenylene sulfide (PPS) technology. They combine long-and short-term heat resistance with broad chemical resistance and they are inherently flame retardant.

*SUPEC is a trademark of the General Electric Company.

Polymer Base:
Polyphenylene sulfide (PPS).

Physical Constants:

Property	ASTM Test Method	G401	G402
Specific gravity	D792	1.6	1.6
Electrical resistivity (Volume basis, 1/16 inch thick), ohm-cm	D257	$>10^{15}$	$>10^{15}$
Thermal coef. expansion, in./in/°F x 10^{-5}	D696	1.3	1.3
m/m°C x 10^{-5}		2.2	2.2

Note: See Table 1 for other physical properties.

PROPERTIES

Table 1 -- ADDITIONAL PHYSICAL PROPERTIES

Property	ASTM Test Method	G401	G402
Dielectric constant (At 1 kHz, 50% rel. hum.)	D150	3.9	3.9
Electrical dissipation factor (At 1 kHz, 50% rel. hum., 73°F [23°C])	D150	0.0014	0.0014
Deflection temperature (unannealed)			
(1/4 in. [6.4mm] thick at 264 psi [1.82MPa]), °F	D648	>500	>500
(1/4 in. [6.4mm] thick at 66 psi [0.45MPa]), °C		>260	>260
Vicat softening point, method B, °F	D1525	>500	>500
°C		>260	>260
Mold shrinkage, in./in. (%)	D955	0.0015 (0.15) 0.004 (0.4)	0.0015 (0.15) 0.004 (0.4)
Water absorption, 24h, 73°F (23°C), %	D570	<0.01	<0.01
Oxygen index, %	D2863	47	47
Vertical burn, V-0 at 0.8mm* (UL bulletin 94)		94 V-O	94 V-0

*This rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

Table 2 -- ROOM TEMPERATURE MECHANICAL PROPERTIES

Property	ASTM Test Method	G401	G402
Tensile strength, psi (MPa)	D638	24500 (170)	22000 (150)
Elongation, %	D638	1.4	1.0
Modulus of elasticity, tension, psi x 10^6 (MPa x 10^3)	D638	2.1 (14.5)	2.1(14.5)
Flexural strength, psi (MPa)	D790	35000 (240)	29000 (200)
Flexural modulus psi x 10^6 (MPa x 10^3)	D790	2.0 (14)	2.0 (14)
Izod impact, notched 1/8 in. (3.2mm) thick ft-lb/in (J/m)	--	1.5 (80)	1.5 (80)
Izod impact, unnotched 1/8 in. (3.2mm) thick ft-lb/in (J/m)	--	6.5 (350)	6.3 (340)
Hardness, Rockwell R	D785	123	123
Taber abrasion (CS17, 1kg), weight loss/100 cycles, mg	D1044	51	51

General Characteristics:

SUPEC G401 resin is a high-strength, high-performance crystalline polymer. SUPEC G402 has slightly better flow properties allowing intricate configurations and thin-wall sections, although at slightly lower properties. Both resins have outstanding long and short term heat resistance. They have resistance to a broad spectrum of chemicals. They are inherently flame retardant, a key advantage over materials requiring flame-retardant additives. Such additives typically leave deposits on mold surfaces during processing or cause plate-out.

Availability:

SUPEC G401 and G402 resins are available in black or natural color.

Applications:

For meeting demanding service requirements in industrial, electrical/electronic, automotive and aircraft markets.

Manufacturer:

General Electric Company
Pittsfield, Massachusetts 01201

Alloy DIGEST

DATA ON WORLD WIDE METALS AND ALLOYS

DERAKANE 8084

Filing Code: P-31
Plastic

NOVEMBER 1991

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

DERAKANE 8084
(Elastomer Modified Vinyl Ester Resin)

DERAKANE 8084 expands the serviceability of thermoset resins in traditional fiber-reinforced plastic applications. The inherent toughness of the epoxy resin has been enhanced with a reactive elastomer.

Chemical Characterization:

DERAKANE 8084 is an elastomer-modified vinyl ester thermosetting resin.

PROPERTIES

Table 1 – TYPICAL ROOM-TEMPERATURE PROPERTIES OF 1/8 INCH CLEAR CASTING

Tensile strength, psi	10000 to 11000
Tensile modulus, psi x 10^5	4.6
Elongation, %	8.0-10.0
Flexural strength, psi	16000 to 18000
Flexural modulus, psi x 10^5	4.4
Heat distortion temperature, °F	170 to 180
Barcol hardness	30

Table 2 – ENGINEERING DATA, CLEAR CASTING

Density of liquid, g/ml	1.060
Density of solid, g/ml	1.147
Cure shrinkage, %	8.2
Dielectric constant	3.46
Dissipation factor	0.011
Adhesive strength, psi*	
To carbon steel	1430
To AISI type 304 stainless steel	1530
To 2024T3 aluminum alloy	970

*Determined using a modified version of ASTM D1002 Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading.

Table 3 – ROOM-TEMPERATURE PROPERTIES OF HAND LAY-UP LAMINATES*

Flexural strength, psi	39000
Flexural modulus, psi x 10^5	12.7
Tensile strength, psi	31500
Tensile modulus, psi x 10^5	14.4

*Laminate thickness, 1/4 inch.
Laminate construction: V/M/M/Wr/M/Wr/M
V=Standard 10 mil corrosion grade C-glass veil.
M=Chopped strand mat of 1.5 oz./ft^2.
Wr=Woven roving glass.

Chemical Resistance:

Extensive data are available from the producer on the maximum service temperature for DERAKANE resins in a variety of chemical environments. Depending on the environment, DERAKANE 8084 resin may be used up to 180°F. The Resin Products Department Technical Service and Development laboratories of The Dow Chemical Company in Freeport, Texas are staffed and equipped to assist customers in making decisions for specific uses of DERAKANE resins.

Storage:

DERAKANE vinyl ester resins are stable at ambient conditions. Storage temperature must be maintained between 50 and 75°F. Keep away from heat sources which might create localized hot spots. Maximum storage time (shelf life) for DERAKANE 8084 is six months.

Handling:

Material Safety Data sheets for DERAKANE vinyl ester resins are available from the producer and should be procured.

Care must be taken to avoid unnecessary contact with the resin, catalysts, and other chemicals which are used in conjunction with normal use of DERAKANE resins. The current OSHA Permissible Exposure Limit (PEL) for styrene vapors is 100 ppm, 8 hour time weighted average.

Disposal:

DERAKANE 8084 vinyl ester resin can be disposed of by incineration or by burying in an approved landfill.

General Characteristics:

DERAKANE 8084 vinyl ester resin offers increased adhesive strength plus superior resistance to abrasion and to severe mechanical stress. Fiber-reinforced DERAKANE 8084 can be fabricated by all techniques applicable to thermosetting products. It has excellent thermal and electrical insulation properties and is resistant to corrosion in a wide variety of chemical environments.

Applications:

Reinforced DERAKANE 8084 vinyl ester resin is used in plastic boats and other recreational equipment, as well as a wide variety of corrosion-resistant equipment applications.

Producer:

The Dow Chemical Company
Dow Plastics
Midland, Michigan 48674

Alloy DIGEST
DATA ON WORLD WIDE METALS AND ALLOYS

STYRON 666D, 685, 685D, 697

Filing Code: P-34
Plastic

APRIL 1992

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

STYRON 666D, 685, 685D, 697

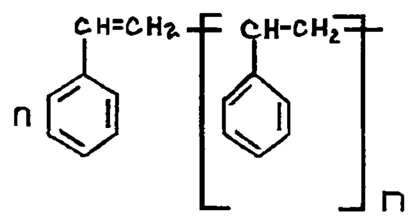
(General Purpose Polystyrene Resins)

STYRON* 666D, 685, 685D and 697 are general purpose thermoplastic polystyrene resins produced by joining styrene monomer molecules into long polymer chains ranging from 100 to 20000 monomer units per chain. They are noncrystalline.

*STYRON is a registered trademark of the Dow Chemical Company.

Chemical Characterization:

The structure for STYRON general purpose polystyrene resins may be represented as shown here:



Chain lengths vary from 100 to 20000 monomer units depending on manufacturing conditions.

PROPERTIES

Table 1 – COMPRESSION MOLDED TEST BAR PROPERTIES* OF FOUR GENERAL PURPOSE POLYSTYRENES

Property	ASTM Test Method	Resin 666D	685	685D	697
Melt flow rate, g/10 min.	D1238 5kg, 200°C	7.5	2.4	1.6	1.8
Linear coef. of thermal expansion, in/in/°F (typical)		4.5	4.5	4.5	4.5
Vicat softening point, °F (°C)	D1525 Rate B	212 (99)	224 (107)	226 (108)	227 (109)
Yield tensile strength, psi (kgf/cm²)	D638	5400 (380)	6200 (437)	6400 (451)	6500 (458)
Ultimate tensile strength, psi (kgf/cm²)	D638	5400 (380)	6200 (437)	6400 (451)	6500 (458)
Ultimate tensile elongation, %	D638	1.3	1.5	1.5	1.9
Tensile modulus psi (kgf/cm²)	D638	460000 (32412)	470000 (33116)	470000 (33116)	490000 (34525)
Rockwell M hardness	D785	74	76	76	76
Deflection temperature @ 264 psi (18.6 kgf/cm²), annealed, °F (°C)	D648	185 (85)	214 (101)	217 (103)	218 (104)
Specific gravity	D792	1.04	1.04	1.04	1.04

*Test bars prepared by injection molding will have somewhat greater strengths.

Table 2 – TYPICAL ELECTRICAL PROPERTIES OF VARIOUS STYRON GENERAL PURPOSE RESINS*

Property	Unit	Value
Volume resistivity	Ohms-cm	>10^{16}
Dielectric strength (short time, 1/8" thick)	Volts/mil	500
Dielectric strength (step by step, 1/8" thick)	Volts/mil	400-600
Dielectric constant, 60 cps	–	2.54
10^3 cps	–	2.54
10^6 cps	–	2.54
Dissipation factor, 60 cps	–	0.0002
10^3 cps	–	0.0002
10^6 cps	–	0.0002
Arc resistance	Seconds	60-135

*Compression molded specimens.

Table 3 – TYPICAL ROOM-TEMPERATURE GAS PERMEABILITY AND WATER VAPOR TRANSMISSION DATA (VARIOUS TYPES OF MOLDED POLYSTYRENE)

Gas Permeability, cc/mil/100 in²/atm/day			Water Vapor Transmission, gm/mil/100in²/day (75-100°F)
O_2	N_2	CO_2	
300-400	40-50	1000-1500	2-10

Corrosion Resistance:

Molded parts of polystyrene are not affected by changes in relative humidity but the material is not considered a weather-resistant plastic. Continuous long-time outdoor exposure results in discoloration and reduction in strength and toughness. Finely dispersed carbon black or ultraviolet stabilizers improve weatherability. Tests on unloaded STYRON general purpose polystyrene resin specimens exposed for 30 days at 75 and 125°F in various media were rated as to changes in surface appearance, dimensions and/or weight. Specimens were unaffected in weak or strong inorganic acids, weak organic acids, alcohols, aliphatic amines, bases, beverages, foodstuffs, polyglycols, pharmaceuticals and salts. Specimens became soft in a few hours when exposed to aldehydes, aromatic amines, esters, polyglycol ethers, hydrocarbons, insecticides and essential oils. Tests on stressed samples were also made to evaluate corrosion cracking resistance. Consult the producer for results.

Machining:

Moldings of STYRON resin are readily machined using conventional methods.

Joining:

Parts molded from STYRON general purpose polystyrene can be solvent welded to each other. Rubber-based adhesives may be used to bond STYRON to metal, wood and glass. Ultrasonic welding may be used to bond STYRON to itself with excellent results.

Processing:

STYRON resins are not hygroscopic, do not readily absorb moisture at room temperature and therefore predrying prior to processing is not normally required. Suggested processing ranges for STYRON general purpose resins are as follows:

Injection Molding: extruder barrel temperature, rear 350 to 450°F, front 375 to 525°F
- mold temperature, 20 to 160°F
- injection back pressure, 10 to 500 psi
- injection pressure, 5000 to 40000 psi.

Injection Blow Molding: extruder temperature,
- rear 300 to 400°F, front 400 to 500°F
- manifold temperature, 450 to 500°F
- nozzle temperature, 450 to 550°F
- cavity temperature, 125 to 200°F
- mold temperature, 30 to 60°F
- injection pressure, 5000 to 20000 psi
- cycle time, 8 to 12 seconds

Extrusion: feed throat; full water cooling
- rear zone temperature, 325 to 375°F
- intermediate zones, 350/400 to 425°F
- front zone temperature, 400 to 450°F
- die temperature, 400 to 450°F
- chill rolls, 100 to 160°F
- compression ratios, 2 1/2:1 to 5:1

Use of Regrind: Good quality regrind in ratios of 15 to 30% with virgin resins can be used to produce quality injected molded parts. With extrusion applications, 50% regrind and virgin resin are common practice.

Handling:

Material Safety Data Sheets for STYRON polystyrene products are available from the producer and should be procured. STYRON resin will burn. Fires can be extinguished with water, fog, foams and other conventional means. Disposal in approved industrial incinerators is suggested. Approved landfill disposal may also be used. STYRON resins are inert, do not readily degrade, will not contribute to landfill instability or evolve gases or leachates known to pollute water resources.

General Characteristics:

STYRON general purpose polystyrene resins are amorphous thermoplastic materials designed for injection molding, injection blow molding and sheet and film extrusion. They are not considered to be weather resistant. They are nonhygroscopic and they are resistant to beverages, foodstuffs and pharmaceuticals. Most comply with FDA requirements. They are highly notch sensitive. Typical values for light transmission range from 88 to 91% at a thickness of 100 mils. They exhibit excellent dimensional stability. They may be recycled as mixtures of regrind and virgin resin. High melt strength and product uniformity make for excellent injection blow molding characteristics. Referring specifically to the four grades cited; STYRON 666D is designed for injection molding applications, particularly for medical, pharmaceutical and food uses. It has intermediate flow characteristics and fast cycle processing. STYRON 685 and 685D are high heat resins designed for medium to thick section applications, appliance parts, housewares, foam sheet and oriented film. Both have good moldability. STYRON 697 is a high heat resin designed for high-speed production of strong light-weight containers by use of the in-line extrusion thermoforming process. All four of these general purpose polystyrene resins have excellent clarity. They meet FDA compliance. They have excellent dimensional stability and being amorphous they exhibit less mold shrinkage than some more crystalline plastics such as polyethylene and polypropylene.

Forms Available:

STYRON general purpose polystyrene resin granules are available in 50 pound bags, bulk truck or bulk rail cars. They are supplied with or without surface lubrication or with external lubrication. Most injection molding and extrusion operations use uncoated STYRON W resins.

Applications:

Food packaging, household lighting, construction and decoration, disposable dinnerware, tumblers, bottles, medical ware, toys, tape reels.

Producer:

The Dow Chemical Company
Midland, Michigan 48674

Alloy DIGEST

GRIVORY G 355 NZ

Filing Code: P-4
Plastic

JUNE 1989

DATA ON WORLD WIDE METALS AND ALLOYS

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

GRIVORY G 355 NZ
(High Impact Resistant Thermoplastic)

GRIVORY® G 355 NZ is an unreinforced, amorphous, high-impact resistant engineering thermoplastic. It is opaque and has a natural ivory color. It can be processed by injection molding, extrusion and blow molding.

GRIVORY® is registered trademark of EMS-Chemie AG, Zurich, Switzerland.

Chemical Characterization:
Grivory® G NZ is an amorphous copolymer, alloyed with an elastomeric material.

Physical Properties:

Property	Test Method	Unit	Value
Glass transition temp.	ASTM D 2117	°F (°C)	275 (135)
Specific gravity	ASTM D792	gm/cu cm	1.07
Moisture absorption	ASTM D570		
24 hr immersion		%	0.38
In air, 23°C/50%RH*		%	1.5
In water, 23°C		%	5
Heat deflection temp.	ASTM D648		
66psi (0.46 MPa)		°F (°C)	270 (132)
264psi (1.82 MPa)		°F (°C)	230 (110)
Linear mold shrinkage	EMS		
flow/tangential		%	0.7/0.8
Thermal coef. expansion	DIN 52328		
(-58 to + 212°F)		in/in°F	4.4×10^{-5}
(-50 to +100°C)		cm/cm°C	7×10^{-5}
Maximum usage temp.	EMS		
Long term in air		°F (°C)	176 (80)
Short term in air		°F (°C)	248 (120)
Vicat softening temp.	DIN 53460		
9.81 Newton (2.20 lb force)		°F (°C)	246 (119)
41.05 Newton (9.23 lb force)		°F (°C)	248 (120)
Volume resistivity	DIN 53492	ohm-cm	10^{15}
Dielectric strength	DIN 53481	kV/mm	34
Comparative tracking index	DIN 53480	V	600+
Surface resistivity	DIN 53482	ohm	10
Dielectric constant	DIN 53483		
At 50 Hz		--	3.1
At 1 kHz		--	3.0
At 100 kHz		--	2.8

*RH = relative humidity.

PROPERTIES

Table 1 -- MECHANICAL PROPERTIES

Property	Test Method	Unit	Value
Tensile strength	ASTM D 638	psi (MPa)	7300 (50)
Elongation at yield	ASTM D 638	%	10
Elongation at break	ASTM D638	%	80
Flexural strength	ASTM D790	psi (MPa)	10400 (72)
Flexural modulus	ASTM D790	psi (MPa)	250000 (1725)
Izod impact strength, notched	ASTM D256		
At 73°F (23°C)		ft-lb/in (J/m)	18 (961)
At -4°F (-20°C)		ft-lb/in (J/m)	15 (801)
Hardness	Shore D	--	77

Processing:

For optimum processing and parts quality, Grivory® G 355NZ should be protected from exposure to a humid environment prior to processing. If hopper residence times are likely to exceed two hours, use of a hopper dryer operating at 176°F (80°C) is recommended. If material is otherwise exposed to a humid atmosphere for more than two hours, drying prior to processing is recommended to ensure that the moisture content does not exceed 0.1%. Use of a vacuum dryer operating at 230°F (110°C) is strongly recommended. A dessicant dryer may also be used, but to avoid oxidation of the material and consequent discoloration, temperatures should be held below 176°F (80°C), with drying times between six and ten hours. For longer periods, overnight for example, dessicant drying is acceptable at temperatures not exceeding 158°F (70°C).

Injection Molding:

Melt temperature	518-554°F (270-290°C)
Mold temperature	176°F (80°C)
Injection speed	Moderately fast
Injection pressure	Medium
Screw speed	Minimum that is consistent with optimum cycle times

Extrusion:

Barrel temperature	434°F (240°C)
Melt temperature	509°F (265°C)
Die temperature	416°F (230°C)
Water bath	54°F (12°C)

Cooling the feed zone at the hopper is recommended.

General Characteristics:

Grivory®G 355NZ is an amorphous copolymer, alloyed with an elastomeric material. Being amorphous, it differs fundamentally in its property profile from that of partially crystalline materials such as Grilon nylon 6 or Grilamid nylon 12. It has a high glass transition temperature of 275°F (135°C) and higher dimensional stability under heat. Its mechanical properties are not affected by uptake of ambient moisture. The chemical resistance of Grivory G 355 NZ against a large number of solvents and against alkalis is good. It is not resistant to acids, especially strong acids.

Forms Available:

Grivory® G 355NZ is supplied ready for processing in free-flowing pellet form, pre-dried to 0.1% moisture and packaged in multiwall, foil-lined, moisture-proof bags containing 25 kg net.

Applications:

Injection molded, extruded and blow molded components. Completely new application and design possibilities are feasible with Grivory® G 355NZ due to its unique profile of properties. The principal features are: high rigidity, high impact strength, no loss of rigidity due to moisture absorption, high dimensional stability. Specific applications: Power tool housings, handles and internal parts; aircraft parts (external and internal); electrical/electronic connectors; fishing reels; camera parts; automotive connectors; commercial and domestic dishwasher parts; raquetball, lacrosse, and tennis raquets; protective helmets; scuba diving equipment parts.

Producer:

EMS-American Grilon, Inc.
P.O. Box 1717
Sumter, South Carolina 29151-1717
Contact: John Mewborn, telephone: (803) 481-3172.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

LEXAN®

Filing Code: P-5
Plastic

JUNE 1989

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

LEXAN®
(Thermoplastic Polycarbonate Resin)

LEXAN* is a thermoplastic polycarbonate resin whose properties make it one of the toughest and most versatile of engineering thermoplastics. It provides the design engineer with exceptional freedom in creating functional, attractive, cost-effective products. It is used in a broad range of industrial products.

*LEXAN® is a registered trademark of GE Plastics.

Chemical Characterization:

General purpose LEXAN® is a polycarbonate thermoplastic resin available in a continuum of tightly controlled viscosities.

PROPERTIES

Table 1 -- PHYSICAL PROPERTIES: SIX GENERAL PURPOSE LEXAN® RESINS

Property	ASTM Test Method	Unit	Resin/Value
Melt flow index,	D1238		
nominal	Condition O		121/ 141L/ 141/ 161/ 101/ 181/
		g/10 min	16.5 11.5 9.5 8.0 6.5 5.3
Specific gravity, solid	D792	–	All/1.20
Specific volume	–	cu in/lb	All/23.1
		c cm/g	All/0.83
Weight/volume	–	lb/cu in	All/0.043
		g/ c cm	All/1.20
Water absorption	D570		
24h @ 73°F (23°C)		%	All/0.15
Equilibrium @ 212°F (100°C)		%	All/0.58
Mold shrinkage, flow, 0.125 in.	D955	in/in x/10^{-6}	All/0.005-0.007
Light transmittance @ 0.125 in	D1003	%	All/89
Haze @ 0.125 in	D1003	%	All/1
Refractive index	D542	–	All/1.586

Table 2 -- THERMAL PROPERTIES

Property	ASTM Test Method	Unit	Resin/Value
DTUL			121/ 141L, 141, 161, 101/ 181/
@ 264 psi (1.82MPa)	D648	°F	265 270 275
0.250 in. (6.35mm)		(°C)	(129) (132) (135)
Specific heat	C351	Btu/lb/°F (J/g/°C	All/0.30 (1.25)
Thermal conductivity	C177	Btu/in/h/ft^2/°F(W/km)	All/1.35 (0.19)
Thermal coef. expansion	D696	in/in/°F (m/m°C)	All/3.75 x 10^{-5} (6.7 x 10^{-5})
Vicat softening temperature	D1525	°F (°C)	All/305-315 (152-157)
Brittleness temperature	D746	°F (°C)	All/<-200 (<-129)
Flammability ratings*	D635	–	All/AEB<1 in.
UL Standard 94 @ 1/16 in.	–	–	All
UL Standard 94 @ 1/8 in.	–	–	All
Oxygen index	D2863	–	All/25.0

*This rating is not intended to reflect hazards presented by this or any other material under actual fire conditions.

Molding Characteristics:

The six grades of LEXAN® general purpose resins provide mold and design versatility. Tight control of each respective grade minimizes lot-to-lot variations and thereby provides for consis-

Table 3 -- ELECTRICAL PROPERTIES (IDENTICAL FOR ALL RESINS)

Property	ASTM Test Method	Unit	Value
Dielectric strength	D149		
Short time, 125mils (3.2mm)		Volts/mil (kV/mm)	380/(15.0)
Dielectric constant	D150		
60HZ		–	3.17
10^6HZ		–	2.96
Power factor			
60HZ	D150	–	0.0009
10^6HZ		–	0.010
Volume resistivity, dry@73°F (23°C)	D257	ohm-cm	$>10^{16}$
Arc resistance	D494		
Stainless steel electrodes		seconds	10^{-11}
Tungsten electrodes		seconds	120

Table 4 -- MECHANICAL PROPERTIES

Property	ASTM Test Method	Unit	Resin/Value
Tensile strength	D638	psi (MPa)	All/10000 (69)
Yield strength	D638	psi (MPa)	All/9000 (62)
Elongation @ rupture	D638		121/ 141L, 141, 161/ 101, 181/
		%	125 130 135
Flexural strength	D790	psi (MPa)	All/14000 (97)
Flexural modulus	D790	10^5psi (MPa)	All/3.40 (2300)
Compressive strength	D695	psi (MPa)	All/12500 (86)
Compressive modulus	D695	10^5psi (MPa)	All/3.45 (2400)
Shear ultimate strength	D732	psi (MPa)	All/10000 (69)
Shear yield strength	D732	psi (MPa)	All/6000 (40)
Shear modulus	–	10^5psi (MPa)	All/1.14 (790)
Notch Izod impact strength,			121/ 14L/ 141/ 161/ 101/ 181/
1/8 in. thick	D256	ft-lb/in (J/m)	13 14 15 16 17 18
			(694) (748) (801) (854) (908) (961)
Tensile impact strength, S-type	D1822	ft-lb/in^2 (kJ/m^2)	225 250 275 290 300 320
			(470) (525) (578) (610) (630) (673)
Instrumented impact energy,			
at peak 73°F (23°C)	D3763	ft-lb (J)	46 47 47 47 48 48
			(62) (64) (64) (64) (65) (65)
Fatigue strength, 2.5mm cycles	D671	psi (MPa)	All/1000 (7.0)
Rockwell hardness	D785	M	All/70
		R	All/118
Deformation under load	D621		
4000psi @ 73°F		%	All/0.2
4000psi @ 158°F		%	All/0.5
Taber abrasion resistance	D1044		
Weight loss		mg/1000 cycles	All/10

tent molding from run-to-run. LEXAN® 121 resin has the highest flow rate of the six grades (16.5g/10min.) and is used in molding intricate, hard-to-fill parts. It is available in natural and transparent colors only. LEXAN® 141 resin, a medium flow-rate material (9.5g/10 min.) is most commonly used for injection molding. LEXAN® 101 resin, a lower flow-rate material (6.5g/10min.) is used for molding thicker sections without sinks. LEXAN® 181, the lowest flow-rate grade of the series (5.3g/10min.) offers superior toughness.

General Characteristics:

LEXAN® general purpose grade polycarbonate resins range in flow rate from 16.5 to 5.3g/10min. and each specific resin is closely controlled to assure consistent run-to-run molding performance.

Deflection temperatures @ 264 psi range from 265 to 275°F; tensile elongation @ rupture ranges from 125 to 135%; and notched Izod impact strength (1/8 in. thick) ranges from 13 to 18 ft-lb/in. The higher values in each case above are for the low flow-rate material (resin 181).

Each resin is available with a variety of additives, for example: for UV stabilization, for FDA compliance and for mold release.

Applications:

Appliance, automotive, electrical and electronic components particularly where toughness is a desired feature. Contact the producer for design, feasibility studies, physical testing, prototyping and other help in getting from concept to production.

Producer:

GE Plastics
Plastics Group
One Plastics Avenue, Pittsfield, Massachusetts 01201.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Pb-1
Lead Alloy

SEPTEMBER, 1954

Published by
Engineering Alloy Digest, Inc.
Upper Montclair, New Jersey

FEDERATED No. 7

FEDERATED NO. 7

(Bearing Alloy)

Federated No. 7 is a lead-base white Babbitt metal used for bearings where speeds, loads and stresses are moderate.

Composition:

Lead	74.00-76.00
Tin	9.25-10.75
Antimony	14.00-16.00
Copper	0.50 max.
Arsenic	0.20 max.
Zinc	none‡
Aluminum	none‡

‡ Defined as 0.005% as determined on a 10 gram sample.

Physical Constants:

Specific gravity, g/cc	9.7
Density, lb./cu. in.	0.350
Solidus temperature, °F	464
Liquids temperature, °F	514

PROPERTIES

Table 1 — BRINELL HARDNESS

Condition	Brinell Hardness (500/10/30)
As-cast	22
At 86°C after 7 days at 302°F	—
At 86°C after 46 days at 302°F	16
At 302°C after 17 hours at 302°F	8.0
At 302°C after 7 days at 302°F	7.0
At 302°C after 46 days at 302°F	5.8

Table 2 — TENSILE PROPERTIES

Test Temperature °F	Tensile Strength psi	Elongation % in 2″
77	10500	4.0
212	5500	25.0
302	3000	52.0
392	1250	100.0

Table 3 — OTHER ENGINEERING PROPERTIES

Compressive strength, psi (at room temp. at 10% reduction in height under load)	17150
Fatigue strength, psi (rotating beam, 20,000,000 cycles at 2000 cycles per minute)	4000

	At 68°F	At 212°F
Compressive yield strength, psi (0.125% set)	3500	1600
Compressive ultimate strength, psi (25% set)	15650	6150
Johnson's elastic limit, psi	2500	1350
Brinell hardness (500/10/30)	22.5	10.5

Table 4 — OPERATING CHARACTERISTICS

Maximum permissible unit pressure, psi	1800
(1) Minimum permissible ZN/P	10
(2) Maximum permissible PV	40000
Maximum oil temperature, °F	225
Minimum journal hardness	Not important

(1) Parameter=oil viscosity times speed over pressure
(2) PV=pressure times speed

Table 5 — PERMISSIBLE STATIC PRESSURE

Temperature °F	Static Pressure psi
70	3500
200	1500
300	800

Chemical Bonding:

It is of the utmost importance to produce a good bond between the shell and the bearing metal if cracking and other bearing failures are to be prevented. In general the following procedure should be used in making this bond:

1. The surface of the shell should be machined or shot-blasted.

2. The machined surface should then be degreased with a solvent degreaser, such as, trichlorethylene vapor or degreased in an alkaline cleaner.

3. The shell should then be dipped in a 50% solution of hydrochloric acid and water and etched for three to five minutes. The reagent should be kept at about 150 deg. F. Following this treatment the surface of the shell should be absolutely clean. Care should be taken to prevent oil or grease from coming in contact with the surface.

4. The next operation is fluxing. The shell is dipped into a flux solution of two parts zinc chloride and one part amonium chloride diluted with water to a 40% aqueous solution which is preferably at a temperature of about 150 deg. F.

5. The bonding alloy (tin or solder of various grades) is then applied by dipping the shell into the molten alloy which is held at a temperature of about 150 deg. above the liquidus temperature. The shell is kept submerged until it has acquired the temperature of the metal bath. Since the shell is now ready for casting of the bearing material, the bonding alloy should be kept molten until the babbitt is poured on it.

Specification Equivalents:

ASTM B23 Gr. 7
Federal QQ-M-161 Gr. 7
U. S. Navy 46M2 Gr. 7
SAE 14

General Characteristics:

Federated No. 7 is a lead-base white babbitt having tin and antimony as the major alloying elements.
This bearing alloy has a desirable plastic impact hardness and is suitably adapted for moderate loads and speeds. This alloy can also be used in the old type thick lined bearings in which the lining is chemically bonded to the shell. Chemical bonding, if properly done, will improve service life of the bearing. It has non-scoring and non-wearing properties, and is resistant to corrosion from organic acid of the type normal to the lubricating oil.

Since this alloy has a relatively low melting point, it is limited to applications where loads and speeds will not generate excessive temperature in service. This alloy (lead-tin-antimony babbitt) is stronger and more suitable for higher speeds, higher loads, and higher operating temperatures than the lead-antimony alloys. It is cheap, easy to cast, has good frictional properties, and is successfully used for railway application and heavy machinery generally where speeds and stresses are moderate. Under more severe service conditions, the tin-base babbitts are more frequently used.

The constituents present in the lead-antimony-tin alloys are antimony crystals or tin-antimony crystals or both in a eutectic matrix consisting of 4% tin, 12% antimony, and 84% lead. Antimony crystals as well as tin-antimony crystals appear as cuboids under the microscope and can only be distinguished by special methods. Both kinds of crystals are hard and brittle and form the load supporting medium similar to that found in the tin-base alloys. Again, as in the case of tin-base alloys, the number and the size of the crystals are influenced by cooling conditions. Supercooling effects are typical for lead-base alloys containing more antimony than the eutectic composition. Casting and cooling conditions affect the microstructure, fracture, and mechanical properties. Segregation occurs under the same conditions as in tin-base alloys, i.e., no segregation takes place as long as the metal is completely liquid. If the metal is allowed to freeze slowly, the antimony and tin-antimony crystals which are lighter than the melt tend to float to the top. Upon remelting, these crystals are easily redissolved, but the melt must be thoroughly stirred to regain uniform composition. Approximate pouring temperature is 650-750 deg. F.

Forms Available:

Castings.

Applications:

Bearings, bushings.

Manufacturer:

Federated Metals Division
American Smelting & Refining Company
Newark, New Jersey

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: Pd–1
Palladium

AUGUST 1971

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

PALLADIUM

PALLADIUM
(Silver-white Noble Metal)

Palladium, one of the six metals of the platinum group, is highly ductile and can be readily worked hot or cold.

Composition:

Palladium	99.85

Note: Commercial purity palladium is nominally 99.85% Palladium (ranging 99.80-99.90%). Higher purity grades up to 99.99+% are available and are sometimes specified for uses where certain impurities are known to be detrimental. Approximately one half of the nominal 0.15% of impurities in commercial palladium comprises other platinum group metals, the other half consists of iron, copper, silicon and small amounts of other base metals.

Physical Constants:

Density, lb/cu in.	0.434
Specific gravity	12.02
Melting point, °F	2829
Thermal coef. expansion/°F (70 to 100°F)	6.41×10^{-6}
Thermal conductivity, Btu/sq ft/hr/°F/in.	493
Specific heat, Btu/lb/°F	0.058
Electrical resistivity, microhm-cm	10.8
Electrical conductivity, % IACS	16
Modulus of elasticity, psi (tension)	16.7×10^{6}
Modulus of rigidity, psi	6.5×10^{6}
Poisson's ratio	0.39

PROPERTIES

Table 1 – TYPICAL ROOM-TEMPERATURE PROPERTIES

Condition	Tensile Strength psi	Yield Strength psi	Elongation (2 in.) %	Diamond Pyramid Hardness
Annealed	28000	5000	30	40
Cold worked, 50%	47000	30000	2	100
Cold worked, 75%	65000	—	1.5	—

Table 2 – EFFECT OF ANNEALING ON TENSILE PROPERTIES OF WIRE

Annealing Temperature °F	Tensile Strength psi	Elongation %
68*	68000	2
390	68000	4
750	52000	5
1110	38000	15
1470	29000	30
1830	28000	23

*Cold worked, 75% reduction.
Note: Annealing time 30 minutes at temperature.

Table 3 – SHORT-TIME ELEVATED-TEMPERATURE TENSILE STRENGTH
(0.050-in. diameter wire, annealed at 2010°F, 5 min)

Test Temperature °F	Tensile Strength psi
68	28000
390	24500
750	18000
1110	12700
1470	8300
1830	3800

Table 4 – STRESS-RUPTURE PROPERTIES

Form	Test Temperature °F	Stress (psi) for Rupture in 10 hr	100 hr
Rod	1700	1000	600
Wire	2370	400	200
Wire	2640	200	100

Heat Treatment:

Anneal: 1470°F, 5 min, cooling method immaterial.
Harden: Palladium cannot be hardened by any thermal treatment.

Machinability:

This soft metal can be cut fairly easily but galls readily. Keep tools sharp to minimize galling and pick-up. Sulfur-free oils are normally recommended for machining. Palladium's machining qualities are much the same as those for pure nickel. Machinability is improved if the palladium is in the cold-worked condition.

Workability:

Palladium is highly ductile and malleable and can be readily worked hot or cold. Wire can be cold drawn without intermediate anneals from a diameter of 0.250 inch to 0.004 in. The metal can withstand drastic forming operations and, like gold, can be beaten into leaf as thin as 1/250,000 of an inch. It has excellent cold working properties and can be easily formed by rolling, deep drawing, spinning, swaging, etc. Sheet can be expanded and wire woven into gauze.

Weldability:

The metal can be joined by tungsten-inert gas welding, resistance welding procedures, or by brazing. Oxidizing oxyhydrogen and oxyacetylene flames are desirable for brazing with platinum brazing alloys melting at 2000 to 2275°F. In using the oxyacetylene flame, special care should be used to keep the metal in the oxidizing portion of the flame to avoid possible embrittlement. A gas-air torch and lower melting white gold alloys are employed for joining palladium jewelry.

Corrosion Resistance:

Palladium is generally resistant to corrosion by most single acids, alkalies and aqueous solutions of simple salts. It is not attacked at room temperature by non-oxidizing acids such as sulfuric, hydrochloric, hydorfluoric, acetic and oxalic. Strongly oxidizing acids such as nitric attack palladium as do ferric chloride and hypochlorite solutions, chlorine, bromine. The metal is not tarnished by dry or moist air at ordinary temperatures. At temperatures in the range 750 to 1450°F, a thin oxide film forms in air. At higher temperatures, the superficial oxide decomposes to give off oxygen, leaving a clean metal surface. At high temperatures, molten salts such as sodium peroxide, hydroxide and carbonate attack palladium but the molten nitrate does not. Hydrogen sulfide attacks the metal at temperatures above 1100°F, producing a low melting phase.

General Characteristics:

Palladium is a silver-white metal which has properties resembling those of platinum and gold, metals closely associated with it in the periodic table. It is the lightest of the platinum group metals, and has the lowest melting point of the group. Palladium work hardens at about the same rate as platinum and is ductile and malleable. It can withstand drastic hot and cold working. Palladium is resistant to corrosion by most single acids and alkalies and by many simple salts. It can be joined by welding and brazing.

Palladium is permeable to hydrogen, particularly at moderately elevated temperatures (300-600°C). Palladium also absorbs hydrogen in such large quantities as to affect its density, ductility and mechanical stability. This is a complex subject and potential users should consult the technical literature.

Forms Available:

Sheet, foil, wire, tubing, powder.

Applications:

Electrical contactors, resistors, thermocouples, thermal fuses, brazing alloys, hydrogen purification, dental service, catalysts, jewelry.

Manufacturer:

Engelhard Minerals and Chemicals Corp.
Murray Hill, N.J. 07974

Mathey Bishop, Inc.
Malvern, Pa. 19355

Handy & Harman
New York, N.Y. 10022.

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

Filing Code: SA-13
Steel-Alloy

DECEMBER, 1953

Published by
Engineering Alloy Digest, Inc.
Upper Montclair, New Jersey

U.S.S. A-R STEEL

U. S. S.* A-R STEEL
(Abrasion Resisting Steel)

U.S.S. A-R Steel, also called U.S.S. Abrasion Resisting Steel, is a low cost abrasion resisting steel for the materials handling industries. It is an intermediate carbon-manganese steel, with better workability than carbon steel of the same hardness level.

Composition:

Carbon	0.35-0.50
Manganese	1.50-2.00
Phosphorus	0.05 max.
Sulphur	0.055 max.
Silicon	0.15-0.35
Iron	balance

* "U.S.S." is a registered trademark of United States Steel.

Machinability:

Can be drilled and machined satisfactorily with standard equipment. However, as is generally true with all high-hardness steels, the machine speeds and feeds must be reduced. High-speed steel drills are necessary and should be kept cool with drilling compound such as a soluble oil or turpentine. For drilling this steel the clearance rake of the drills should be less than for steels of lower hardness.

Workability:

Shearing: material in thicknesses up to 1/2" should be sheared at temperatures not lower than room temperature. Thicknesses over 1/2" to 1" should be preheated to 600-800 deg. F for shearing or should be gas cut. Thicknesses exceeding 1" should be gas cut. Punching: Can be punched successfully in thicknesses up to 1/2" at temperatures not lower than room temperature. More power is required than for equal thicknesses of structural carbon steel. The possibility of fine cracks in the material around the punched hole makes it advisable to ream after punching.

Can be readily hot formed and can be cold formed if proper precautions are taken. Hot forming may be carried out at temperatures up to approximately 1500 deg. F without appreciably affecting the abrasion resisting properties of the steel. Hot working should be employed for severe formations as well as for material over 1/2" in thickness. Cold forming of as-rolled product can be accomplished only with extreme care. Edge preparation is highly desirable and should be performed in a direction parallel to the edge. This must be done to remove any minute cracks which may remain from shearing, or to remove any other irregularity which may serve as a starting point for a crack. Flat rolled products intended for relatively severe cold forming, for drilling, or for any operation where uniformity of hardness is essential, should be heat treated prior to performing any of these operations. Material in thicknesses of 1/2" and under should be heated to 1200-1300 deg. F, maintained approximately one hour per inch of thickness, and cooled in air. Thicknesses over 1/2" should be quenched in water from 1575-1625 deg. F and then drawn at 1100-1150 deg. F. The object of these treatments is to improve the workability of the steel without materially affecting its abrasion resistance The normal surface hardness after these treatments is generally in the range of 200 to 250 Brinell.

Weldability:

Welds may be made on U.S.S. A-R Steel by using various types of bare and shielded-arc type electrodes. Bare electrodes produce brittle welds with a tensile strength considerably below that of the base metal. Consequently, their use is not recommended if high quality joints are required. Low carbon shielded-arc electrodes produce ductile welds of high quality although they do not have as high a tensile strength as the base metal. Alloy shielded-arc electrodes will produce welds having physical properties comparable to the base metal in every respect. The welding procedure to employ is similar to that recommended for plain low-carbon steels except that preheating should be used on heavy sections and in cases where the hard fusion zone may be objectionable.

Whenever possible, annealing at 1100-1200 deg. F after welding is recommended to increase the ductility of the heat-affected zone and to improve the general quality of the joint. Metallic-arc welding: The relatively large amounts of carbon and manganese in this steel require that certain precautions be taken in welding. If this steel is welded with ordinary cellulose-covered electrodes, hydrogen is absorbed in the vicinity of the weld and underbead cracking generally results. The most effective way to prevent underbead cracking is to use low-hydrogen electrodes such as the ASTM-AWS E10015 and E10016 grades. Welded joints made with these electrodes will have strengths equal to or in excess of those of the base metal, even with the reinforcements ground off.

If 100% joint efficiency is not needed, low-hydrogen electrodes of lower strengths may be used, e.g., E7015, E7016, E8015, or E8016.

The use of the low-hydrogen electrode will prevent or greatly decrease underbead cracking and thereby maintain the strength of the joint, but the hardness near the joint will remain high unless the material has been preheated or the joint is postheated. High hardness in the vicinity of the weld results in cracking of the material at relatively small angles of bend. Accordingly, if the application is such that great resistance to abuse is required, it is suggested that the material be preheated to about 350 deg. F before welding, or that the joint be postheated. In the following table are shown the results of bend tests made on welded butt joints.

Preheating should be employed for tack welding, because the base metal adjacent to small tack welds is most likely to be excessively hard.

The increase in hardness which accompanies the welding of Abrasion Resisting Steel is greater for thick plates than for thin plates because of the greater quenching capacity of the thick plates.

Gas welding: U.S.S. A-R Steel can be gas welded, but welds made with the rods generally used will not develop the full strength of this steel. In addition, the gas-welding rods available deposit weld metal very much softer than that of the base metal, and such soft metal would be readily worn away by the abrading medium. This non-uniform abrasion can be prevented to some extent by the use of a hard-surfacing rod for depositing the outer layers of weld metal. One inherent advantage in gas welding is that steep temperature gradients do not exist. Therefore, the weldment cools more slowly and excessive hardness is not obtained. Whether this advantage is sufficient to overcome the higher cost of the welding, the lower strength of the joint, and the faster wear of the weld metal will depend upon the particular circumstances involved.

Joint Efficiencies, as Determined by Tension Tests, of Butt Joints in 3/4-Inch Thick Abrasion Resisting Steel Welded with E10016 Type Electrodes.

Initial Plate Temperature, °F	*Post Heat Treatment*	*Reinforcement*	*Tensile Strength, psi*	*Location of Failure*	*Joint Efficiency, %*
70	None	Removed	110,100	Base Metal	100
70	None	In place	112,200**	Base Metal	100
350	None	Removed	110,800	Base Metal	100
350	None	In place	109,200**	Base Metal	100
350	SRA*	Removed	105,900	Weld Metal	96
350	SRA*	In place	106,800**	Base Metal	100

* Stress-Relief Annealed at 1025 deg. F for 2 1/2 hours.

** Values calculated from cross-section areas adjacent to reinforcements.

Results of Bend Tests of Butt Joints in 3/4-Inch-Thick Abrasion Resisting Steel Welded with E10016 Type Electrodes-Width of Specimen 1 1/2-Inches, Inside Radius of Bend, 3/4-Inch

Initial Plate Temperature, °F	*Post Heat Treatment*	*Angle of Bend to Failure, Degrees*
70	None	16
350	None	Over 100
350	SRA*	Over 100

* Stress-Relief Annealed at 1025 deg. F for 2 1/2 hours.

Corrosion Resistance:

Its corrosion resistance in industrial atmospheres is somewhat higher than that of structural carbon steel and approaches that of structural copper steel. Test data during a period of 4 years, between exposures of 4 to 8 years, indicate relative losses in weight as 1.00 for structural copper steel, 1.25 for U.S.S. A-R Steel, and 1.75 for structural carbon steel. In applications under water, in the soil, or where chemical corrosion is involved, this steel should exhibit a corrosion resistance similar to that shown by either structural carbon or structural copper steels.

General Characteristics:

Because resistance to abrasion is the fundamental consideration, U.S.S. A-R Steel is generally furnished to the chemical composition range shown. The surface hardness of the as-rolled steel will usually be in the range of 200 to 250 Brinell. When a certain minimum or maximum Brinell hardness is desired, the product must be ordered stress relieved or otherwise heat treated.

Forms Available:

Plates, bars, hot rolled strip and hot rolled sheets.

Applications:

Baffle plates, grader and mixer blades, drag and clamshell bucket, gravel chutes, dredge pipe, liners, screens, wearing plates, dust collectors, grinding mills, hoppers.

Manufacturer:

United States Steel Corporation
Pittsburgh 30, Pennsylvania

Alloy DIGEST™

TIMETAL® 6-2-4-2

DATA ON WORLDWIDE METALS AND ALLOYS

ASM INTERNATIONAL® The Materials Information Society

Filing Code: Ti-140
Titanium

June 2007

Published by: ASM International
Materials Park, Ohio 44073-0002
440-338-5151 CustomerService@asminternational.org
Fax 440-338-4634 www.asminternational.org

TIMETAL® 6-2-4-2
(Medium-Strength Elevated-Temperature Titanium Alloy)

Timetal 6-2-4-2 has a combination of tensile strength, creep strength, toughness, and high-temperature stability for long-term application at temperatures up to 538 °C (1000 °F).

Timetal is a registered trademark of Timet.

Chemical Composition, wt.%:

Aluminum	5.50–6.50
Tin	1.80–2.20
Zirconium	3.60–4.40
Molybdenum	1.80–2.20
Silicon	0.06–0.13
Iron	0.25 max
Oxygen	0.15 max
Carbon	0.08 max
Nitrogen	0.05 max
Hydrogen	0.0180–0.0125
Residual elements, each	0.10 max
Residual elements, total	0.40 max
Titanium	bal

Physical Properties:

(Typical values at room temperature of about 20–25 °C (68–78 °F) unless otherwise noted.)

Density, kg/m^3 (lb/in.^{3})	4540 (0.164)
Beta transus, °C (°F)	995 ± 15 (1825 ± 25)
Melting point, °C (°F)	1705 (3100)
Thermal conductivity, W/m · K (Btu/(ft · h · °F))	6.92 (4.00)
Specific heat capacity, J/kg · K (Btu/lb · °F)	460 (0.110)
Electrical resistivity, μΩ · m (Ω circular-mil/ft)	1.85–1.90 (1113–1143)
Magnetic permeability	Nonmagnetic
Coefficient of thermal expansion, 0–100 °C (32–212 °F), 10^{-6}/K (10^{-6}/°F)	7.7 (4.3)

Mechanical Properties:

Modulus of elasticity, typical, 20–25 °C (68–78 °F) GPa (10^6 psi)	114 (16.5)

See also Tables 1 and 2.

Heat Treatment:

Condition	Treatment, generalized
Stress relief anneal	482–649 °C (900–1200 °F) 1–4 h, air cool
Mill anneal	704–843 °C (1300–1550 °F), air cool
Solution treatment	15–30 °C (25–50 °F) below beta transus, 1 h water quench
Aging	538–593 °C (1000–1100 °F) 8 h, air cool

Table 1 Typical Tensile Properties

Temperature		Rod diameter		Yield strength, 0.2%		Tensile strength			
°C	°F	mm	in.	MPa	ksi	MPa	ksi	Elongation on 4D, %	Reduction in area, %
20	68	38	1.50	895	130	1004	146	19	42
		28	1.10	895	130	1018	148	19	44
		18	0.71	955	139	1045	152	18	40
480	896	38	1.50	545	79	716	104	26	63
		28	1.10	557	81	723	105	27	65
		18	0.71	565	82	735	107	25	67

Table 2 Creep and Post-Creep Tensile Properties

Creep properties						Post-creep tensile properties at room temperature					
Temperature		Stress				Yield strength, 0.2%		Tensile strength			
°C	°F	MPa	ksi	Time, h	Total plastic strain, %	MPa	ksi	MPa	ksi	Elongation, %	Reduction in area, %
450	842	386	56	100	0.066	951	138	1038	151	19	37
		386	56	300	0.109	...	...	...	...	...	...
500	932	300	44	100	0.060	951	138	1038	151	18	39
		300	44	300	0.125	...	...	...	...	...	...
540	1004	170	25	100	0.178	...	...	...	...	...	...

Table 3 Heat Treatments for Sheet

Treatment	Temperature °C	Temperature °F	Time, h	Cooling method
Duplex anneal (DA)				
First stage	900	1650	...	Air cool
Second stage	785	1450	...	Air cool
Triplex anneal (TA)				
First stage	900	1650	2	Air cool
Second stage	785	1450	...	Air cool
Third stage	595	1100	2	Air cool

Table 4 Heat Treatments for Bar and Forgings

Section size mm	Section size in.	Treatment	Temperature °C	Temperature °F	Time, h	Cooling method
>63.5	>2.5	Anneal	955	1750	1	Air cool
		Stabilization	595	1100	8	Air cool
<63.5	<2.5	Anneal	900	1650	1	Air cool
		Stabilization	595	1100	8	Air cool

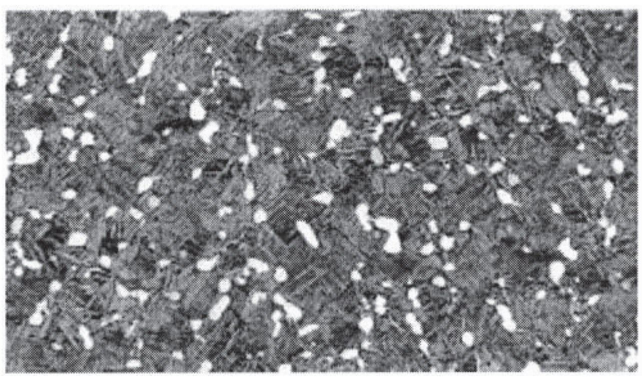


Fig. 1 Typical microstructure at 200×

Specific heat treatment for sheet is shown in Table 3 and for bar and forgings in Table 4.

Weldability:

Weldability is fair. Contact the producer for more information.

Forgeability:

Rough forging is carried out at 1038–1066 °C (1900–1950 °F). Finish forging is done at 954–982 °C (1750–1800 °F).

General Characteristics:

Timetal 6-2-4-2 has a combination of tensile strength, creep strength, toughness, and high-temperature stability for long-term application at temperatures up to 538 °C (1000 °F). Its primary application is gas turbine compressor components such as blades, disc, and impellers. This alloy is also used in sheet metal form for engine afterburner structures and for various hot airframe skin applications. Forging and machining characteristics of this alloy are very similar to Timetal 6-4. A typical microstructure at 200× is shown in Fig. 1.

Product Forms Available:

Sheet, bar, and forgings

Applications:

The primary application is gas turbine compressor components.

Producer:

Timet
Denver, CO 80202
(303) 296-5600
www.timet.com

Alloy Digest

Alloy DIGEST — DATA ON WORLD WIDE METALS AND ALLOYS

HYLITE-60

Filing Code: Ti-54
Titanium Alloy

JANUARY 1968

Published by
Engineering Alloys Digest, Inc.
Upper Montclair, New Jersey

HYLITE-60
(Alpha-Beta Titanium Alloy)

Hylite 60 is an alpha plus beta alloy having high tensile strength and good creep properties. It is suitable for compressor discs and blades and other highly stressed components up to 500°C.

Composition:

Hydrogen	0.013 max.*
Aluminum	2.0–4.0
Tin	5.0–7.0
Zirconium	4.0–6.0
Molybdenum	1.0–3.0
Silicon	0.3–0.7
Titanium	Remainder

*Hydrogen on forgings 0.015 max.

Physical Constants: (at 20°C)

Density, lb/cu.in.	0.172
Specific gravity	4.73
Electrical resistivity, microhm-cm	153
Thermal conductivity, cal/cm^2/cm/sec/°C	0.017
Thermal coef. expansion/°C x 10^{-6} (20-100°C)	7.9
Modulus of elasticity, psi x 10^6	16.2

PROPERTIES

Table 1 – TYPICAL MECHANICAL PROPERTIES
(1" dia. bar, fully heat treated)

Tensile strength, psi	156000
Yield strength, psi (0.05%)	121000
, psi (0.10%)	129500
, psi (0.20%)	136200
, psi (0.50%)	143600
, psi (1.0%)	152800
Elongation, %	
(L = 5D) (L = $5.65\sqrt{So}$)	12.0
(L = $4\sqrt{So}$)	14.0
Reduction of area, %	17

Table 2 – TYPICAL ELEVATED TEMPERATURE PROPERTIES
(1" dia. bar, fully heat treated)

Test Temperature °C	Tensile Strength psi	Yield Strength, psi 0.05%	0.10%	0.20%	0.50%	1.0%	Elongation % L = $4\sqrt{So}$	Reduction of Area %
200	129500	90000	93600	99600	107800	114500	18.0	47
300	122000	73900	83600	92000	100800	109000	18.0	47
400	113700	79200	85900	90300	97200	101500	18.5	47
500	109800	79500	84400	87100	92500	98600	19.5	53
600	97700	60500	66000	72500	81500	87600	22.5	55
650	68300	30800	36400	42100	53000	57300	38.5	67
700	57400	22800	26900	30500	37500	42800	58.0	86

Table 3 – TYPICAL FATIGUE PROPERTIES
(Wohler fatigue tests on 5/8" dia. rolled bar in the fully heat treated condition)

Test Temperature °C	Specimen	Fatigue Strength, psi at 20×10^6 cycles	40×10^6 cycles	100×10^6 cycles
20	Plain	±94100	±94100	–
	Notched	±49300	±49300	–
450	Plain	±82100	±81700	±80700
	Notched	±41900	±41500	±41500
500	Plain	±82900	±81700	±80700
	Notched	±40400	±39700	±39300
600	Plain	–	–	±53800

(Stress concentration factor or notched specimens, approximately 2.4)

Table 4 – CREEP RUPTURE PROPERTIES
(5/8" and 1" dia. roller bars in the fully heat treated condition)

Test Temperature °C	Time Hours	Stress, psi to Produce Plastic Strain of 0.05%	0.10%	0.20%	Stress, psi to Produce Rupture
400	100	–	67200	–	–
	300	–	60500	–	–
450	30	57000	–	–	–
	100	50000	60500	72800	–
	300	–	54500	70500	–
	1,000	–	–	66500	–
	3,000	–	–	63800	–
	10,000	–	–	60000	–
500	30	38600	–	–	–
	100	29200	46000	58300	–
	300	21300	39900	53800	–
	1,000	–	28700	43900	–
	3,000	–	–	28100	–
550	30	20200	–	–	–
	100	14200	21000	29200	67700
	300	8700	13500	19800	52200
	1,000	–	–	–	44100
600	100	–	–	–	31900
	300	–	–	–	22400
	1,000	–	–	–	20200

Table 5 – CREEP PROPERTIES
(Results from a 24" dia. compressor disc forging in the fully heat treated condition)

Temperature °C	Time Hours	Stress, psi to Produce a Total Plastic Strain of 0.10%	0.20%
450	100	59700	80700
	300	52000	77300
	1000	47100	70600
500	100	47100	–
	300	40900	–

Heat Treatment:

Solution Treatment: Heat at 1000°C for one hour per inch of section and air cool.

Aging Treatment: After the solution treatment reheat to 550°C, hold at temperature for 24 hours, air cool.

Machinability:

This alloy requires rigid set-up, heavy feed, slow speed, and adequate coolant. Its machinability is similar to that of other titanium alloys. Carbide tools such as K6, 883, and HA are recommended for turning. High speed steel tools can be used but necessitate lower cutting speeds. With carbides use cutting speeds of 120-160 sfpm and feeds of 0.008-0.015 ipr. With high speed steels use cutting speeds of 30-60 sfpm and feeds of 0.004-0.007 ipr.

Carbide turning tools should be ground to 0 deg. back rake, 6 deg. side rake, 6 deg. side and end cutting-edge angles, 6 deg. relief angle and 0.040 inch nose radius. High speed steel turning tools should be ground to 5 deg. back rake, 5-15 deg. side rake, 5-15 deg. side cutting-edge, 5 deg. end cutting edge, 5 deg. relief angle and 0.010 inch nose radius.

Workability:

The beta transus for this alloy is in the region of 950°C (1740°F). Initial ingot (melt) breakdown may be carried out in the range 1000-800°C (1830-1470°F). Intermediate working is normally carried out with a maximum temperature of 940°C (1725°F) with a final 30% reduction below 920°C (1690°F).

Weldability:

Completely weldable when adequately protected. Use the same techniques as for commercial pure titanium. Recommend the aircomatic and heliarc methods, spot and seam welding.

Corrosion Resistance:

The corrosion resistance characteristics are similar to the commercially pure grades of titanium. It is highly resistant to salt water, many acids, alkalis, and other chemicals. Galvanically, this alloy is near the noble end of the scale, and galvanic couples behave like austenitic stainless steel.

Pickling:

Descale in standard sodium hydride or Hooker bath, followed by water quench and brief brightening dip (10% HNO_3–1/4% HF.)

Pickle in 25% HNO_3–2% HF. Finger stains are removed by most detergents.

General Characteristics:

Hylite 60 is an alpha-beta titanium alloy supplied with a maximum hydrogen content of 0.013% (130 p.p.m.). It possesses superior creep strength to Hylite 50 and is therefore most suitable for compressor discs and other highly stressed components up to 500°C.

Forms Available:

Bars and billets for forging are normally supplied in the stress relieved (i.e. annealed) condition. Bars and billets for machining and forgings are normally supplied in the heat treated condition.

Applications:

Jet engine components, airframe forgings, fasteners, turbine compressor discs.

Manufacturer:

Jessop-Saville, Ltd.
Sheffield, England

Alloy DIGEST
DATA ON WORLD WIDE METALS AND ALLOYS

ZAMAK 3

Filing Code: Zn-1
Zinc Alloy
Revised September 1991
DEC. 1953; AUG. 1966

Published by: Alloy Digest, Inc. / 201-677-9161
27 Canfield Street, Orange, N.J. 07050 / U.S.A.

ZAMAK 3

(General Purpose Zinc Die Casting Alloy)

ZAMAK 3 is the most widely used general purpose zinc-base die casting alloy. It provides an excellent combination of strength and ductility. It has good impact strength. It is the designer's first choice for die casting applications.

Composition (Principal Elements):

Aluminum	3.9-4.3
Copper	0.1 max.
Magnesium	0.025-0.05
Zinc	Largely the remainder

Physical Properties:

Density, lb/cu in.	0.24
kg/m^3	6600
Melting range, °F	718-728
°C	381-387
Thermal coef. expansion/°F (68-212°F)	15.2 x 10^{-6}
/°C (20-100°C)	27.4 x 10^{-6}
Thermal conductivity, Btu/ft • hr • °F	65.3
W/m • K	113.0
Electrical conductivity, % IACS	27
Pattern shrinkage, in/in	0.006

PROPERTIES

Table 1 – MECHANICAL PROPERTIES

Tensile strength, ksi (MPa)	41 (283)
Yield strength (0.2% offset), ksi (MPa)	32 (221)
Elongation (2"), %	10
Shear strength, ksi (MPa)	31 (214)
Compressive strength, ksi (MPa)	60 (414)
Modulus of elasticity, ksi (MPa)	12400 (85500)
Fatigue strength (Rotary bend, 5 x 10^8 cycles)	
ksi (MPa)	6.9 (47.6)
Impact strength (1/4" unnotched Charpy)	
ft-lb (J)	43 (58)
Hardness, Brinell	82

Heat Treatment:

ZAMAK 3 is used as cast. Die casting alloys are generally not heat treated.

Machinability:

ZAMAK 3, like other zinc alloys, machines rapidly with minimal tool wear. Machining rates rival those of free machining brass and can be 3 times faster than for gray cast iron. Tool breakage is not a problem. Superior net shape casting capability frequently obviates machining.

Workability:

Like other ZAMAK alloys, ZAMAK 3 has sufficient ductility to permit bending and crimping in post-casting assembly.

Joining:

ZAMAK 3 can be MIG or TIG welded. It can also be brazed using special zinc filler rods. The alloy is most often joined by mechanical methods. Flaring, riveting and crimping are common low-cost joining methods.

Corrosion Resistance:

ZAMAK 3 has excellent corrosion resistance under normal atmospheric conditions, and in many aqueous, industrial and petroleum environments. Corrosion resistance can be enhanced by plating, painting and zinc anodizing. Electroplating is generally a multi-layered coating (one or two copper layers, one or two nickel layers and a final layer of chromium, gold or brass. When resistance to corrosion and abrasion are paramount, chromium is the preferred final coating.

General Characteristics:

ZAMAK 3 has an excellent combination of tensile strength, ductility, toughness (impact strength), fatigue strength and finishing characteristics, all at favorable cost. Its modulus of elasticity is greater than those of magnesium and aluminum die casting alloys and much greater than that of engineering plastics. Thermal and electrical conductivity are good. The alloy is nonsparking and nonmagnetic. Damping capacity is excellent. The alloy has excellent dimensional stability, often obviating the need for machining after casting. Applications above 250°F (121°C) are beyond the capability of ZAMAK 3. High constant stress applications should also be avoided. The alloy can be produced in "hot chamber" die casting machines which provide fast cycle times and reduced production costs.

Forms Available:

Ingot, die castings.

Applications:

Automotive components (housings, heat sinks, trim, handles), electronics, household faucets, hand tools and a wide variety of general purpose applications where net shape, precision and physical properties are important.

Producer:

Noranda Sales Corporation
Toronto, Ontario M5H 3X2
Canada