HIGH PERFORMANCE

Pfinodal®

COPPER ALLOY STRIP

AMETEK®

SPECIALTY METAL PRODUCTS

HIGH PERFORMANCE Pfinodal® COPPER ALLOY STRIP

SPINODAL Metallurgy

- Spinodal strengthening occurs spontaneously during aging and results from submicroscopic chemical composition fluctuations
- For Pfinodal, the alloying elements are homogeneous throughout the strip prior to aging due to the wrought powder metallurgy process
- Spinodal hardening is a distinctly different metallurgy process
- The amount of cold rolling, aging temperature and time all affect the strength and formability of Pfinodal

PFINODAL Properties and Benefits

- Excellent high-temperature stress relaxation resistance
- High strength and excellent formability
- Lack of distortion during aging
- Available in mill hardened and age hardenable tempers
- Excellent solderability and resistance to intermetallic formation at high temperature
- Excellent corrosion resistance and ease of cleaning. In moist ammonia it resists corrosion for over 500 hrs. at 40°C
- Lower initial cost and cost savings during processing

PFINODAL CHEMICAL COMPOSITION

NICKEL	14.5-15.5%
TIN	7.5-8.5%
COPPER	BALANCE
COPPER AND NAMED ELEMENTS	99.90%
OTHER ELEMENTS	0.10% MAXIMUM

C72900 is CDA-UNS designation for Cu-15 Ni-8 Sn alloy.
ASTM B-740 standard specification for Copper-Nickel-Tin Spinodal alloy strip.

PHYSICAL PROPERTIES OF PFINODAL C72900

Electrical Conductivity at 68°F (20°C)	7.8	% IACS
Electrical Conductivity at 392°F (200°C)	7.3	% IACS
Thermal Capacity (Specific Heat)	0.09 (30x10³)	BTU / lb° at 68° (J/Kg K)
Thermal Conductivity	17 29	BTU / ft•HR•°F at 68° w/m°K at 20°C
Coefficient of Thermal Expansion	9.1x10⁻⁶ 16.4x10⁻⁶	In/In/°F 68°F - 572°F Per °C, 20°C - 200°C
Modulus of Elasticity (Tension)	18.5x10⁶ (127x10³)	Psi (MPa)
Modulus of Rigidity	7.5x10⁶ (52x10³)	Psi (MPa)
Density	0.323 (8.95)	lb/in³ (gm/cc)

Available in

Age Hardenable Tempers

MECHANICAL PROPERTIES OF PFINODAL ALLOY C72900

Age Hardenable (annealed and cold worked)

Standard Designation	Temper Name	0.2% YS ksi (MPa)	UTS ksi (MPa)	Elongation (%)	Hardness VHN	Minimum Bend Ratio 90° Bad Way	Minimum Bend Ratio 180° Bad Way
TB00	Solution HT	25-45 (172-310)	64-85 (441-586)	32-60	100-150	0	0
TD01	¼ Hard	52-75 (358-517)	75-100 (517-689)	18-35	150-235	0	0
TD02	½ Hard	75-100 (517-689)	85-110 (586-758)	8-20	190-275	0-0.5t	0.5-1t
TD03	¾ Hard	90-115 (620-793)	95-120 (655-827)	3-12	210-290	0.5-1t	1.5-2t
TD04	Hard	95-125 (655-862)	100-130 (689-896)	1-10	220-300	2-3t	3-4t

Age Hardened (annealed and cold worked, parts age hardened)

Standard Designation	Spinodal Hardening Treatment	0.2% YS ksi (MPa)	UTS ksi (MPa)	Elongation (%)	Hardness VHN
TX00	700°F/2 hr. (370°C/2 hr.)	100-130 (619-896)	120-150 (827-1034)	6-20	275-350
TS01	700°F/2 hr. (370°C/2 hr.)	115-145 (793-1000)	130-160 (896-1103)	4-16	290-365
TS02	700°F/2 hr. (370°C/2 hr.)	135-165 (931-1138)	145-175 (1000-1206)	3-12	315-390
TS03	700°F/2 hr. (370°C/2 hr.)	145-175 (1000-1206)	155-185 (1069-1275)	2-9	325-400
TS04	675°F/2 hr. (360°C/2 hr.)	155-185 (1069-1275)	165-195 (1138-1344)	2-6	335-410

Available in

Mill Hardened Tempers

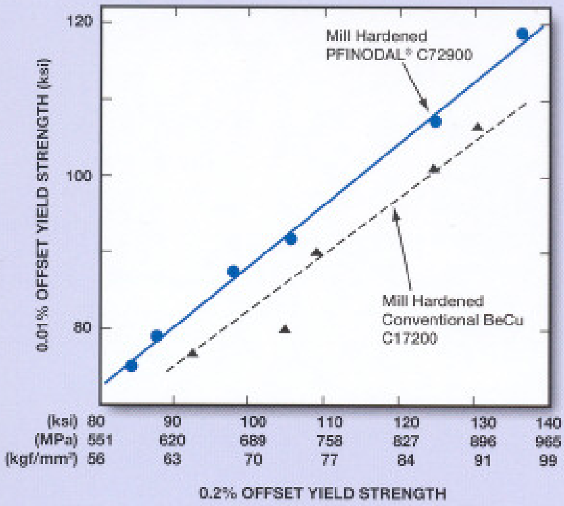
MILL HARDENED TEMPER DESIGNATIONS FOR PFINODAL C72900

(cold worked and hardened)

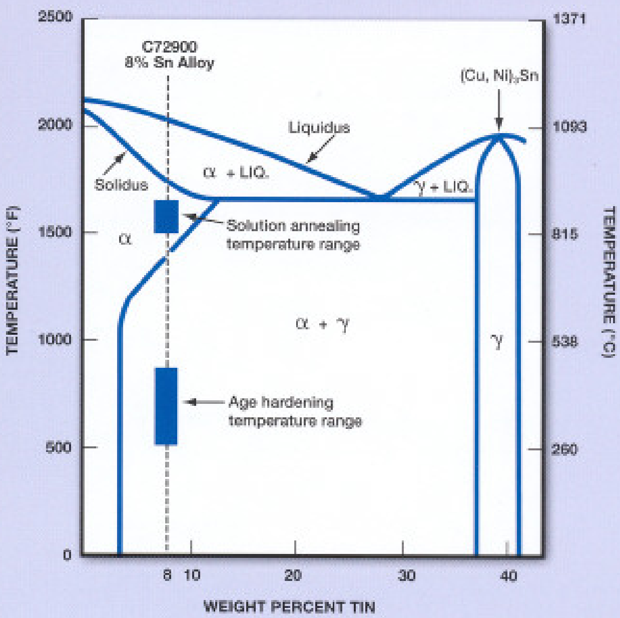
Standard Designation	0.01% YS ksi (MPa)	0.2% YS ksi (MPa)	UTS ksi (MPa)	Elongation (%)	Hardness (VHN)	Minimum Bend Ratio 90° Bad Way	Minimum Bend Ratio 180° Bad Way
TM00	65-90 (448-620)	75-95 (517-655)	95-115 (655-792)	22-36	190-290	0	0-0.5t
TM02	75-100 (517-689)	90-110 (620-758)	105-125 (723-862)	15-30	215-315	0-0.5t	0.5-1t
TM04	90-115 (620-729)	105-125 (723-862)	115-135 (792-930)	10-24	245-345	0-1t	0.8-1.5t
TM06	100-125 (689-862)	120-145 (827-999)	130-150 (896-1034)	6-16	270-370	0.5-6.0t	2-3t
TM08	115-140 (792-965)	140-170 (965-1171)	150-178 (1034-1226)	2-10	305-405	*—	—

**Minimum bend radius measured in 3 point bending in an unsupported die*

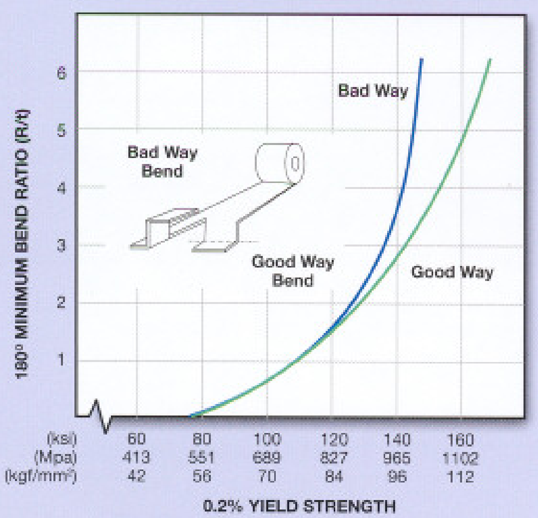
0.01% YIELD STRENGTH VS. 0.2% YIELD STRENGTH FOR PFINODAL AND BeCu STRIP



Cu-Ni-Sn PSEUDO-BINARY PHASE DIAGRAM



PFINODAL 180° MINIMUM BEND RATIO VS. 0.2% YIELD STRENGTH

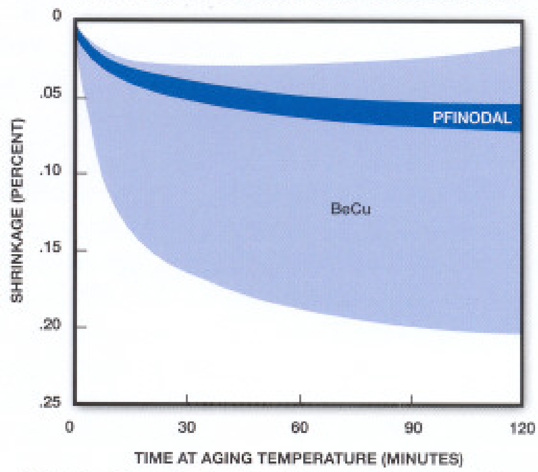


No Distortion

Pfinodal parts can be age hardened with a simple heat treatment and no distortion of parts will occur. No fixturing is required. Age hardenable Pfinodal is recommended for part geometries requiring the highest strength with excellent formability.

Other age hardenable alloys, such as beryllium-copper, can severely distort during the hardening heat treatment. This distortion, caused by differential shrinkage, can result in parts with poor dimensional accuracy. Fixture heat treating of beryllium-copper parts can be used in some cases to restrain this distortion but at significantly higher processing costs.

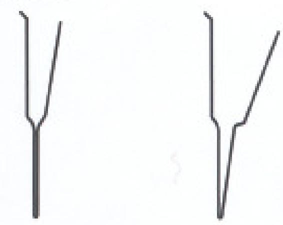
DIMENSIONAL CHANGES OF PFINODAL AND BeCu DURING AGE HARDENING



NOTE: 0 to 40% cw. Longitudinal and Transverse Directions Both Alloys Aging Temperatures: Pfinodal — 700°F (371°C) BeCu — 600°F (316°C)

DISTORTION IN BeCu PARTS

Distortion occurs in BeCu part



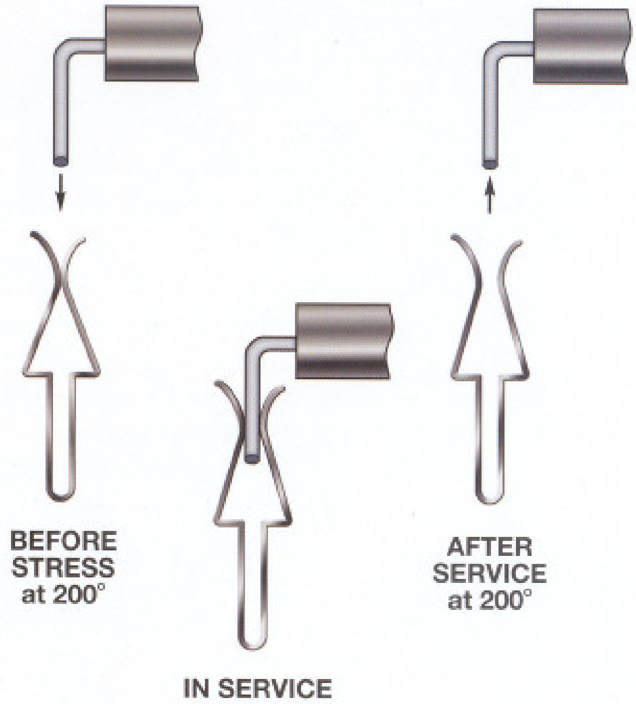
Unaged and Aged BeCu Alloy C17200

No distortion in Pfinodal part

Unaged and Pfinodal Alloy C72900

Stress/Thermal Relaxation

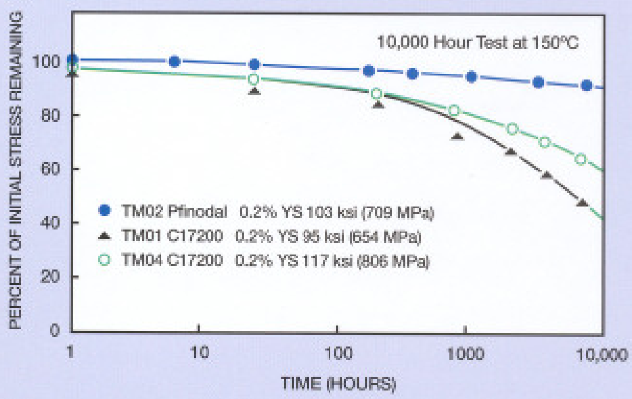
The significance of high temperature stress (thermal) relaxation resistance of Pfinodal is the maintenance of contact spring pressure over a long period of time at high temperature. When a contact engages the mating members are deflected and elastic stress and strain forms along the length of the beam. Over a long period of time at room temperature, essentially none of this stress or strain is lost. As the temperature increases, some of the elastic stress in ordinary alloys relaxes and the elastic strain is converted to permanent deflection. As the temperature and time increases, so does the amount of permanent deflection. Upon removal of the deflection member, the spring no longer returns to its original position, but remains partially open. Upon reinserting the mating member, the amount of spring pressure is less because the elastic deflection is less. Lower spring pressure can cause intermittent or no electrical contact between the spring and the mating member.

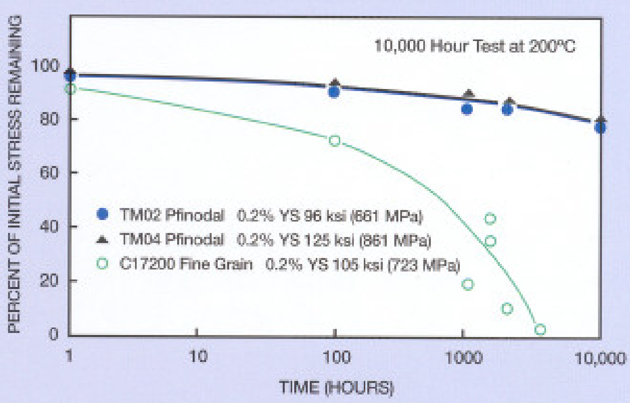


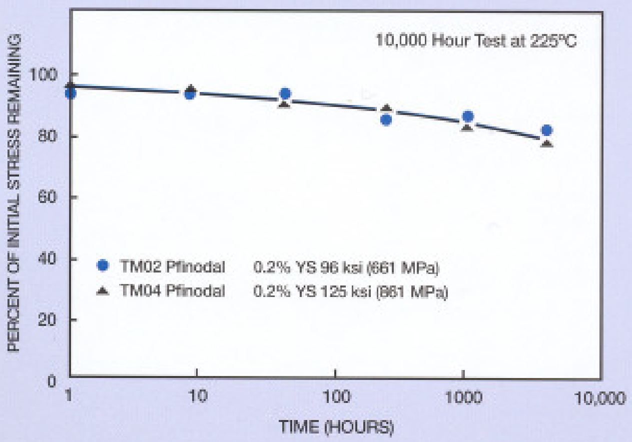
This is an illustration of the relaxation which can occur in a material without the stress relaxation of Pfinodal.

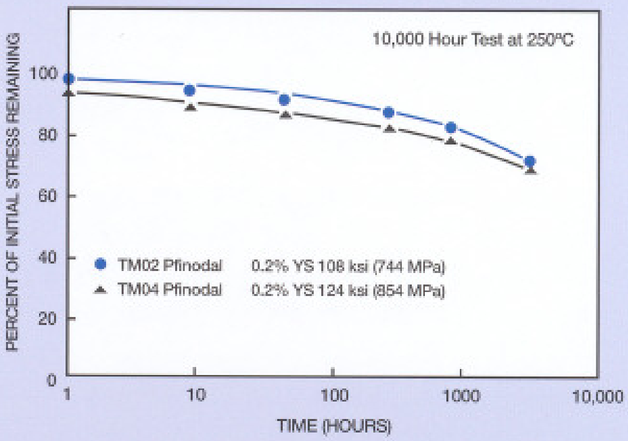
STRESS (THERMAL) RELAXATION

All Tests Run at Initial Stress of 80% of the 0.2% Offset Yield Strength









Equipment and Atmosphere

Aging of Pfinodal is best performed in recirculating ovens having excellent temperature uniformity. Vacuum or muffle type furnaces may be used, and as with all furnaces or ovens, furnace loading and temperature control should be taken into consideration to be certain that all parts attain the proper temperature.

Any common inert or reducing atmosphere can be used. To take advantage of the excellent surface characteristics of Pfinodal, a slightly reducing atmosphere such as nitrogen-3% hydrogen (forming gas) is preferred. This will generally result in post-heat treated parts exhibiting excellent solderability without the need for surface cleaning or acid pickling.

The use of salt pots is not recommended because of the need to post-clean all copper base alloys. If salt pots are used, thorough cleaning to remove all residual salts from parts is required.

Heat Treating Parameters for PFINODAL Parts

Recommended aging cycle ranges to achieve peak or near peak strength in Pfinodal are shown in table below:

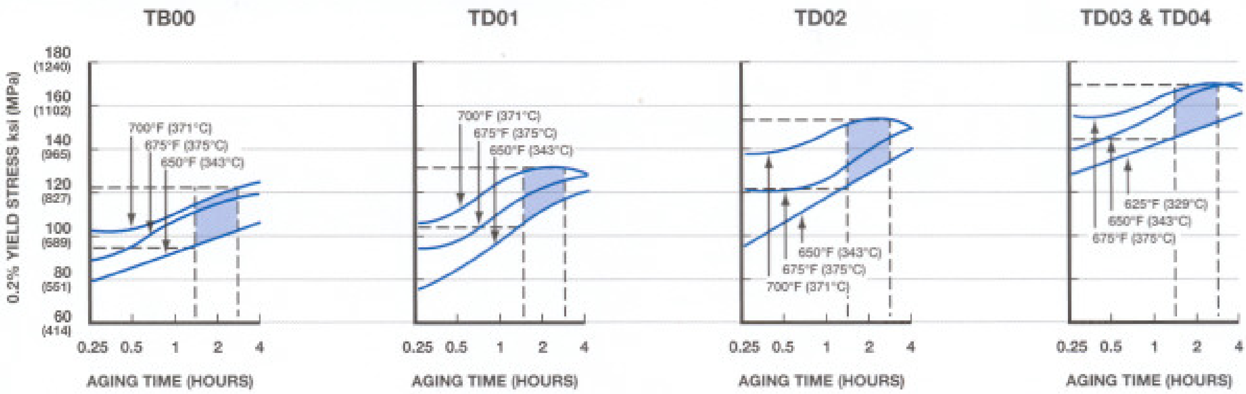
PFINODAL PEAK/NEAR PEAK AGING PARAMETERS

TEMPER	TEMPERATURE / TIME
TB00 TD01 TD02	675° - 700°F (357° - 371°C) / 2 hours
TD03 TD04	650° - 675°F (343° - 357°C) / 2 hours

Alternative time/temperature cycles may be used to suit individual requirements while maintaining good mechanical properties.

It is recommended that the furnace temperature be below 200°F (93°C) before removal of parts to avoid surface tarnish.

HEAT TREATING CURVES FOR PFINODAL PARTS



(SHADED AREA REFLECTS TYPICAL RANGE)

Special Consideration for Heat Treatment of PFINODAL Parts

To optimize the performance of Pfinodal in any particular application one may wish to consider using alternate heat treatments.

1. *In part geometries where the maximum stressed area has been heavily formed, a 25°F (14°C) lower aging temperature is recommended. This would result in peak strength in the critically stressed area.*
2. *In parts requiring some ductility after aging to accommodate a limited forming operation (bending, twisting, crimping, etc.), a 25°F (14°C) lower aging temperature is recommended. This heat treatment would result in a slight decrease in as-aged strength and more ductility.*
3. *In parts undergoing severe forming operations after aging (such as restamping or 90° solder tail twisting), an even lower aging temperature may be required [50°F (28°C) or more below the peak aging temperature].*
4. *Overaging is not recommended. Upon overaging, the loss in strength and ductility can be significant. For a given ductility requirement, underaging will result in higher strengths and ductility than overaging.*
5. *For specific recommendations for your part, please consult AMETEK. We can also provide assistance in obtaining sources for heat treating parts.*

Burn-In and Elevated Temperature Applications

Pfinodal C72900 Copper-Nickel-Tin Spinodal Alloy provide high reliability at an economical cost for applications at normal temperatures as well as for higher temperature usage. For burn-in and elevated temperature applications in the range from 125°C to 225°C, Pfinodal delivers superior resistance to stress relaxation for long life, in addition to excellent surface characteristics which simplify processing. Pfinodal exhibits good shelf life and good solderability and is easily plated or inlaid. For plating and soldering, milder cleaning solutions and less aggressive fluxes can be used. When soldering high temperature components, careful cleaning to remove flux residues is extremely important.

SOLDERING

All copper-base alloys can react at high temperatures with the tin in tin-containing solders to form intermetallic phases. In order to insure good, long-term solder joint properties at a high temperature, proper selection of a solder is required.

Good engineering practice suggests the use of a solder having a melting point of about 50°C above the operating temperature of the parts being soldered.

For Temperatures Above 150°C

At these very high temperatures, in order to minimize intermetallic phase formation that can occur with any copper alloy, it is necessary to use a high lead solder containing a maximum of 10% tin. Excellent field experience has been obtained with the 10% Sn-88%Pb-2%Ag solder. Laboratory data also shows excellent compatibility of this solder with Pfinodal at 225°C. The 10% Sn-90%Pb solder is not recommended for temperatures above 200°C.

For Temperatures Up to150°C

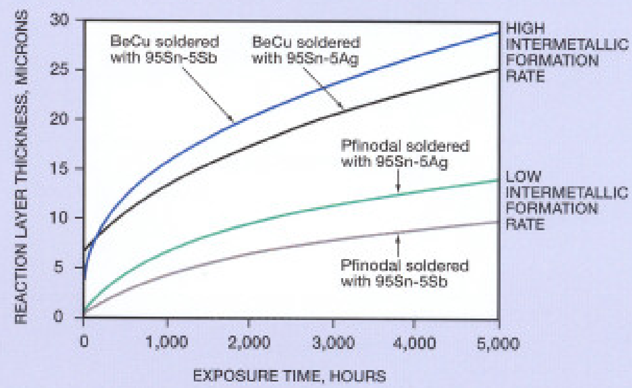
All tin-lead solders can be used in this temperature range.

APPLICATION OF COMMON SOLDERS

ASTM* Alloy Grade	Composition	Solidus °C	Solidus °F	Liquidus °C	Liquidus °F	Suggested Temperature Ranges of Use with Pfinodal: Up to 150°C	150°C 200°C	Above 200°C
	Tin/Lead							
Sn63	63Sn/37Pb	183	361	183	361	•		
Sn60	60Sn/40Pb	183	361	190	374	•		
Sn50	50Sn/50Pb	183	361	216	421	•		
Sn45	45Sn/55Pb	183	361	227	441	•		
Sn40A	40Sn/60Pb	183	361	238	460	•		
Sn30A	30Sn/70Pb	183	361	255	491	•		
Sn25A	25Sn/75Pb	183	361	266	511	•		
Sn15	15Sn/85Pb	225	437	290	554	•		
Sn10A	10Sn/90Pb	268	514	302	576	•	•	
Sn5	5Sn/95Pb	308	586	312	594	•	•	•
Sn2	2Sn/98Pb	316	601	322	611	•	•	•
	Silver Bearing							
Sn96	96.5Sn/3.5Ag	221	430	224	434	•		
—	95Sn/5Ag	221	430	241	465	•		
Sn10B	10Sn/88Pb/2Ag	268	514	299	570	•	•	•
Ag2.5	97.5Pb/2.5Ag	300	576	304	580	•	•	•
	Tin/Antimony							
—	100Sn	232	450	232	450	•		
Sb5	95Sn/5Sb	233	452	240	464	•		

Solidus: Temperature at which melting begins during heating, or freezing ends during cooling.
Liquidus: Temperature at which material is completely molten during heating, or freezing begins during cooling.
** From ASTM Standard B32-83. Others without ASTM Grade from ASM Metals Handbook, 9th Edition, Volume 6.*

Lower Intermetallic Formation Rate of Solders at 150°C with Pfinodal C72900 than with BeCu C17200



AMETEK Specialty Metal Products (SMP) is a pioneer in specialty metals with more than 50 years of experience and numerous patents in technically advanced metallurgical materials, and is a world leader in metal powder, strip, wire, and bonded products.

AMETEK SMP also produces stainless steel and nickel clad alloys, as well as stainless steel, cobalt, and nickel alloy powders. It is a leader in metal strip, specialty shaped and electronic wire, and advanced metal matrix composites used in thermal management applications.

AMETEK SMP is a unit of AMETEK, Inc. (NYSE: AME) a leading global manufacturer of electronic instruments and electric motors. It has over 10,000 colleagues working at more than 80 manufacturing facilities and more than 80 sales and service centers in the United States and around the world.

AMETEK®

SPECIALTY METAL PRODUCTS
21 Toelles Road, Wallingford, CT 06492 U.S.A.
Phone: +1 203-265-6731 • Fax: +1 203-949-8876
www.ametekmetals.com • wfd.sales@ametek.com

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