MATERION

Tech Brief

Copper Beryllium Alloys

Alloy Strip Temper Selection

Copper beryllium is a precipitation-hardenable copper alloy. This means that it derives most of its strength from heat treatment as opposed to the cold work that is exclusively relied upon by most other copper alloys. Copper beryllium alloys possess a great advantage by providing a combination of high strength, good conductivity and excellent formability.

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The heat treating step also provides copper beryllium and copper-nickel-tin alloys with excellent resistance to stress relaxation over standard cold worked copper alloys. The copper-nickel-tin alloys, strengthened by a special type of hardening called spinodal decomposition, feature very high strength, good formability and very good corrosion resistance. Heat treatment provides nickel beryllium strip with very high strength, good formability and exceptional stress relaxation resistance.

COPPER BERYLLIUM ALLOYS

There are two classes of copper-beryllium alloys. The high strength copper-beryllium alloys (Alloys 25, 190 and 290), which have the highest strength of any copper alloy, are widely used in electronic connectors, switches and springs. These high-strength alloys have electrical and thermal conductivities that are about 20% of pure copper. The high-conductivity copper-beryllium alloys (Alloys 3, 174, and Brush 60® and BrushForm® 47) have about 50% of copper's conductivity at a lower strength level and are used in power connectors and relays. Alloys 390® and 390E strip feature both high strength and high conductivity.

Copper beryllium is strengthened primarily by heat treatment. It is available in two forms – age hardenable and mill hardened. In the age hardenable form, the material is soft and ductile. It will form easily. It must then be heat treated to full strength and conductivity after the forming operations are complete. In the mill hardened form, the material is age hardened at the mill, so no further heat treatment is required. (In other words, it is purchased in the partially age hardened state.) However, the formability at a given strength level will not be as good as that of the heat treatable material.

AGE HARDENABLE COPPER BERYLLIUM TEMPERS

Alloy 25 is the age hardenable, high-strength copper-beryllium alloy. Once it is heat treated, it will have a strength unsurpassed by any other copper alloy. Alloy 25 is available as solution annealed (the softest, most formable state) and cold rolled to various strength levels (¼ H, ½ H and H). The ¼, ½ and full hard designations refer to cold work only and have nothing to do with heat treatment. After aging for the proper time and temperature, the solution annealed (A) temper becomes AT. Similarly, the ¼ H becomes ¼ HT, the ½ H becomes ½ HT and the H becomes HT. These are the only outcomes of proper age hardening. It is not possible, for example, to heat treat ¼ H material to the ½ HT or HT conditions.

Figure 1: Effects of Cold Work and Precipitation Hardening

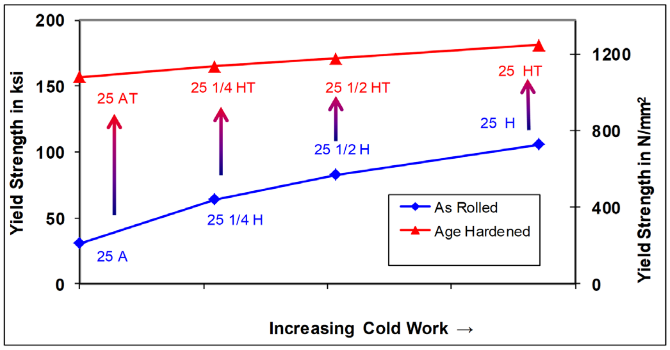

Figure 1 shows the effects of cold work and standard precipitation hardening on Alloy 25. While cold work does increase the strength of the base metal, it reaches a point of diminishing returns. Large amounts of cold work can increase anisotropy (directionality of properties) in strip materials and decrease

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formability capability. Note also that precipitation hardening can double or triple the strength of the as rolled material.

Alloy 25 is not available in strip form in the age hardened (pre-heat treated) condition. This means that it is not possible to purchase Alloy 25 strip in the AT, ¼ HT, ½ HT or HT forms. It can only be purchased in the A, ¼ H, ½ H or H forms and then heat treated accordingly after forming. Once it is heat treated, no additional forming is possible, since it will be at maximum strength and minimum ductility (i.e., it will be too "brittle" to form). Please see Table 1 for reference. (Additional temper information is available in ASTM B601.) If you need the high strength of Alloy 25 and do not want to heat treat, you should instead look at the mill hardened Alloys 190 or 290.

Additional information on age hardening practices including the proper temperatures, times and atmospheres can be found in our Tech Briefs "Heat Treating Copper Beryllium" and "Heat Treating Distortion of Alloy 25 Copper Beryllium". Non-standard heat treatments such as underaging or overaging to improve conductivity or ductility are also possible, as described in the first tech brief.

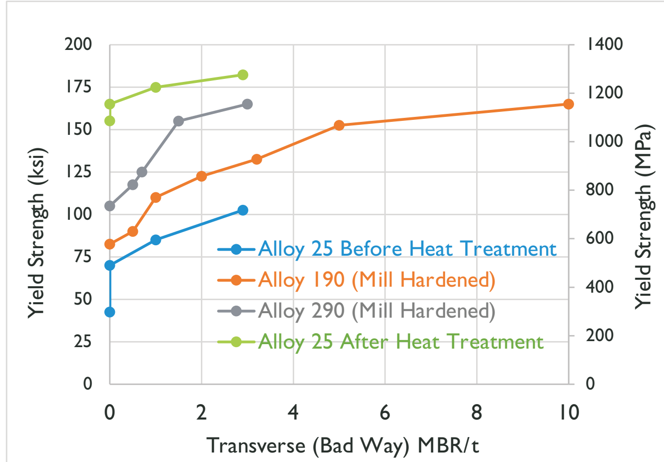
MILL HARDENED COPPER BERYLLIUM TEMPERS

If the high strength of Alloy 25 is desired, but heat treating is an obstacle, then mill hardened material should be purchased. The mill hardened versions of Alloy 25 are called Alloy 190 and Alloy 290. All three alloys have the same composition (UNS C17200, CuBe2), but are processed very differently and have different properties. Alloys 190 and 290 are partially aged to less than peak strength and hardness before leaving the mill.

The strength to formability ratios of Alloys 190 and 290 will not be as good as that found in Alloy 25. The lowest strength tempers of 190 and 290 will have very good formability. At increasing levels of strength, however, the formability becomes progressively more limited. Alloy 190 XHMS is the strongest mill hardened temper, with a strength nearly equal to Alloy 25 HT. However, its limited formability restricts its use to flat or nearly flat parts. Please see the Tech Brief "Formability of Strip Alloys" for more information.

Alloy 290 provides superior formability to Alloy 190 at the same strength level. However, Alloy 190 provides inherently better flatness than Alloy 290. Alloy 190 is thus more appropriate for parts that require tight flatness tolerances, or for parts made by photochemical machining.

Figure 2: Formability-Strength Trade-offs in C17200 (CuBe2) High-Strength Copper Beryllium Strip Alloys 25, 190 and 290



HIGH CONDUCTIVITY COPPER BERYLLIUM TEMPERS

The high conductivity copper beryllium Alloys 3, 174, Brush 60 Alloy, 390 Alloy and 390E are available in mill hardened form only. No heat treatment needs to be performed on these alloys. However, the temper designations of these alloys is different from the high-strength Alloy 25. In Alloy 25, age hardenable tempers end in A or H (solution annealed or cold worked) or in AT or HT (heat treated). The mill hardened Alloy 190 tempers end in AM or HM and the Alloy 290 tempers follow the modern ASTM convention of beginning with TM.

However, the high conductivity alloys follow a different convention, and all end in HT, not HM. The original high conductivity alloys were available in both age hardenable and mill hardened tempers. Since there was no property difference between HM and HT tempers, the HT designation was used for both in the ASTM specifications. This convention remains, even though the age hardenable versions of these alloys are rarely used.

COPPER NICKEL TIN ALLOY TEMPERS

BrushForm® 158 and BrushForm® 96 alloy strip are available in both heat treatable and mill hardened tempers. The temper designations (also specified in ASTM B601) are identical to Alloy 25 and 190 copper beryllium with the addition of some higher strength tempers.

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SELECTING THE PROPER ALLOY

The first step in selecting the proper copper beryllium material is to decide on the high strength or the high conductivity family. If high strength is required, select Alloy 25 only if heat treatment after forming is a viable option. If it is not an option, or if the parts are very thin and thus susceptible to age hardening distortion, then Alloy 190 or 290 would be the proper choice. If current carrying capacity is an issue, then Alloy 3, 174, Brush 60, 390 or 390E would be the appropriate choice.

QMet® 200 strip has strength and conductivity similar to Alloys 3 and 174, but does not contain beryllium. QMet 300 strip has higher conductivity (around 80% IACS) with slightly lower strength. Both QMet alloys possess very good formability.

BrushForm® 158 alloy would be used in applications requiring high strength if it is desired to use a non-beryllium-containing material. Due to its relatively low conductivity (7% IACS), it is rarely used where conductivity is required, and is most often used for high strength spring applications. BrushForm 96 Alloy will provide higher conductivity (about 10% IACS), but with lower strength than BrushForm 158 Alloy.

Due to its corrosion resistance, high strength and resilience, and high temperature capability (up to 350°C), Alloy 360 nickel beryllium is used for Belleville spring washers in fire protection sprinkler systems and for connectors in high temperature or otherwise harsh environments.

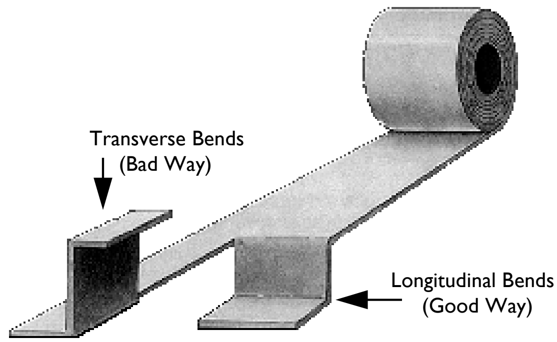
SIZE LIMITATIONS

Please note that there are different thickness limitations for various alloys and tempers. For example, very soft alloys and tempers are typically not available in foil gauges, as they would typically not be able to support their own weight during processing. Very high strength tempers will need extra amounts of cold work, so these will typically not be available in thicker sizes. Please consult with your sales engineer to determine availability.

SELECTING THE PROPER TEMPER

Once the alloy is selected, the next step would be to select the temper. First, you will need to examine all the bends that will need to be formed in your part. Determine the tightest (smallest bend radius) bend in both the good way (longitudinal) and bad way (transverse), direction, as defined in Figure 3. Divide these 2 values by the material thickness to determine the minimum bend radius to thickness (MBR/t) ratio in each direction. When selecting a material, make sure that the MBR/t ratio for the material chosen is smaller than the tightest values for your design.

Figure 3: Good Way and Bad Way Bends



As a general rule, connectors are usually laid out with spring beams oriented in the transverse direction, so bad way formability is usually more important than good way formability. For more information, see Tech Brief "Formability of Materion Performance Alloy Strip Products".

Once you know your formability requirements, determine the maximum stress in the part using finite element or other modelling and then select a material with a yield strength that exceeds this value with an appropriate safety factor, subject to the formability requirements listed above. (If the part is subjected to cyclic loading, then the fatigue strength at the desired number of cycles should be used instead of the yield strength.) If the stress level is unknown, then simply choose the highest strength temper that meets the formability requirements of the design.

Figures 4 through 9 show the strength vs formability of all Materion's high-performance copper strip alloys. The tables below list the yield strength, fatigue strength, conductivity and formability of each of these materials as well. The meaning of each temper also is listed in the table. Please note that the temper designations for the age hardenable material are precisely defined. However, the temper designations for mill hardened material are not. This allows for proprietary processing.

SAFE HANDLING OF COPPER BERYLLIUM

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-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 occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact the Customer Technical Service Department at +1.800.375.4205.

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DISCLAIMER

Only the buyer can determine the appropriateness of any suggested processing practice, end-product or application. Materion is not able to make any warranty regarding its recommendations, the suitability of Materion's product, or its processing suggestions for buyer's end product, application or equipment.

Figure 4: High-Strength, Heat-Treatable Strip – Good Way Formability

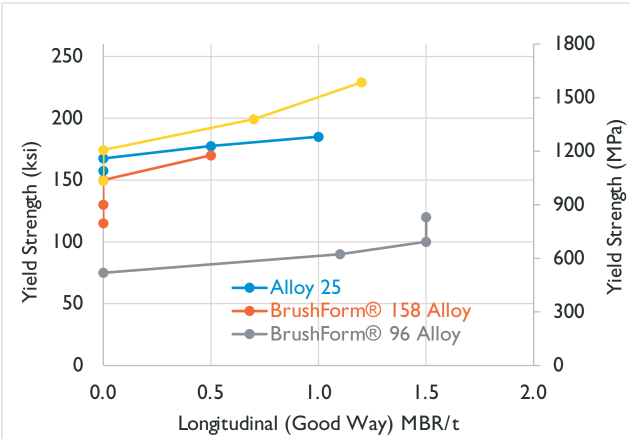

Figure 5: High-Strength, Heat-Treatable Strip – Bad Way Formability

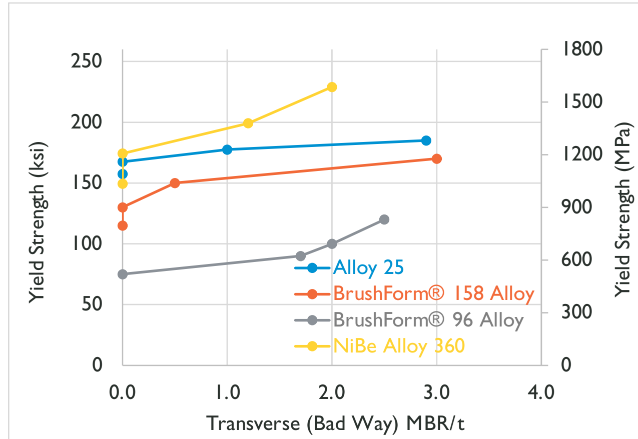

Figure 6: High-Strength, Mill Hardened Strip – Good Way Formability

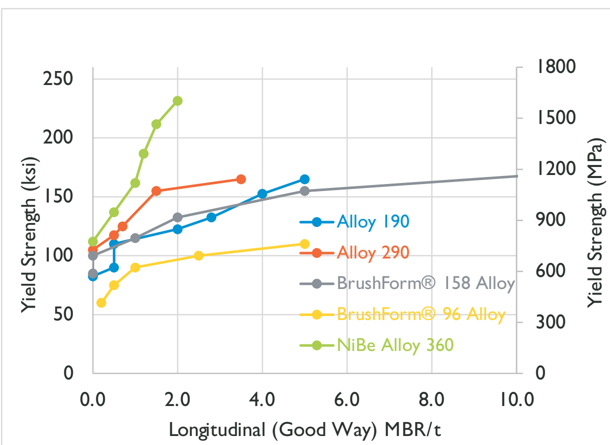

Figure 7: High-Strength, Mill Hardened Strip – Bad Way Formability

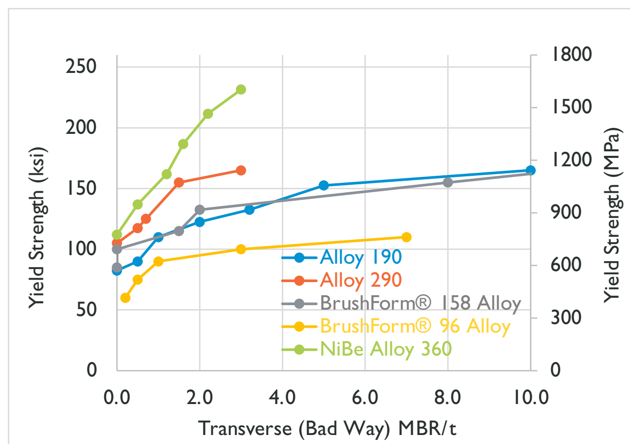

Figure 8: High-Conductivity Strip – Good Way Formability

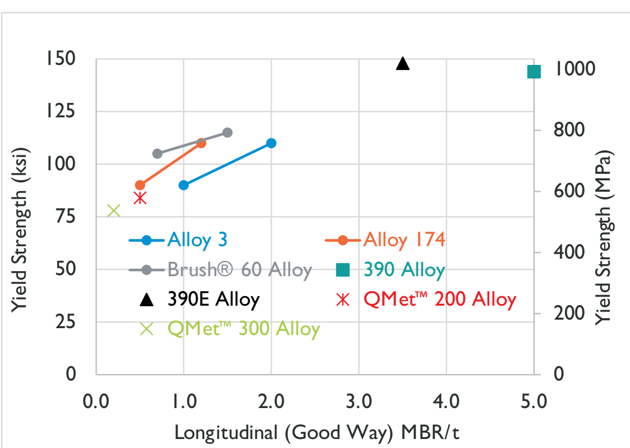

Figure 9: High-Conductivity Strip – Bad Way Formability

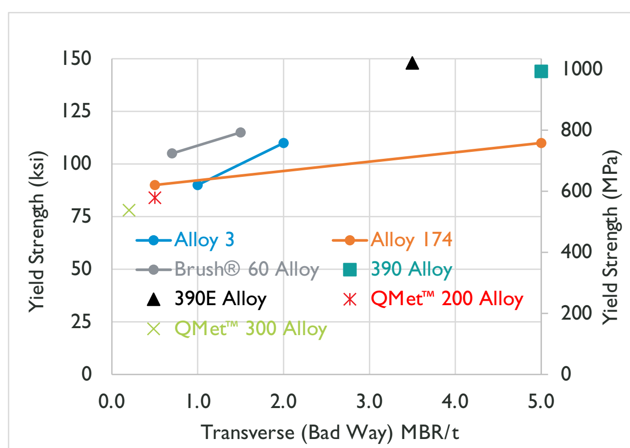

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Table 1: Copper Beryllium Strip Alloy Properties and Temper Designations

Alloy	Temper	Meaning of Temper	ASTM Temper	Condition	0.2% Offset Yield Strength Range ($Rp_{0,2}$)		90° V-Block Bend Formability		Electrical Conductivity
					(ksi)	(MPa)	Long.	Trans.	(% IACS)
25 (C17200, CuBe2)	A	Solution Annealed	TB00	Before Heat Treament (as Received)	30 - 55	200 - 380	0.0	0.0	15 - 19
	1/4 H	"A" Cold Worked to 1/4 H	TD01		60 - 80	410 - 560	0.0	0.0	15 - 19
	1/2 H	"A" Cold Worked to 1/2 H	TD02		75 - 95	510 - 660	0.5	1.0	15 - 19
	H	"A" Cold Worked to H	TD04		90 - 115	620 - 800	1.0	2.9	15 - 19
	AT	"A" After Heat Treatment	TF00	3 hr @ 600°F / 315°C	140 - 175	960 - 1210	-	-	22 - 28
	1/4 HT	"1/4 H" After Heat Treatment	TH01	2 hr @ 600°F / 315°C	150 - 185	1030 - 1280	-	-	22 - 28
	1/2 HT	"1/2 H" After Heat Treatment	TH02	2 hr @ 600°F / 315°C	160 - 195	1100 - 1350	-	-	22 - 28
	HT	"H" After Heat Treatment	TH04	2 hr @ 600°F / 315°C	165 - 205	1130 - 1420	-	-	22 - 28
190 (C17200, CuBe2)	AM	Annealed (Mill Hardened)	TM00	Mill Hardened	70 - 95	380 - 660	0.0	0.0	17 - 28
	1/4 HM	1/4 Hard (Mill Hardened)	TM01		80 - 110	550 - 760	0.5	0.5	17 - 28
	1/2 HM	1/2 Hard (Mill Hardened)	TM02		95 - 125	650 - 870	0.5	1.0	17 - 28
	HM	Hard (Mill Hardened)	TM04		110 - 135	750 - 940	2.0	2.0	17 - 28
	SHM	Spring (Mill Hardened)	TM05		125 - 140	860 - 970	2.8	3.2	17 - 28
	XHM	Extra Hard (Mill Hardened)	TM06		135 - 170	930 - 1180	4.0	5.0	17 - 28
	XHMS	Extra Spring Hard (Mill Hardened)	TM08		150 - 180	1030 - 1250	5.0	10.0	17 - 28
290 (C17200, CuBe2)	TM02	1/2 Hard (Mill Hardened)	TM00	Mill Hardened	95 - 115	650 - 800	0.0	0.0	17 - 26
	TM03	3/4 Hard (Mill Hardened)	TM03		110 - 125	760 - 860	0.5	0.5	17 - 26
	TM04	Hard (Mill Hardened)	TM04		115 - 135	790 - 940	0.7	0.7	17 - 26
	TM06	Extra Hard (Mill Hardened)	TM06		135 - 155	930 - 1070	1.5	1.5	17 - 26
	TM08	Extra Spring Hard (Mill Hardened)	TM08		155 - 175	1060 - 1210	3.5	3.0	17 - 26
3 (C17510, CuNi2BE)	AT	Annealed (Mill Hardened)	TF00	Mill Hardened	80 - 100	550 - 690	1.0	1.0	45 - 60
	HT	Hard (Mill Hardened)	TH04		100 - 120	650 - 830	2.0	2.0	48 - 60
174 (C17410, CuCo0, 5Be0,3)	1/2 HT	1/2 Hard (Mill Hardened)	TH02	Mill Hardened	80 - 100	550 - 685	0.5	0.5	50 min.
	HT	Hard (Mill Hardened)	TH04		100 - 120	685 - 870	1.2	5.0	45 - 60
Brush 60® (C17460) Strip	3/4 HT	3/4 Hard (Mill Hardened)	TH03	Mill Hardened	95 - 115	655 - 795	0.7	0.7	50 min.
	HT	Hard (Mill Hardened)	TH04		105 - 125	720 - 860	1.5	1.5	50 min.
390 (C17460)	HT	Hard (Mill Hardened)	TH04	Mill Hardened	135 - 153	930 - 1055	2.0[1] 5.0[2]	2.0[1] 5.0[2]	44 min.
390E (C17500)	EHT	Extra Hard (Mill Hardened)	TH04	Mill Hardened	138 min.	951 min.	0.5[3] 2.0[4] 2.5[5] 3.5[6]	0.5[3] 2.0[4] 2.5[5] 3.5[6]	42 min.

Notes: (1) For strip 0.004" and thinner
(2) For strip greater than 0.004" thick.
(3) For strip 0.002" and thinner
(4) For strip thicker than 0.002" up to 0.004"
(5) For strip thicker than 0.004" up to 0.006"
(6) For strip thicker than 0.006" up to 0.008"

continued

Table 2: Other Strip Alloy Properties and Temper Designations

Alloy	Temper	Meaning of Temper	ASTM Temper	Condition	0.2% Offset Yield Strength Range ($Rp_{0.2}$)		90° V-Block Bend Formability		Electrical Conductivity
					(ksi)	(MPa)	Long.	Trans.	(% IACS)
Brush-Form® 158 (C72900, CuNi15Sn8) Copper Nickel Tin Strip	A	Solution Annealed	TB00	Before Heat Treament (as Received)	25 - 45	170 - 310	0.0	0.0	7
	1/4 H	"A" Cold Worked to 1/4 H	TD01		52 - 75	360 - 520	0.0	0.0	7
	1/2 H	"A" Cold Worked to 1/2 H	TD02		75 - 100	520 - 690	0.0	0.5	7
	H	"A" Cold Worked to H	TD04		95 - 125	660 - 860	0.5	3.0	7
	AT	"A" After Heat Treatment	TF00	3 hr @ 700°F / 375°C	100 - 130	690 - 900	-	-	7
	1/4 HT	"1/4 H" After Heat Treatment	TS01		115 - 145	790 - 1000	-	-	7
	1/2 HT	"1/2 H" After Heat Treatment	TS02		135 - 165	930 - 1140	-	-	7
	HT	"H" After Heat Treatment	TS04		155 - 185	1070 - 1280	-	-	7
	TM00	Annealed (Mill Hardened)	TM00	Mill Hardened	75 - 95	515 - 655	0.0	0.0	7
	TM02	1/2 Hard (Mill Hardened)	TM02		90 - 110	620 - 760	0.0	0.0	7
	TM04	Hard (Mill Hardened)	TM04		105 - 125	720 - 860	1.0	1.5	7
	TM06	Spring (Mill Hardened)	TM06		120 - 145	830 - 1000	2.0	2.0	7
	TM08	Extra Spring Hard (Mill Hardened)	TM08		140 - 170	970 - 1170	5.0	8.0	7
	TM10	Extra Spring Hard (Mill Hardened)	TM10		165 - 195	1140 - 1345	-	-	7
	TM16	Mill Hardened by Special Processes to Extremely High Strength	-		198 - 212	1365 - 1462	-	-	7
	TM18		-		199 typ.	1375 typ.	-	-	7
	TM19		-		199 typ.	1375 typ.	-	-	7
Brush-Form® 96 (C72700, CuNi9Sn6) Copper Nickel Tin Strip	A	Solution Annealed	TB00	Before Heat Treament (as Received)	37 typ.	255 typ.	0.0	0.0	7
	1/4 H	"A" Cold Worked to 1/4 H	TD01		53 typ.	365 typ.	1.1	1.7	7
	1/2 H	"A" Cold Worked to 1/2 H	TD02		67 typ.	462 typ.	1.5	2.0	7
	H	"A" Cold Worked to H	TD04		88 typ.	607 typ.	1.5	2.5	7
	AT	"A" After Heat Treatment	TF00	2 hr @ 700°F / 375°C	75 typ.	517 typ.	-	-	10
	1/4 HT	"1/4 H" After Heat Treatment	TS01		90 typ.	621 typ.	-	-	10
	1/2 HT	"1/2 H" After Heat Treatment	TS02		100 typ.	689 typ.	-	-	10
	HT	"H" After Heat Treatment	TS04		120 typ.	827 typ.	-	-	10
	TM00	Annealed (Mill Hardened)	TM00	Mill Hardened	60 typ.	414 typ.	0.2	0.2	10
	TM02	1/2 Hard (Mill Hardened)	TM02		75 typ.	517 typ.	0.5	0.5	10
	TM04	Hard (Mill Hardened)	TM04		90 typ.	621 typ.	1.0	1.0	10
	TM06	Extra Hard (Mill Hardened)	TM06		100 typ.	689 typ.	2.5	3.0	10
	TM08	Extra Spring Hard (Mill Hardened)	TM08		110 typ.	758 typ.	5.0	7.0	10

continued

Table 2: Other Strip Alloy Properties and Temper Designations - Continued

Alloy	Temper	Meaning of Temper	ASTM Temper	Condition	0.2% Offset Yield Strength Range ($Rp_{0.2}$)		90° V-Block Bend Formability		Electrical Conductivity
					(ksi)	(MPa)	Long.	Trans.	(% IACS)
Alloy 360 (N03360, NiBe2) Nickel Beryllium Strip	A	Solution Annealed	-	Before Heat Treament (as Received)	40 - 70	280 - 480	0.0	0.0	4
	1/4 H	"A" Cold Worked to 1/4 H	-		65 - 125	450 - 860	0.0	0.0	4
	1/2 H	"A" Cold Worked to 1/2 H	-		115 - 170	790 - 1170	0.7	1.2	4
	H	"A" Cold Worked to H	-		150 - 190	1030 - 1310	1.2	2.0	4
	AT	"A" After Heat Treatment	-	2.5 hr @ 925°F / 510°C	150 min.	1030 min.	-	-	6
	1/4 HT	"1/4 H" After Heat Treatment	-		175 min.	1210 min.	-	-	6
	1/2 HT	"1/2 H" After Heat Treatment	-	1.5 hr @ 925°F / 510°C	200 min.	1380 min.	-	-	6
	HT	"H" After Heat Treatment	-		230 min.	1590 min.	-	-	6
	MH2	Varying and proprietary amounts of cold work and mill hardening heat treatment to achieve varying degrees of strength and formability	-	Mill Hardened	100 - 125	690 - 860	0.0	0.0	5
	MH4		-		120 - 155	830 - 1070	0.5	0.5	5
	MH6		-		150 - 175	1030 - 1210	1.0	1.2	5
	MH8		-		170 - 205	1170 - 1410	1.2	1.6	5
	MH10		-		200 - 225	1380 - 1550	1.5	2.2	5
	MH12		-		220 - 245	1520 - 1690	2.0	3.0	5
QMet 200 Strip	HT	Cold Worked and Age Hardened	-	Mill Hardened	80 min.	550 min.	0.5 max	0.5 max	48 min.
QMet 300 Strip	HT	Cold Worked and Age Hardened	-	Mill Hardened	72.5 min.	500 min.	0.2	0.2	78 min.