Wired for your Success

Technical Data Book

MWS Wire Industries

World's Largest Selection of Specialty and Magnet Wire

mwswire.com

Company Profile

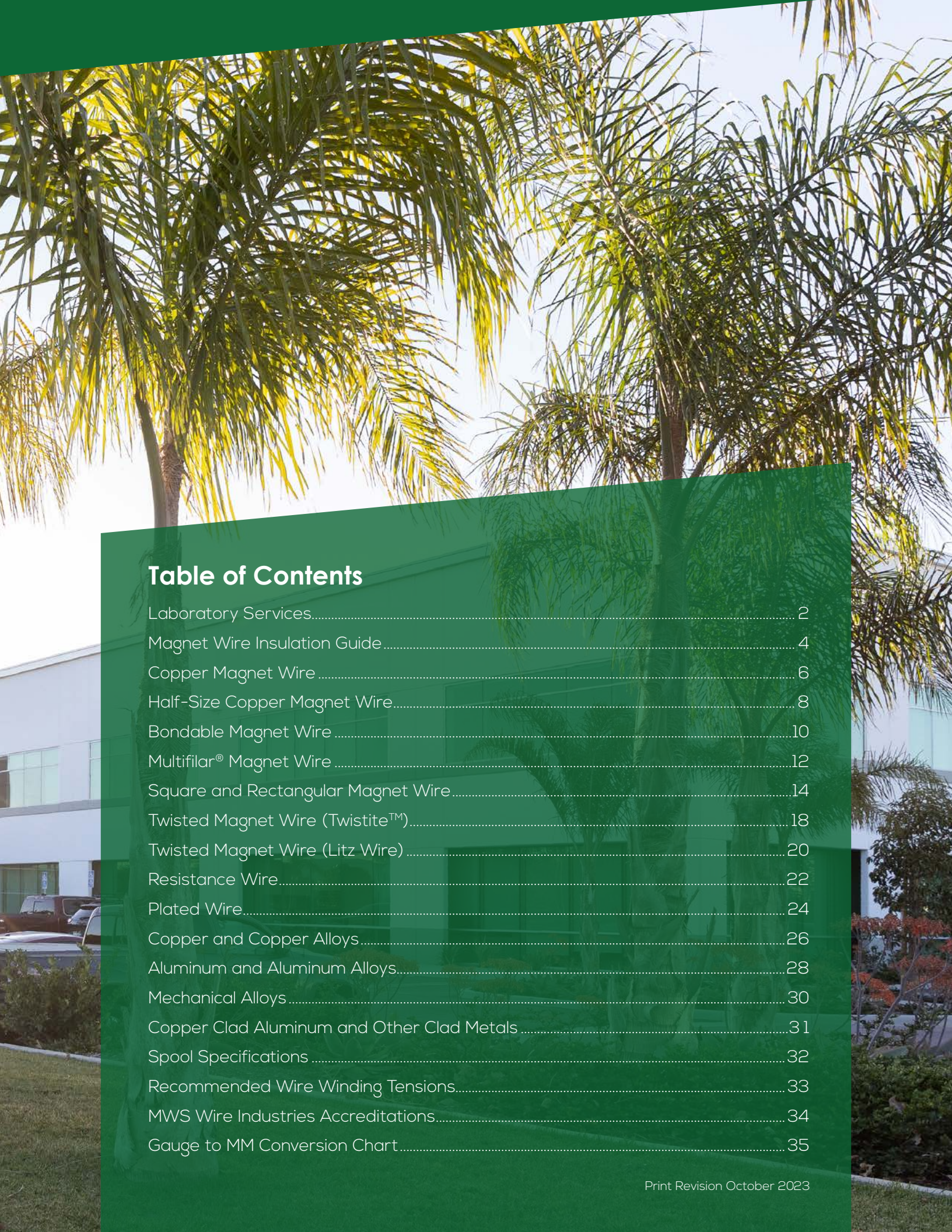
Responsive Solutions

Since 1968 MWS Wire Industries has operated under the simple premise that total customer satisfaction is the key to our long-term success and growth. Our primary objective is to exceed our customers' expectations of product quality and service.

Whether it's same-day delivery from our inventory of 50,000 unique wire items or producing a wire to meet a customer's just-in-time production schedule, our highly trained staff of wire professionals is committed to meeting the needs of wire users worldwide on time, every time.

From new product development – where we build special wires to improve the overall performance of electronic components – to R&D production of wire for new and innovative applications, MWS has the resources to give you a competitive edge.

MWS Wire Industries, located in Oxnard, California since 2020, keeps in inventory the largest variety of magnet wire and specialty wire made to commercial, military, and customer specifications. This facility houses drawing, shaping, rolling, twisting, and film coating equipment for production of wire for high technology users worldwide.



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Laboratory Services

Consistent and impeccable product quality is an essential requirement for our wire users. MWS maintains one of the most comprehensive wire testing facilities in the wire industry, capable of testing per NEMA MW 1000 for insulated copper and aluminum magnet wire, as well as to unique customer specifications. MWS is a qualified UL producer to OBWM2, Magnet wire component.

Testing capabilities include:

Dimensional Analysis
Contact and non-contact laser micrometer analysis, and cross-section optical measurements for concentricity and corner radius measurements.

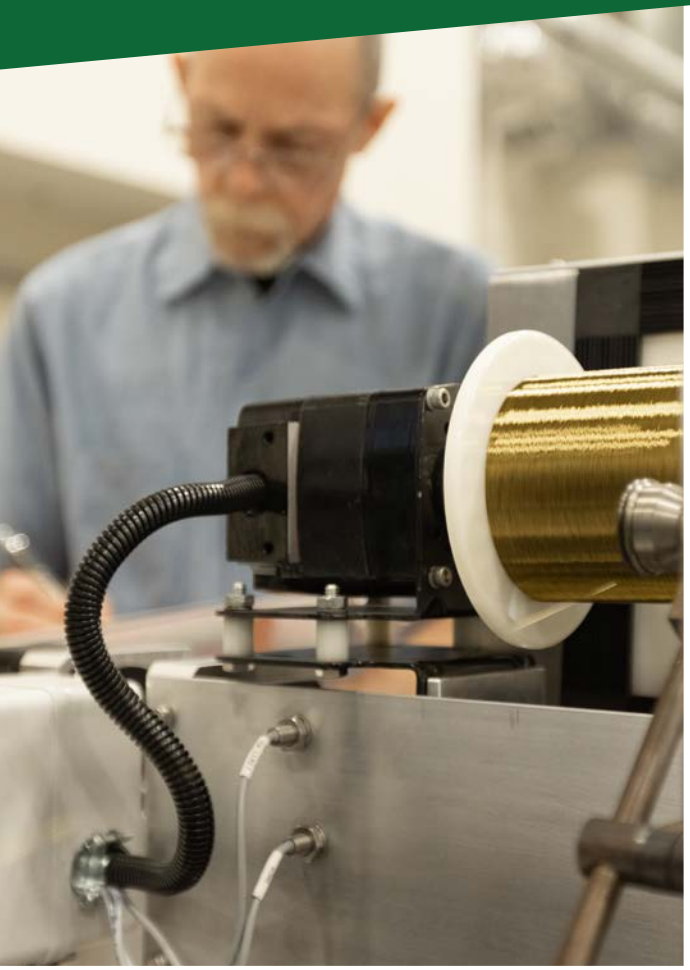
Mechanical Properties
Stress/strain analysis; tensile, yield, break strength values.

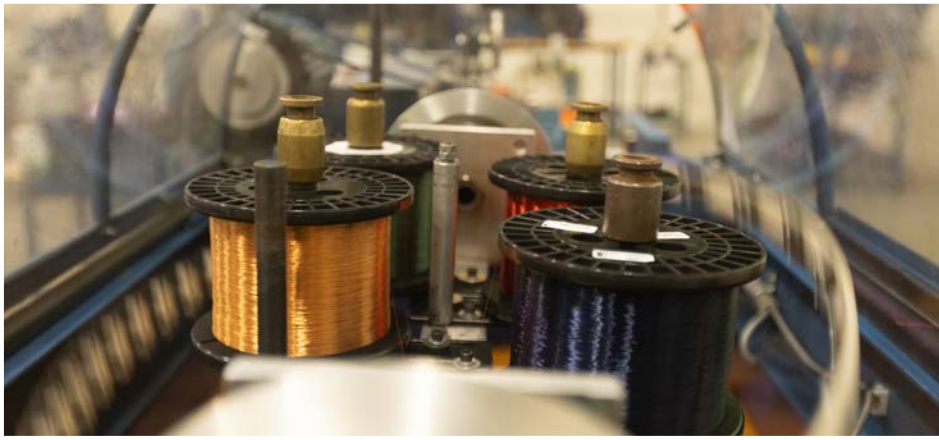
Electrical Properties
DC resistance, dielectric strength, capacitance, impedance, continuity of insulation, completeness of insulation cure, and TCR measurements.

Thermal Properties
Thermoplastic flow, heat shock, insulation adherence, thermal endurance, and solderability of insulations per NEMA MW 1000.

Material Analysis
Base metal chemical analysis accurate to 1ppm. Insulated material analysis performed using infrared spectroanalysis.

Special Testing
To customer specification, custom-built test equipment for unique applications.





Manufacturing

MWS produces custom round, square, rectangular, ribbon, Multifilar®, Twistite™ and Microsquare™ wires in a state of the art manufacturing facility. Products offered include film insulated wire conforming to NEMA MW 1000 and IEC 60317 in temperature classes 105 to 240°C, from single through quadruple insulation builds. Low minimums, quick deliveries and superior quality are our standards.

Magnet Wire Insulation Guide

THERMAL CLASS	INSULATION TYPE	MWS PRODUCT CODE	NEMA STANDARD (MW1000)	IEC STANDARD (60317)	FEDERAL SPECIFICATION
105°C	Plain Enamel	PE	**NONE**	NONE	NONE
	Formvar	F	**MW 15 (RD)** **MW 18 (SQ & RECT)**	60317-1 (RD) 60317-17 (SQ & RECT)	JW 1177/14 (RD) JW1177/16 (SQ & RECT)
155°C	Polyurethane - 155	P155	**MW79**	60317-20	JW 1177/ 41
	Polyurethane Nylon - 155	PN155	**MW80**	60317-21	JW 1177/ 42
	Polyurethane Bondable - 155	PB155	**MW131**	60317-35	NONE
	Polyurethane Nylon Bondable - 155	PNB155	**MW136**	NONE	NONE
180°C	Polyurethane - 180	P180	**MW82**	60317-51	NONE
	Polyurethane Nylon - 180	PN180	**MW83**	60317-55	NONE
	Polyester-imide	PT	**MW30**	60317-8	JR 1177/ 12
	Polyester-Nylon	PTN	**MW76**	60317-22	JW 1177/ 38
	Solderable Polyester	SPT	**MW77**	60317-23	JW 1177/ 39
	Solderable Polyester Nylon	SPTN	**MW78**	NONE	JW 1177/ 40
	Polyurethane Bondable - 180	PB180	**MW 132**	NONE	NONE
	Polyurethane Nylon Bondable - 180	PNB180	**MW137**	NONE	NONE
	Polyester-imide Bondable	PTB	**NONE**	60317-37	NONE
	Polyester-amide-imide Bondable	APTB	**MW102**	60317-38	NONE
	Solderable Polyester Bondable	SPTB	**NONE**	60317-36	NONE
200°C	Polyester - 200	PT200	**MW74**	60317-42	JW 1177/43
	Polyester A/I Topcoat	APT	**MW 35 (RD)** **MW 36 (SQ & RECT)**	60317-13 (RD) 60317-29 (SQ & RECT)	JW 1177/ 14 (RD) JW1177/ 13 (SQ & RECT)
	Polyester A/I Polyamideimide	APTIG	**MW73**	60317-13	NONE
240°C	Polyimide - ML*	ML	**MW 16 (RD)** **MW 20 (SQ & RECT)**	60317-46 (RD) 60317-47 (SQ & RECT)	JW 1177/ 15 (RD) JW1177/ 18 (SQ & RECT)

*Registered trademark of Industrial Summit Technology

INSULATION CHARACTERISTICS	GENERAL APPLICATIONS
Plain Enamel was one of the earliest film insulations developed for automotive ignition coils. Today it is primarily used in musical instruments for pickup coils. It is manufactured to single build dimensions and stocked in sizes 41 to 44 AWG.	Pickup coils for guitars and other instruments
Formvar was an early synthetic insulation composed of modified polyvinyl resins designed for continuous operation at 105C. It has excellent abrasion resistance and is compatible with most varnishes and impregnating compounds.	Oil filled transformers, motors, solenoids, superconducting coils or other cryogenic applications
Solderable film composed of modified polyurethane resins designed for fine wire applications with excellent resistance to moisture and most solvents.	Relays, high frequency coils and transformers, solenoids, small motors
Solderable dual film composed of modified polyurethane resins with a polyamide (nylon) overcoat that provides improved lubricity for ease of winding.	Appliance motors, relays, torroidal coils, fractional HP motors
Solderable polyurethane or polyurethane with nylon overcoat and a superimposed thermoplastic butyral film for coils requiring Class F service. Coils may be bonded by heat or with isopropyl alcohol. Generally made as Type 1 insulation build equal to heavy overall diameter.	Voice coils, helical coils, inductors, self-supporting coils
Polyurethane film designed for applications requiring high thermal resistance and low soldering temperature.	Relays, ignition coils, solenoids, small transformers
Polyurethane with polyamide (nylon) overcoat for applications requiring high thermal properties and chemical resistance. Soldering temperature is 390°C.	Relays, pulse transformers, small appliance motors
Film insulation composed of modified polyester resins with excellent chemical resistance.	Solenoids, servo motors, small appliance motors
Dual film composed of modified polyester resins with a nylon overcoat. Combines continuous 180°C operating temperature and low coefficient of friction for superior winding and insertion properties.	Motor stators, fractional HP motors
Film insulation composed of modified polyesterimide resins designed to solder at 470°C, generally made at 24 AWG and finer sizes.	High temperature relays, transformers, automotive coils
Dual film composed of modified polyesterimide resins with nylon overcoat for superior performance where winding stresses may be severe. Designed to solder at 470°C, this insulation is made mostly in heavier gauge sizes.	Transformers, automotive coils, appliance motors
Dual (Polyurethane Nylon) insulation system with superimposed thermoplastic film combining high thermal resistance, solderability, and self-bonding features.	Self-supporting coils, relays, voice coils
These are wires that combine characteristics of various class 180°C film insulations with self-bonding feature. Bonding method depends on choice of bond coat. May be made as Type 1 (heavy diameter) or Type 2 (triple diameter) construction.	Voice coils, inductors, yoke coils, small motors
A dual coat system composed of THEIC modified polyester, combined with a corona resistant shield coat of polyamideimide (A/I) overcoat designed to withstand severe voltage stresses.	Inverter duty motors, high voltage motors
Film composed of aromatic polyimide resin that features high cut through, exceptional chemical resistance, minimal outgassing and capable of continuous operation at 240°C in extremely harsh environments.	High temperature continuous duty coils, hermetically sealed relays, fractional and integral HP motors

Copper Magnet Wire Data

SIZE (AWG)	BARE COPPER								
	DIAMETER (INCHES)			RESISTANCE** (OHMS PER 1000 FT. AT 20°C)			FEET PER POUND	POUNDS PER 1,000 FT.	CIRCULAR MILS NOMINAL
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.			
6	.1604	.1620	.1633	.3875	.3952	.4031	12.59	79.44	26,240
7	.1429	.1443	.1454	.4885	.4981	.5079	15.87	63.03	20,820
8	.1272	.1285	.1294	.6156	.6281	.6410	20.01	49.98	16,510
9	.1133	.1144	.1153	.7774	.7924	.8079	25.24	39.62	13,090
10	.1009	.1019	.1027	.9795	.9988	1.019	31.82	31.43	10,380
11	.0898	.0907	.0916	1.236	1.261	1.286	40.2	24.9	8,226
12	.0800	.0808	.0816	1.558	1.589	1.620	50.6	19.8	6,529
13	.0713	.0720	.0727	1.962	2.001	2.040	63.7	15.7	5,184
14	.0635	.0641	.0647	2.477	2.524	2.572	80.4	12.4	4,109
15	.0565	.0571	.0577	3.115	3.181	3.249	101	9.87	3,260
16	.0503	.0508	.0513	3.941	4.019	4.099	128	7.81	2,581
17	.0448	.0453	.0458	4.944	5.054	5.167	161	6.21	2,052
18	.0399	.0403	.0407	6.261	6.386	6.514	203	4.92	1,624
19	.0355	.0359	.0363	7.871	8.047	8.229	256	3.90	1,289
20	.0317	.0320	.0323	9.941	10.13	10.32	323	3.10	1,024
21	.0282	.0285	.0288	12.50	12.77	13.04	407	2.46	812.3
22	.0250	.0253	.0256	15.82	16.20	16.59	516	1.94	640.1
23	.0224	.0226	.0228	19.95	20.31	20.67	647	1.55	510.8
24	.0199	.0201	.0203	25.17	25.67	26.19	818	1.22	404.0
25	.0177	.0179	.0181	31.66	32.37	33.10	1,030	.970	320.4
26	.0157	.0159	.0161	40.01	41.02	42.07	1,310	.765	252.8
27	.0141	.0142	.0143	50.72	51.43	52.17	1,640	.610	201.6
28	.0125	.0126	.0127	64.30	65.33	66.37	2,080	.481	158.8
29	.0112	.0113	.0114	79.80	81.22	82.68	2,590	.387	127.7
30	.0099	.0100	.0101	101.7	103.7	105.8	3,300	.303	100.0
31	.0088	.0089	.0090	128.0	130.9	133.9	4,170	.240	79.21
32	.0079	.0080	.0081	158.1	162.0	166.2	5,160	.194	64.00
33	.0070	.0071	.0072	200.1	205.7	211.7	6,550	.153	50.41
34	.0062	.0063	.0064	253.2	261.3	269.8	8,320	.120	39.69
35	.0055	.0056	.0057	319.2	330.7	342.8	10,500	.0949	31.36
36	.0049	.0050	.0051	398.7	414.8	431.9	13,200	.0757	25.00
37	.0044	.0045	.0046	490.1	512.1	535.7	16,300	.0613	20.25
38	.0039	.0040	.0041	617.0	648.2	681.9	20,600	.0484	16.00
39	.0034	.0035	.0036	800.2	846.6	897.1	27,000	.0371	12.25
40	.0030	.0031	.0032	1,013	1,079	1,152	34,400	.0291	9.61
41	.0027	.0028	.0029	1,233	1,323	1,423	42,100	.0237	7.84
42	.0024	.0025	.0026	1,534	1,659	1,801	52,900	.0189	6.25
43	.0021	.0022	.0023	1,960	2,143	2,352	68,300	.0147	4.84
44	.0019	.0020	.0021	2,352	2,593	2,873	82,600	.0121	4.00
45	.00169	.00176	.00183	3,080	3,348	3,616	106,500	.00939	3.10
46	.00151	.00157	.00164	3,870	4,207	4,544	134,400	.00744	2.47
47	.00135	.00140	.00146	4,868	5,291	5,714	169,200	.00591	1.96
48	.00119	.00124	.00129	6,205	6,745	7,285	213,400	.00469	1.54
49	.00107	.00111	.00116	7,744	8,417	9,090	269,700	.00371	1.23
50	.00095	.00099	.00103	9,734	10,580	11,430	339,700	.00294	.980
51	.00085	.00088	.00092	12,320	13,390	14,460	428,400	.00233	.775
52	.00075	.00078	.00081	15,690	17,050	18,410	540,000	.00185	.608
53	.00067	.00070	.00073	19,480	21,170	22,860	681,200	.00147	.490
54	.00060	.00062	.00065	24,820	26,980	29,140	859,100	.00116	.384
55	.00053	.00055	.00057	31,540	34,280	37,020	1,083,000	.000923	.303
56	.00047	.00049	.00051	39,730	43,190	46,650	1,366,000	.000732	.240

**Values are based on a resistivity of 10.371 Ohms/CMF at 20°C (100% IACS conductivity). Minimum resistance values are based on maximum bare diameter. Maximum resistance values are based on minimum bare diameter.

Dimensional values derived from NEMA MW1000-2020 Standard

SINGLE BUILD DIAMETERS (INCHES)			HEAVY BUILD DIAMETERS (INCHES)			TRIPLE BUILD DIAMETERS (INCHES)			QUADRUPLE BUILD DIAMETERS (INCHES)			SIZE (AWG)
MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
.1622	.1648	.1665	.1640	.1656	.1672	.1651	.1679	.1688	.1663	.1685	.1706	6
.1446	.1469	.1485	.1464	.1478	.1492	.1475	.1492	.1508	.1488	.1506	.1525	7
.1289	.1302	.1314	.1307	.1320	.1332	.1317	.1333	.1348	.1330	.1349	.1365	8
.1150	.1162	.1173	.1167	.1179	.1190	.1177	.1191	.1205	.1190	.1205	.1221	9
.1026	.1037	.1047	.1043	.1054	.1064	.1052	.1064	.1076	.1077	.1088	.1098	10
.0915	.0925	.0936	.0931	.0942	.0952	.0940	.0952	.0963	.0964	.0974	.0983	11
.0816	.0825	.0835	.0832	.0842	.0851	.0840	.0851	.0861	.0864	.0873	.0881	12
.0729	.0737	.0746	.0745	.0754	.0762	.0752	.0762	.0771	.0777	.0785	.0793	13
.0651	.0659	.0666	.0667	.0675	.0682	.0683	.0691	.0698	.0699	.0707	.0714	14
.0580	.0587	.0594	.0595	.0603	.0610	.0611	.0618	.0625	.0626	.0633	.0640	15
.0517	.0524	.0531	.0532	.0539	.0545	.0546	.0553	.0560	.0561	.0568	.0574	16
.0462	.0469	.0475	.0476	.0482	.0488	.0489	.0496	.0502	.0503	.0510	.0516	17
.0412	.0418	.0424	.0425	.0431	.0437	.0438	.0444	.0450	.0451	.0458	.0464	18
.0367	.0373	.0379	.0380	.0386	.0391	.0392	.0398	.0404	.0405	.0412	.0418	19
.0329	.0335	.0340	.0341	.0346	.0351	.0352	.0358	.0363	.0364	.0371	.0377	20
.0293	.0298	.0303	.0304	.0310	.0315	.0316	.0321	.0326	.0327	.0334	.0340	21
.0261	.0266	.0270	.0271	.0276	.0281	.0282	.0287	.0292	.0293	.0300	.0306	22
.0234	.0239	.0243	.0244	.0249	.0253	.0254	.0259	.0263	.0264	.0271	.0277	23
.0209	.0213	.0217	.0218	.0223	.0227	.0228	.0232	.0236	.0237	.0244	.0250	24
.0186	.0190	.0194	.0195	.0199	.0203	.0204	.0208	.0212	.0213	.0220	.0226	25
.0166	.0170	.0173	.0174	.0178	.0182	.0183	.0187	.0191	.0192	.0198	.0204	26
.0149	.0153	.0156	.0157	.0161	.0165	.0166	.0170	.0173	.0174	.0180	.0185	27
.0133	.0137	.0140	.0141	.0144	.0147	.0148	.0152	.0155	.0156	.0162	.0167	28
.0119	.0123	.0126	.0127	.0130	.0133	.0134	.0138	.0141	.0142	.0147	.0151	29
.0106	.0109	.0112	.0112	.0117	.0121	.0119	.0123	.0126	.0125	.0132	.0138	30
.0094	.0097	.0100	.0100	.0104	.0108	.0106	.0110	.0114	.0112	.0119	.0125	31
.0085	.0088	.0090	.0090	.0094	.0097	.0096	.0099	.0102	.0101	.0107	.0112	32
.0075	.0078	.0081	.0080	.0084	.0087	.0085	.0089	.0092	.0090	.0096	.0101	33
.0067	.0070	.0072	.0071	.0075	.0078	.0076	.0080	.0083	.0081	.0086	.0091	34
.0059	.0062	.0065	.0064	.0067	.0070	.0068	.0072	.0075	.0072	.0077	.0082	35
.0053	.0056	.0058	.0057	.0060	.0063	.0061	.0064	.0067	.0065	.0070	.0074	36
.0048	.0050	.0052	.0051	.0055	.0057	.0055	.0058	.0061	.0058	.0063	.0067	37
.0042	.0045	.0047	.0046	.0049	.0051	.0049	.0052	.0055	.0052	.0056	.0060	38
.0037	.0040	.0042	.0040	.0043	.0045	.0043	.0046	.0049	.0046	.0050	.0054	39
.0033	.0035	.0037	.0035	.0038	.0041	.0038	.0041	.0044	.0041	.0045	.0049	40
.003	.0032	.0033	.0032	.0035	.0037	.0035	.0038	.0040	.0037	.0041	.0044	41
.0026	.0028	.0030	.0029	.0031	.0033	.0031	.0034	.0036	.0033	.0036	.0039	42
.0023	.0025	.0027	.0025	.0027	.0029	.0027	.0030	.0032	.0029	.0033	.0036	43
.0021	.0023	.0024	.0023	.0025	.0026	.0025	.0027	.0029	.0027	.0030	.0032	44
.00189	.00205	.0022	.00209	.00225	.0024	.00219	.00245	.00270	.00239	.00265	.00290	45
.00171	.00173	.0020	.00181	.00196	.00210	.00201	.00221	.00240	.00221	.00241	.00260	46
.00145	.00158	.00170	.00165	.00178	.00190	.00185	.00198	.00210	.00205	.00218	.00230	47
.00129	.0014	.00150	.00139	.00155	.00170	.00159	.00175	.00190	.00169	.00190	.00210	48
.00117	.00124	.00130	.00127	.00139	.00150	.00147	.00159	.00170	.00157	.00174	.00190	49
.00105	.00113	.00120	.00115	.00128	.00140	.00125	.00143	.00160	.00135	.00158	.00180	50
.00095	.00103	.00110	.00105	.00117	.00129	.00115	.00133	.00150	.00125	.00148	.00170	51
.00085	.00093	.00100	.00095	.00107	.00115	.00105	.00123	.00140	.00115	.00138	.00160	52
.00072	.00079	.00085	0.0008	.0009	.00103	.00087	.00104	.00121	.00097	.00118	.00139	53
.00065	.0007	.00075	.00073	.00082	.00095	-	-	-	-	-	-	54
.00058	.00064	.00070	.00066	.00075	.00087	-	-	-	-	-	-	55
.00052	.00059	.00065	0.0006	.00069	.00081	-	-	-	-	-	-	56

Half-Size Copper Magnet Wire

Dimensional Values Derived from NEMA MW1000-2020 Standard

SIZE (AWG)	BARE COPPER								
	DIAMETER (INCHES)			RESISTANCE** (OHMS PER 1000 FT. AT 20°C)			FEET PER POUND	POUNDS PER 1000 FT.	CIRCULAR MILS NOMINAL
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.			
10 1/2	.0952	.0962	.0971	1.10	1.12	1.14	35.6	28.1	9,270
11 1/2	.0847	.0856	.0864	1.39	1.41	1.44	44.9	22.3	7,360
12 1/2	.0755	.0763	.0770	1.75	1.78	1.81	56.6	17.7	5,840
13 1/2	.0672	.0679	.0685	2.22	2.24	2.29	71.4	14.0	4,620
14 1/2	.0599	.0605	.0611	2.77	2.82	2.88	90.0	11.1	3,670
15 1/2	.0534	.0539	.0544	3.49	3.56	3.64	113	8.83	2,920
16 1/2	.0475	.0480	.0485	4.41	4.48	4.58	143	7.00	2,310
17 1/2	.0423	.0427	.0431	5.56	5.66	5.77	180	5.55	1,830
18 1/2	.0376	.0380	.0384	7.00	7.14	7.30	228	4.39	1,450
19 1/2	.0336	.0339	.0342	8.81	8.97	9.19	286	3.50	1,160
20 1/2	.0299	.0302	.0305	11.1	11.4	11.6	362	2.76	912
21 1/2	.0266	.0269	.0272	14.0	14.3	14.5	457	2.19	724
22 1/2	.0237	.0239	.0241	17.7	18.0	18.5	573	1.74	576
23 1/2	.0211	.0213	.0215	22.2	22.6	23.3	721	1.39	458
24 1/2	.0188	.0190	.0192	28.1	28.7	29.3	915	1.09	361
25 1/2	.0167	.0169	.0171	35.5	36.3	37.2	1,160	.865	286
26 1/2	.0149	.0150	.0152	44.3	45.5	46.7	1,450	.690	228
27 1/2	.0133	.0134	.0135	56.1	57.7	58.6	1,840	.543	180
28 1/2	.0118	.0119	.0120	70.8	73.2	74.5	2,290	.436	144
29 1/2	.0105	.0106	.0107	90.6	92.3	94.0	2,940	.340	112
30 1/2	.0094	.0095	.0096	114.9	117.3	119.9	3,735	.2715	89.61
31 1/2	.0083	.0084	.0085	143.1	146.5	150.1	4,665	.2170	71.61
32 1/2	.0074	.0075	.0076	179.1	183.9	189.0	5,855	.1735	57.21
33 1/2	.0066	.0067	.0068	226.7	233.5	240.8	7,435	.1365	45.05
34 1/2	.0059	.0060	.0061	286.2	296.0	306.3	9,410	.1075	35.53
35 1/2	.0052	.0053	.0054	359.0	372.8	387.4	11,850	.0853	28.18
36 1/2	.0046	.0047	.0048	444.4	463.5	483.8	14,750	.0685	22.63
37 1/2	.0041	.0042	.0043	553.6	580.2	608.8	18,450	.0549	18.13
38 1/2	.0036	.0037	.0038	708.6	747.4	789.5	23,800	.0428	14.13
39 1/2	.0032	.0033	.0034	907	963	1,025	30,700	.0331	10.93
40 1/2	.0029	.0030	.0031	1,123	1,201	1,288	38,250	.0264	8.73
41 1/2	.0025	.0026	.0027	1,384	1,491	1,612	47,500	.0213	7.05
42 1/2	.0023	.0024	.0025	1,747	1,901	2,077	60,600	.0168	5.55
43 1/2	.0020	.0021	.0022	2,156	2,368	2,613	75,450	.0134	4.42
44 1/2	.0018	.0019	.0020	2,716	2,971	3,245	94,550	.01075	3.55
45 1/2	.00160	.00166	.00174	3,475	3,778	4,080	120,450	.00842	2.785
46 1/2	.00142	.00148	.00154	4,369	4,749	5,129	151,800	.00668	2.215
47 1/2	.00127	.00132	.00137	5,537	6,018	6,500	191,300	.00530	1.750
48 1/2	.00113	.00117	.00122	6,975	7,581	8,188	241,550	.00420	1.385
49 1/2	.00101	.00105	.00109	8,739	9,499	10,260	304,700	.00333	1.105
50 1/2	.00090	.00093	.00097	11,027	11,985	12,945	384,050	.00264	.8775

**Values are based on a resistivity of 10.371 Ohms/CMF at 20°C (100% IACS conductivity). Minimum resistance values are based on maximum bare diameter. Maximum resistance values are based on minimum bare diameter.

SINGLE BUILD DIAMETERS (INCHES)			HEAVY BUILD DIAMETERS (INCHES)			SIZE (AWG)
MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
-	-	-	.0985	.0996	.1007	10 1/2
-	-	-	.0880	.0890	.0900	11 1/2
-	-	-	.0787	.0796	.0805	12 1/2
-	-	-	.0704	.0712	.0720	13 1/2
.0615	.0622	.0629	.0630	.0638	.0645	14 1/2
.0549	.0556	.0563	.0564	.0571	.0578	15 1/2
.0489	.0496	.0502	.0503	.0510	.0516	16 1/2
.0436	.0443	.0449	.0450	.0456	.0462	17 1/2
.0389	.0395	.0400	.0401	.0407	.0413	18 1/2
.0348	.0354	.0359	.0360	.0366	.0371	19 1/2
.0310	.0316	.0321	.0322	.0327	.0332	20 1/2
.0277	.0282	.0287	.0288	.0293	.0298	21 1/2
.0247	.0252	.0257	.0258	.0263	.0267	22 1/2
.0221	.0226	.0230	.0231	.0236	.0240	23 1/2
.0197	.0202	.0206	.0207	.0211	.0215	24 1/2
.0176	.0180	.0184	.0185	.0189	.0193	25 1/2
.0157	.0161	.0165	.0166	.0170	.0173	26 1/2
.0141	.0145	.0148	.0149	.0153	.0156	27 1/2
.0126	.0129	.0132	.0133	.0137	.0140	28 1/2
.0112	.0115	.0118	.0119	.0123	.0126	29 1/2
.0100	.0103	.0106	.0106	.0111	.0115	30 1/2
.0090	.0093	.0095	.0095	.0099	.0103	31 1/2
.0080	.0083	.0086	.0085	.0089	.0092	32 1/2
.0071	.0074	.0077	.0076	.0080	.0083	33 1/2
.0063	.0066	.0069	.0068	.0071	.0074	34 1/2
.0056	.0059	.0062	.0061	.0064	.0067	35 1/2
.0051	.0053	.0055	.0054	.0058	.0060	36 1/2
.0045	.0048	.0050	.0049	.0052	.0054	37 1/2
.0040	.0043	.0045	.0043	.0046	.0048	38 1/2
.0035	.0038	.0040	.0038	.0041	.0043	39 1/2
.0032	.0034	.0035	.0034	.0037	.0039	40 1/2
.0028	.0030	.0032	.0031	.0033	.0035	41 1/2
.0025	.0027	.0029	.0027	.0029	.0031	42 1/2
.0022	.0024	.0026	.0024	.0026	.0028	43 1/2
.00200	.00215	.00230	.00220	.00238	.00250	44 1/2
.00180	.00189	.00210	.00195	.00211	.00225	45 1/2
.00158	.00166	.00185	.00173	.00187	.00200	46 1/2
.00137	.00149	.00160	.00152	.00166	.00180	47 1/2
.00123	.00132	.00140	.00133	.00147	.00160	48 1/2
.00111	.00119	.00125	.00121	.00134	.00145	49 1/2
.00100	.00108	.00115	.00110	.00123	.00135	50 1/2

Bondable Magnet Wire

Bondable magnet wire, also referred to as self-bonding magnet wire, is film insulated wire top-coated with a thermoplastic adhesive. When activated, the thermoplastic bonds turn to turn windings to produce self-supporting coils or coils of unusual or difficult configuration. Use of bondable magnet wire may offer advantages over conventional magnet wire in certain winding applications, eliminating the need for bobbins as well as taping or varnishing steps. Activation of the bondcoat may be achieved with either heat, or in some cases solvent, or a combination of the two. Although bondcoats may be added to any conventional film, consideration should be given to the resoftening temperature of the adhesive in that it may not withstand the operating temperature of higher rated primary insulations.

Bonding Methods

Solvent Bonding

Some bondcoats can be activated by applying certain solvents during or after the coil winding process. Application of the solvent, usually via saturated wick during winding, causes the bondcoat to reflow. The process requires the use of a fixture to hold the coil in place while the solvent is drying. Once dry, the coil should be heated to dry off any residual solvent which might cause long-term coil failure, as well as to complete the bonding process.

Heat Bonding

All bondcoats can be heat bonded, either by oven-heating or by directing hot air on to the wire during winding. In either case, the principle is to heat the winding slightly above the bondcoat's reflow temperature and then cool it below its rated bond strength temperature. Oven bonding is accomplished by heating the coil for a period of time sufficient to obtain uniform heating throughout the winding, followed by a cooling cycle.

Heating time is generally 10 to 30 minutes, depending on the size of the winding. Disadvantages of oven bonding are the longer bonding time as well as the potential need for many winding fixtures. Hot air bonding, though done typically at slower winding speed, has the advantage of the elimination of a secondary bonding operation. This method is cost effective and usually associated with low temperature bondcoats and wire sizes smaller than 34 AWG.

Resistance Bonding

Resistance bonding is done by applying electric current to the winding to electrically heat it to the proper bond temperature. Bonding voltage and time are dependent on wire size and coil design, and therefore will need to be developed experimentally for each specific application. This method has the advantages of being quick and generating uniform heat distribution. It is typically used for wire sizes heavier than 34 AWG.

Bondable Overcoats

TYPE	SOLVENT ACTIVATION	BONDING TEMP (°C)*	SOFTENING TEMP (°C)**
Polyvinyl Butyral	Alcohol	110 - 140	105
Epoxy	Acetone	150 - 200	130
Polyester	None	190 - 210	130
Polyamide	None	200 - 230	180

*May vary based on wire size and coil design
**Most room temperature bond strength lost at this point

Values below derived from NEMA 2020 Standard

SIZE (AWG)	BARE WIRE DIAMETER (INCHES)			TYPE 1				TYPE 2				SIZE (AWG)
				MIN. INCREASE IN DIAMETER (INCHES)		OVERALL DIAMETER (INCHES)		MIN. INCREASE IN DIAMETER (INCHES)		OVERALL DIAMETER (INCHES)		
	MIN.	NOM.	MAX.	FILM COAT	BOND COAT	MIN.	MAX.	FILM COAT	BOND COAT	MIN.	MAX.	
14	.0635	.0641	.0647	.0016	.0006	.0657	.0682	.0032	.0006	.0673	.0698	14
15	.0565	.0571	.0577	.0015	.0006	.0586	.0610	.0030	.0006	.0601	.0625	15
16	.0503	.0508	.0513	.0014	.0006	.0523	.0545	.0029	.0006	.0538	.0560	16
17	.0448	.0453	.0458	.0014	.0006	.0468	.0488	.0028	.0006	.0482	.0502	17
18	.0399	.0403	.0407	.0013	.0006	.0418	.0437	.0026	.0006	.0431	.0450	18
19	.0355	.0359	.0363	.0012	.0006	.0373	.0391	.0025	.0006	.0386	.0404	19
20	.0317	.0320	.0323	.0012	.0005	.0334	.0351	.0024	.0005	.0346	.0363	20
21	.0282	.0285	.0288	.0011	.0005	.0298	.0315	.0022	.0005	.0309	.0326	21
22	.0250	.0253	.0256	.0011	.0005	.0266	.0281	.0021	.0005	.0276	.0292	22
23	.0224	.0226	.0228	.0010	.0005	.0239	.0253	.0020	.0005	.0249	.0263	23
24	.0199	.0201	.0203	.0010	.0005	.0214	.0227	.0019	.0005	.0223	.0236	24
25	.0177	.0179	.0181	.0009	.0005	.0191	.0203	.0018	.0005	.0200	.0212	25
26	.0157	.0159	.0161	.0009	.0005	.0171	.0182	.0017	.0005	.0179	.0191	26
27	.0141	.0142	.0143	.0008	.0005	.0154	.0165	.0016	.0005	.0162	.0173	27
28	.0125	.0126	.0127	.0008	.0005	.0138	.0147	.0016	.0005	.0146	.0155	28
29	.0112	.0113	.0114	.0007	.0004	.0123	.0133	.0015	.0004	.0131	.0141	29
30	.0099	.0100	.0101	.0007	.0004	.0110	.0121	.0013	.0004	.0116	.0128	30
31	.0088	.0089	.0090	.0006	.0004	.0098	.0108	.0012	.0004	.0104	.0114	31
32	.0079	.0080	.0081	.0006	.0004	.0089	.0097	.0011	.0004	.0094	.0103	32
33	.0070	.0071	.0072	.0005	.0003	.0078	.0087	.0010	.0003	.0083	.0092	33
34	.0062	.0063	.0064	.0005	.0003	.0070	.0078	.0009	.0003	.0074	.0083	34
35	.0055	.0056	.0057	.0004	.0003	.0062	.0070	.0009	.0003	.0067	.0075	35
36	.0049	.0050	.0051	.0004	.0003	.0056	.0063	.0008	.0003	.0060	.0067	36
37	.0044	.0045	.0046	.0004	.0003	.0051	.0057	.0007	.0003	.0054	.0061	37
38	.0039	.0040	.0041	.0003	.0002	.0044	.0051	.0007	.0002	.0048	.0055	38
39	.0034	.0035	.0036	.0003	.0002	.0039	.0045	.0006	.0002	.0042	.0049	39
40	.0030	.0031	.0032	.0003	.0002	.0035	.0041	.0005	.0002	.0037	.0044	40
41	.0027	.0028	.0029	.0003	.0002	.0032	.0037	.0005	.0002	.0034	.0040	41
42	.0024	.0025	.0026	.0002	.0002	.0028	.0033	.0005	.0002	.0031	.0036	42
43	.0021	.0022	.0023	.0002	.0001	.0024	.0029	.0004	.0001	.0026	.0032	43
44	.0019	.0020	.0021	.0002	.0001	.0022	.0026	.0004	.0001	.0024	.0029	44
45	.00169	.00176	.00183	.0002	.0001	.00199	.0024	.0004	.0001	.00219	.0027	45
46	.00151	.00157	.00164	.0002	.0001	.00181	.0021	.0003	.0001	.00191	.0024	46
47	.00135	.00140	.00146	.0001	.0001	.00155	.0019	.0003	.0001	.00175	.0021	47
48	.00119	.00124	.00129	.0001	.0001	.00139	.0017	.0002	.0001	.00149	.0019	48
49	.00107	.00111	.00116	.0001	.0001	.00127	.0015	.0002	.0001	.00137	.0017	49
50	.00095	.00099	.00103	.0001	.0001	.00115	.0014	.0002	.0001	.00125	.0016	50

Bondable wire sizes finer than 50 AWG available upon request.

Multifilar® Magnet Wire

Parallel bonded magnet wire for more consistent capacitance and impedance characteristics.

Where constant parallel alignment of multiple strands is an advantage, Multifilar® magnet wire is the right choice. Its parallel-bonded, color-coded construction offers benefits for many applications.

Engineers should specify Multifilar® when concerned with space, weight, and reliability. Where consistent capacitance and impedance characteristics are required, Multifilar® magnet wire outperforms windings using two separate magnet wires.

Production users benefit from increased layer winding speeds, tighter windings that deliver more power in less space, reduced labor and handling.

Color coding assists in conductor identification and reduces termination errors.

MWS custom manufactures Multifilar® magnet wire to assure flat, parallel construction in sizes 16 AWG and finer, and up to 20 conductors (for constructions of greater than 20 conductors, contact our sales department) wide in some sizes.

Ten insulation colors are offered in polyurethane and poly-nylon films. Red, green and natural are standard for all film types. Consult the chart on the next page for available film insulations and colors.

General Product Information

INSULATION CODE NO.	INSULATION TYPE	THERMAL CLASS	DIELECTRIC CONSTANT	NEMA MW 1000 DESIGNATION	AVAILABLE COLORS
1	Polyurethane 155	155	3.70	MW 79-C	Red, Green, Natural, Blue, Yellow Black, Violet, Orange, White, Brown
1	Polyurethane 180	180	3.70	MW 82-C	
2	Poly-Nylon 155	155	3.81	MW 80-C	Red, Green, Natural, Blue, Yellow Black, Violet, Orange, White, Brown
2	Poly-Nylon 180	180	3.81	MW 83-C	
4	Polyester 200	200	3.82	MW 74-C	Red, Green, Natural, Black
5	Armored Polyester	200	3.86	MW 35-C	Red, Green, Natural, Black
6	Solderable Polyester	180	3.76	MW 77-C	Red, Green, Natural, Black
7	Formvar	105	7.40	MW 15-C	Red, Green, Natural, Black
8	Polyimide (ML)	240	3.90	MW 16-C	Red, Green, Natural, Black

BOND CODE NO.	BOND COAT (OPERATING TEMPERATURE)	SOLVENT*
1	Polyvinyl Butyral (105°C)	Alcohol
2	Nylon (105°C)	None
3	Epoxy (130°C)	MEK or Acetone
4	Polyester (130°C)	None
5	Polyamide (165°C)	None
6	Polyimide (ML) (240°C)	None

*Bonding films can be softened and removed by immersion in the solvent noted, except nylon, polyester, polyamide and ML which are non-soluble. Wiping with a soft cloth dampened with solvent may be necessary to separate wires.

Finished wire thermal class based on the underlying enamel of the individual strand.

Part Number Ordering System

Make your own part number by following the guidelines outlined below

B 2 38 1 1 1 1 (155)

Product Letter
For all Multifilar® magnet wire

Number of Conductors
Use ( ) for more than 9 conductors

AWG Size

Insulation Build
1 = Single
2 = Heavy
3 = Triple
4 = Quadruple

Insulation Type
See above chart for correct code number

Color Code
0 = None Required
1 = Red/Green
2 = Green/Clear
3 = Red/Green/Clear
4 = Red/Green/Clear/Blue
9 = Special - call for color code

Bonding Film
See above chart for correct code number

Thermal Class
For Poly and Poly-Nylon insulations specify 155 or 180 thermal class

EXAMPLE = 2 Conductors - 38 AWG Single Polyurethane 155° - Red/Green - Butyral Bond

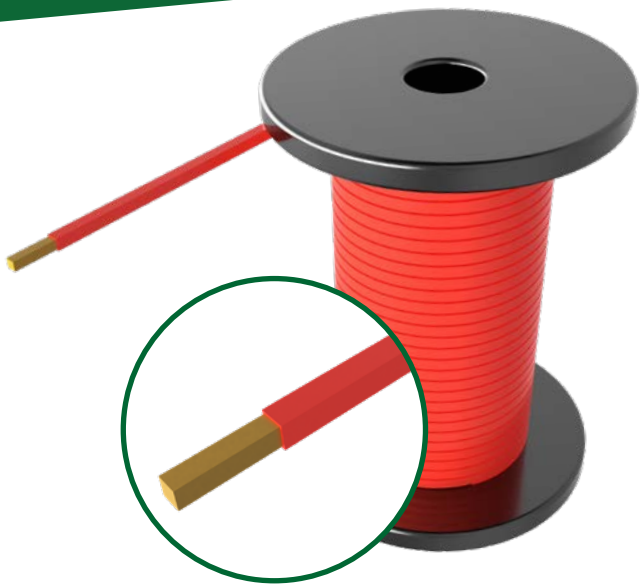
Square and Rectangular Magnet Wire

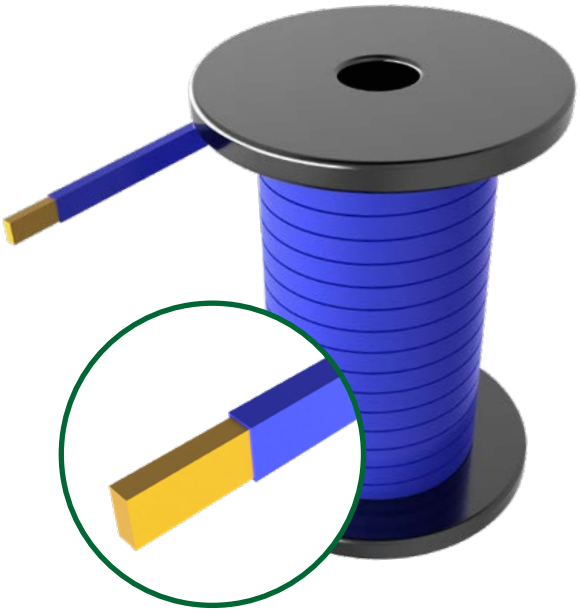
Miniature square and rectangular magnet wire for specialty coil and motor windings.

When product miniaturization calls for tighter dimensional specifications, MWS Microsquare™ film-coated magnet wire allows design engineers to create compact coils and small motors that deliver more power in less space.

Microsquare™ means miniature square and rectangular copper and aluminum magnet wire. Custom-produced by MWS in sizes smaller than 14 AWG or 3500 sq. mil. cross-sectional area, Microsquare™ is available in a wide range of solderable and high-temperature insulations and a variety of colors, with or without bondable overcoats. See pages 4 and 5 for information on film insulations and page 10 for information on bondable overcoats. Microsquare™ magnet wire was developed to provide improved winding uniformity and maximum use of space.

Rectangular wire when used in coil making creates a denser winding that dissipates heat better than a round wire coil. Less 'air' between layers generates more power at higher operating temperatures. MWS has been a leader in enameled rectangular wire for 50 years. Our proprietary processes can produce enamel coated wires as thin as .002" with widths up to .300". We off many insulation options including polyimide, polyester-amide/imide, polyurethane, in addition to the option of a bond top coat.





Part Number Ordering System

Make your own part number by following the guidelines outlined below

M 22 1 1 2 1 (155)

Product Letter
For all Microsquare™ magnet wire

Square AWG Size
From chart.
Use 88 for special square size.
Use 99 for rectangular sizes.

Conductor Material
1 = Copper
2 = Aluminum
3 = Special

Insulation Build
1 = Single
2 = Heavy
3 = Triple
4 = Quadruple
9 = Special

Insulation Type*
1 = Polyurethane - 155 / 180
2 = Poly-Nylon - 155 / 180
3 = Polyester - 180
4 = Polyester - 200
5 = Polyurethane Bondable
6 = Solderable Polyester - 180
7 = Formvar
8 = ML
9 = Special

Color Code
1 = Natural
2 = Green
3 = Red
4 = Blue
9 = Special

Thermal Class
For Poly and Poly-Nylon insulations specify 155 or 180 thermal class

EXAMPLE = 22 AWG - Square Copper - Single Poly-Nylon 155°C - Natural
NOTE: For part numbers starting with 88 or 99, please show wire dimensions after basic part number.

Square

SIZE (AWG)	BARE COPPER									HEAVY BUILD			SIZE (AWG)
	DIMENSIONS (INCHES)			RESISTANCE* (OHMS PER 1000 FT. AT 20°C)			SQUARE MILS	CORNER RADIUS	POUNDS PER 1000 FT	DIMENSIONS (INCHES)			
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	NOM.	NOM.		MIN. INCREASE	MIN. O.D.	MAX. O.D.	
1	.2864	.2893	.2922	.09627	.09895	.1020	82,320	.039	317.2	.003	.2894	.2972	1
2	.2550	.2576	.2602	.1217	.1253	.1295	64,980	.039	250.4	.003	.2580	.2652	2
3	.2271	.2294	.2317	.1539	.1589	.1648	51,250	.039	197.5	.003	.2301	.2367	3
4	.2023	.2043	.2063	.1949	.2018	.2100	40,370	.039	155.6	.003	.2053	.2113	4
5	.1801	.1819	.1837	.2470	.2568	.2689	31,710	.039	122.2	.003	.1831	.1887	5
6	.1604	.1620	.1636	.3101	.3211	.3345	25,360	.031	97.75	.003	.1634	.1686	6
7	.1429	.1443	.1457	.3929	.4084	.4277	19,940	.031	76.86	.003	.1459	.1507	7
8	.1272	.1285	.1298	.4981	.5210	.5501	15,630	.031	60.25	.003	.1302	.1348	8
9	.1133	.1144	.1155	.6267	.6513	.6812	12,510	.026	48.20	.003	.1163	.1205	9
10	.1009	.1019	.1029	.7951	.8309	.8757	9,803	.026	37.78	.003	.1039	.1079	10
11	.0897	.0907	.0917	.9914	1.033	1.085	7,883	.020	30.38	.003	.0927	.0967	11
12	.0798	.0808	.0818	1.254	1.317	1.397	6,185	.020	23.84	.003	.0828	.0868	12
13	.0710	.0720	.0730	1.565	1.641	1.734	4,964	.016	19.13	.003	.0740	.0780	13
14	.0631	.0641	.0651	1.980	2.094	2.239	3,889	.016	14.99	.003	.0661	.0701	14

*Based on 100% conductivity IACS

Microsquare™

SIZE (AWG)	BARE DIMENSION (INCHES)	BARE WIRE TOLERANCE*	RESISTANCE (OHMS PER 1000 FT. AT 20°C)			CORNER RADIUS	SQ. MIL AREA	SIZE (AWG)
	MIN.		MIN.	NOM.	MAX.			
15	.0571	± .0005"	2.601	2.761	2.801	.010"	3,175	15
16	.0508	± .0005"	3.281	3.483	3.534	.010"	2,495	16
17	.0453	± .0005"	4.135	4.390	4.453	.009"	1,983	17
18	.0403	± .0005"	5.225	5.546	5.627	.008"	1,569	18
19	.0359	± .0005"	6.570	6.975	7.076	.008"	1,234	19
20	.0320	± .0004"	8.302	8.685	8.845	.007"	982	20
21	.0285	± .0004"	10.46	10.94	11.15	.006"	781	21
22	.0253	± .0004"	13.17	13.78	14.03	.005"	619	22
23	.0226	± .0004"	16.60	17.37	17.69	.005"	489	23
24	.0201	± .0003"	21.06	22.03	22.44	.005"	383	24
25	.0179	± .0003"	26.00	26.81	27.62	.004"	307	25
26	.0159	± .0003"	32.86	33.88	34.91	.003"	245	26
27	.0142	± .0003"	41.43	42.73	44.02	.003"	194	27
28	.0126	± .0003"	52.51	54.15	55.79	.0025"	153	28
29	.0113	± .0003"	65.83	67.89	69.94	.002"	124	29
30	.0100	± .0003"	83.62	86.24	88.85	.002"	97	30
31	.0089	± .0002"	104.0	107.2	110.5	.0015"	77	31
32	.0080	± .0002"	132.7	136.9	141.0	.0015"	62	32
33	.0071	± .0002"	167.5	172.8	178.0	.001"	49	33
34	.0063	± .0002"	207.4	213.8	220.3	.001"	38	34
35	.0056	± .0002"	263.3	271.5	279.8	.001"	30	35

Minimum and maximum overall dimensions will be the same as those for the equivalent round size.

EXAMPLE: 22 square heavy build: MINIMUM O.D. = .0271"
MAXIMUM O.D. = .0281"

* Conformance to dimensional tolerance is based on the average of at least three measurements per axis using a minimum 12" sample length. Individual measurements outside the tolerance limits will not be cause for rejection.

Square and Rectangular Magnet Wire

Aluminum

Square

SIZE (AWG)	BARE ALUMINUM									HEAVY BUILD			SIZE (AWG)
	DIMENSIONS (INCHES)			RESISTANCE* (OHMS PER 1000 FT. AT 20°C)			SQUARE MILS	CORNER RADIUS	POUNDS PER 1000 FT	DIMENSIONS (INCHES)			
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	NOM.	NOM.		MIN. INCREASE	MIN. O.D.	MAX. O.D.	
1	.2864	.2893	.2922	.1558	.1601	.1650	82,320	.039	96.46	.003	.2894	.2972	1
2	.2550	.2576	.2602	.1969	.2028	.2096	64,980	.039	76.15	.003	.2580	.2652	2
3	.2271	.2294	.2317	.2491	.2572	.2666	51,250	.039	60.06	.003	.2301	.2367	3
4	.2023	.2043	.2063	.3154	.3265	.3399	40,370	.039	47.30	.003	.2053	.2113	4
5	.1801	.1819	.1837	.3997	.4156	.4351	31,710	.039	37.16	.003	.1831	.1887	5
6	.1604	.1620	.1636	.5017	.5196	.5412	25,360	.031	29.72	.003	.1634	.1686	6
7	.1429	.1443	.1457	.6357	.6609	.6920	19,940	.031	23.37	.003	.1459	.1507	7
8	.1272	.1285	.1298	.8059	.8431	.8902	15,630	.031	18.32	.003	.1302	.1348	8
9	.1133	.1144	.1155	1.014	1.054	1.102	12,510	.026	14.66	.003	.1163	.1205	9
10	.1009	.1019	.1029	1.286	1.344	1.417	9,803	.026	11.49	.003	.1039	.1079	10
11	.0897	.0907	.0917	1.604	1.672	1.755	7,883	.020	9.237	.003	.0927	.0967	11
12	.0798	.0808	.0818	2.028	2.131	2.260	6,185	.020	7.248	.003	.0828	.0868	12
13	.0710	.0720	.0730	2.532	2.655	2.806	4,964	.016	5.817	.003	.0740	.0780	13
14	.0631	.0641	.0651	3.203	3.389	3.623	3,889	.016	4.557	.003	.0661	.0701	14

*Based on 61.8% conductivity IACS

Microsquare™

SIZE (AWG)	BARE DIMENSION (INCHES)	BARE WIRE TOLERANCE*	RESISTANCE (OHMS PER 1000 FT. AT 20°C)			CORNER RADIUS	SQ. MIL AREA	SIZE (AWG)
	MIN.		MIN.	NOM.	MAX.			
15	.0571	± .0005"	4.134	4.2624	4.393	.010"	3,175	15
16	.0508	± .0005"	5.210	5.372	5.535	.010"	2,495	16
17	.0453	± .0005"	6.566	6.722	6.977	.009"	1,983	17
18	.0403	± .0005"	8.294	8.554	8.813	.008"	1,569	18
19	.0359	± .0005"	10.43	10.76	11.08	.008"	1,234	19
20	.0320	± .0004"	13.18	13.60	14.01	.007"	982	20
21	.0285	± .0004"	16.64	17.16	17.68	.006"	781	21
22	.0283	± .0004"	20.86	21.52	22.17	.005"	619	22
23	.0226	± .0004"	26.37	27.19	28.02	.005"	489	23
24	.0201	± .0003"	33.41	34.45	35.50	.005"	383	24
25	.0179	± .0003"	41.98	43.30	44.61	.004"	307	25
26	.0159	± .0003"	52.99	54.65	56.30	.003"	245	26
27	.0142	± .0003"	66.82	68.90	70.99	.003"	194	27
28	.0126	± .0003"	84.74	87.38	90.03	.0025"	153	28
29	.0113	± .0003"	106.2	109.6	112.9	.002"	124	29
30	.0100	± .0003"	134.8	139.0	143.2	.002"	97	30

Minimum and maximum overall dimensions will be the same as those for the equivalent round size.

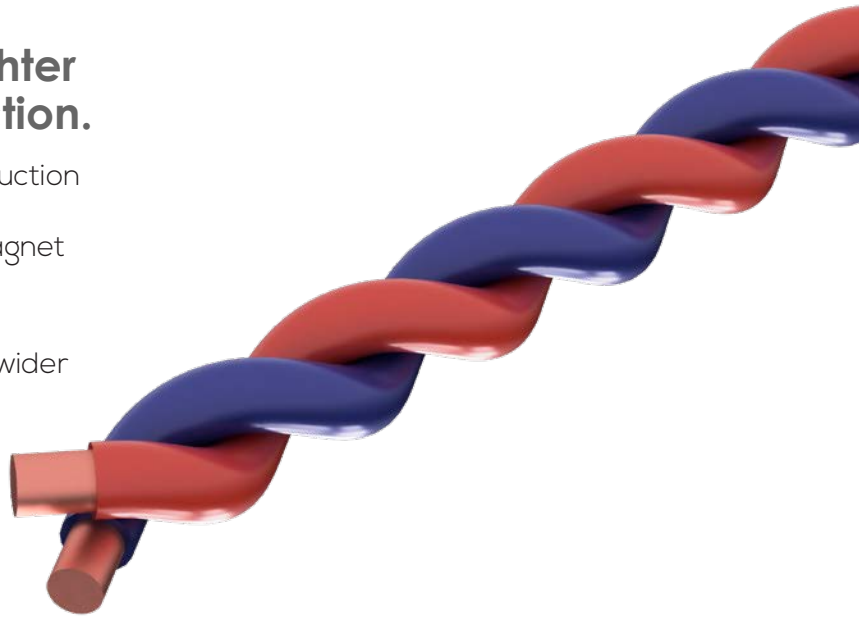
EXAMPLE: 22 square heavy build: MINIMUM O.D. = .0271"
MAXIMUM O.D. = .0281"

* Conformance to dimensional tolerance is based on the average of at least three measurements per axis using a minimum 12" sample length. Individual measurements outside the tolerance limits will not be cause for rejection.

Twisted Magnet Wire

Twistite™

For superior performance and tighter control over twisted wire construction.



For those who use twisted magnet wire in the production of custom toroid, ferrite and recording head coils, specialty audio and R.F. transformers, Twistite™ magnet wire offers several advantages over other twisted magnet wire constructions.

Because Twistite™ is custom produced by MWS, a wider range of twisting constructions is possible.

Manufacturing capabilities include:

- Up to 50 twists per inch on fine wire
- Up to 50 conductors
- Twisting tolerance as tight as ±1%
- Tightly controlled capacitance, inductance and impedance characteristics
- Up to 10 colors in some sizes for conductor identification
- Wide selection of insulations 105 - 240°C (single through quadruple film builds - See page 4 & 5)
- Range of sizes: 16 through 52 AWG
- Wide variety of conductor materials: copper, silver, plated conductors, and specialty alloys

Part Number Ordering System

Make your own part number by following the guidelines outlined below

Product Letter
For all Twistite™ magnet wire

Number of Conductors
Use ( ) for more than 9 conductors

AWG Size
Use 88 for special size

Twisting Tightness
Number of twists per inch

Thermal Class
For Poly and Poly-Nylon insulations specify 155 or 180 thermal class

T - 03 38 1 2 2 3 - 10 (155)

Conductor Material
1 = Copper
2 = Silver
3 = Aluminum
4 = Silver Plated Copper
5 = Gold Plated Copper
9 = Special

Insulation Build
1 = Single
2 = Heavy
3 = Triple
4 = Quadruple
9 = Special

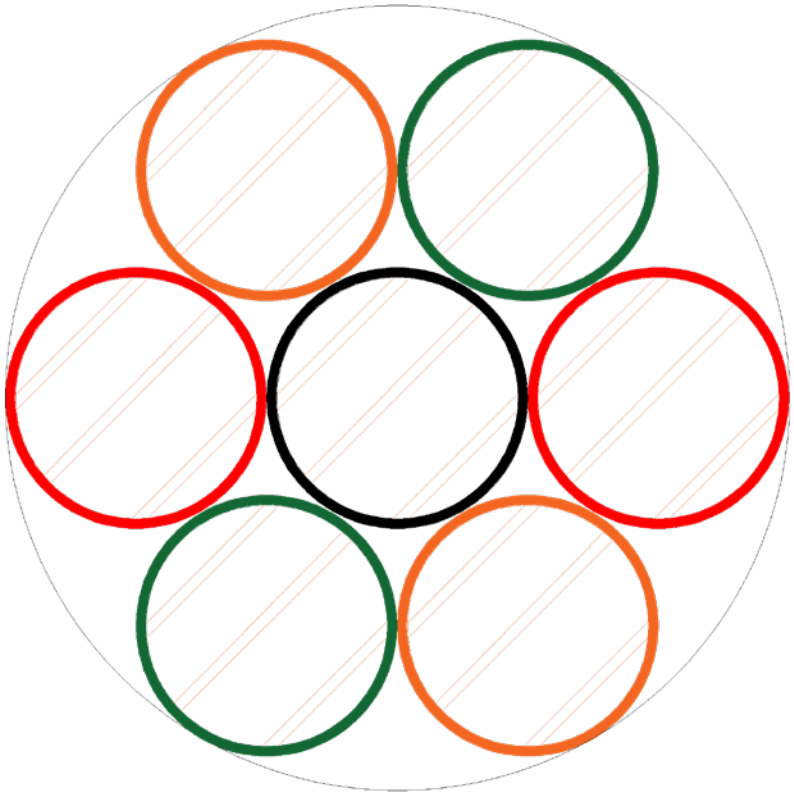
Insulation Type*
1 = Polyurethane - 155 / 180
2 = Poly-Nylon - 155 / 180
3 = Polyester - 180
4 = Polyester - 200
5 = Polyurethane Bondable
6 = Solderable Polyester - 180
7 = Formvar
8 = ML
9 = Special

Color Code
0 = None Required
1 = Red/Green
2 = Green/Natural
3 = Red/Green/Natural
4 = Red/Green/Natural/Blue
9 = Special

EXAMPLE = 3/38 Copper - Heavy Poly Nylon 155°C - Red/Green/Natural - 10 Twists Per Inch

*See pages 4 and 5 for a complete listing of insulations. Twistite™ is a trademark of MWS Wire Industries.

TWISTITE™					SINGLE BUILD		HEAVY BUILD	
# OF STRANDS	SIZE (AWG)	CIRCULAR MILS	NEAREST AWG EQUIV. (CIR. MILS)	RESISTANCE (OHMS PER 1000 FT. AT 20°C)	NOMINAL O.D. (INCHES)	FEET PER POUND	NOMINAL O.D. (INCHES)	FEET PER POUND
2	20	2,048	17	5.07	0.055	151	0.056	146
5	20	5,120	13	2.03	0.086	62	0.089	61
10	20	10,240	10	1.01	0.122	31	0.126	31
20	20	20,480	7	0.51	0.173	16	0.179	16
2	24	808	21	12.84	0.035	378	0.036	360
5	24	2,020	17	5.13	0.055	157	0.058	153
10	24	4,040	14	2.57	0.078	79	0.081	78
20	24	8,080	11	1.28	0.110	40	0.115	40
25	24	10,100	10	1.03	0.123	32	0.129	32
2	30	200	27	51.85	0.018	1,483	0.019	1,371
5	30	500	23	20.74	0.028	625	0.030	604
10	30	1,000	20	10.37	0.040	318	0.043	313
20	30	2,000	17	5.19	0.056	160	0.060	159
25	30	2,500	16	4.15	0.063	129	0.068	128
2	40	19	37	539.	0.006	14,851	0.006	13,520
5	40	48	33	215.8	0.009	6,396	0.010	6,136
10	40	96	30	107.9	0.013	3,282	0.014	3,212
20	40	192	27	53.95	0.018	1,663	0.020	1,645
25	40	240	26.5	43.16	0.020	1,334	0.022	1,322



Twisted Magnet Wire cont.

Litz Wire

The term "Litz wire" is derived from the German word Litzendraht, meaning "woven wire." Generally defined, it is a wire constructed of individually film-insulated wires bunched or braided together in a uniform pattern of twists and length of lay.

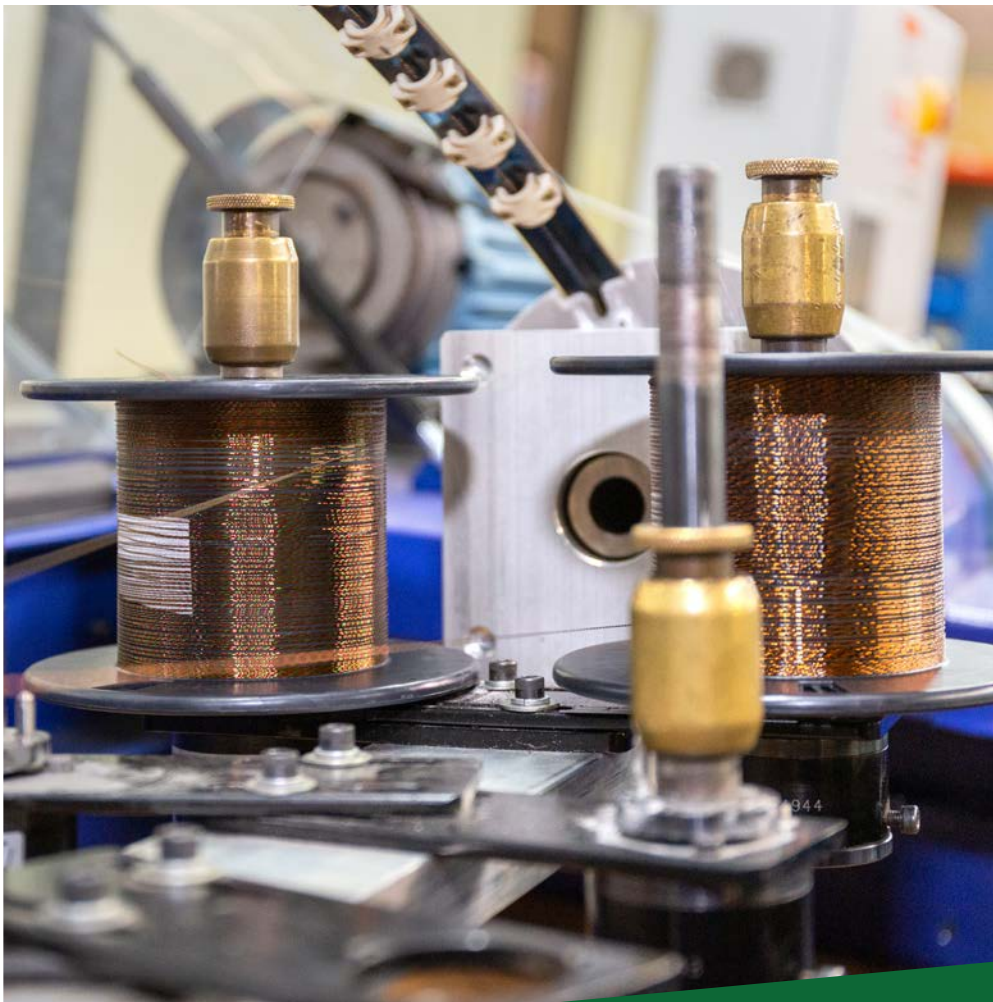
The multistrand configuration minimizes the power losses otherwise encountered in a solid conductor due to the "skin effect" or the tendency of radio frequency current to be concentrated at the surface of the conductor.

In order to counteract this effect, it is necessary to increase the amount of surface area without appreciably increasing the size of the conductor. It is also essential to position each individual strand in the Litz construction in a uniform pattern, moving from the center to the outside and back in a given length.

Even properly constructed Litz wires will exhibit some skin effect due to the limitations of stranding. Wires intended for higher frequency ranges require more strands of a finer gauge size than Litz wires of equal cross-sectional area, but composed of fewer and larger strands.

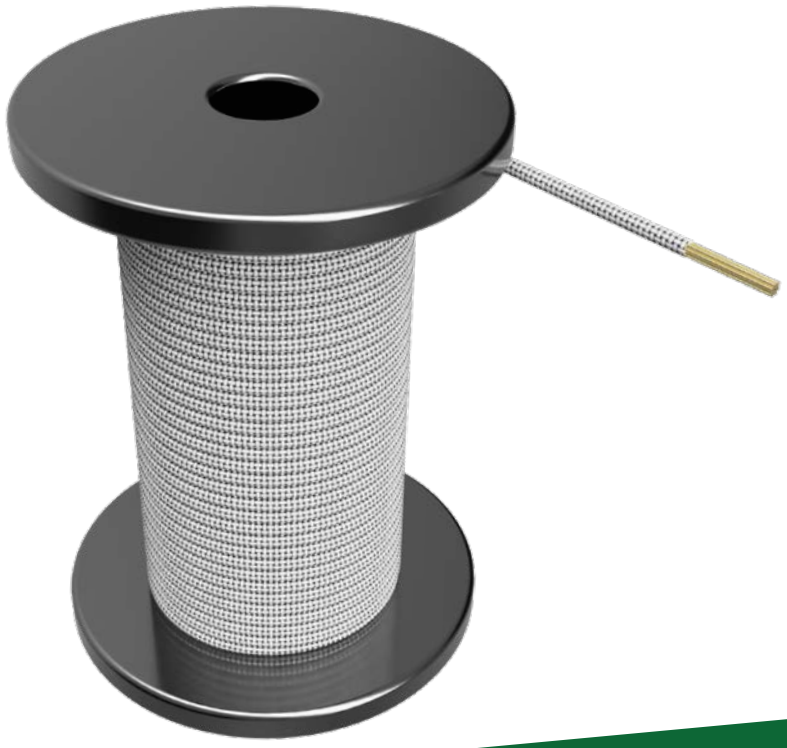
Polyurethane and Polyurethane Nylon are the films most often used for insulating individual strands because of their low electrical losses and their solderability. Other insulations shown on pages 4 and 5 can also be used. Litz wires are generally further insulated with a single or double wrap or serving of a textile - typically nylon - but are also available unserved.

The data that follows covers a broad range of sizes but is not intended to represent all possible constructions available. Inquire as to particular Litz wire constructions and allow us to provide you with wire to meet your specifications.



					UNSERVED				SERVED	
					SINGLE BUILD		HEAVY BUILD			
# OF STRANDS	SIZE (AWG)	CIRCULAR MILS	NEAREST AWG EQUIV. (CIR. MILS)	RESISTANCE (OHMS PER 1000 FT. AT 20°C)	NOMINAL O.D. (INCHES)	FEET PER POUND	NOMINAL O.D. (INCHES)	FEET PER POUND	NOMINAL O.D. (INCHES)	FEET PER POUND
10	34	397	24	26.13	0.026	798	0.027	784	0.029	770
50	34	1,985	17	5.226	0.057	162	0.061	162	0.065	161
100	34	3,969	14	2.613	0.081	81	0.087	81.3	0.092	81.1
200	34	7,938	11	1.307	0.114	41	0.122	40.7	0.131	40.7
10	40	96	30	108	0.013	3,282	0.014	3,212	0.015	3,140
50	40	481	23.5	21.58	0.029	670	0.031	667	0.033	664
100	40	961	20.5	10.79	0.040	336	0.044	335	0.047	335
500	40	4,805	13.5	2.158	0.090	67	0.098	67.3	0.106	67.3
1,000	40	9,610	10.5	1.079	0.128	34	0.139	33.7	0.15	33.7
10	44	40	34	259	0.008	7,849	0.009	7,674	0.010	7,493
100	44	400	24	25.93	0.027	807	0.029	805	0.031	803
500	44	2,000	17	5.186	0.059	162	0.065	162	0.070	162
1,000	44	4,000	14	2.593	0.084	81	0.091	80.9	0.099	80.9
2,000	44	8,000	11	1.297	0.119	40	0.129	40.5	0.139	40.5
10	48	15	38	675	0.005	20,511	0.006	19,963	0.006	19,197
100	48	154	28	67.45	0.016	2,101	0.018	2,095	0.020	2,086
500	48	770	21	13.49	0.036	421	0.040	421	0.045	420
1,000	48	1,540	18	6.745	0.051	211	0.057	211	0.064	210
2,000	48	3,080	15.5	3.373	0.072	105	0.080	105	0.090	105

Our Litz wire calculator provides Litz wire characteristics for sizes 18 to 43 AWG.



To view the Litz wire calculator scan the QR code

or please visit https://mwswire.com/litz-wire-tool

Resistance Wire

MWS offers many nickel based alloys that are used in RTD sensors, resistors, rheostats, voltage control relays, heating elements, potentiometers, and other components. Engineers design around properties unique to each alloy. These include resistance, thermoelectric properties, high tensile strength, coefficient of expansion, magnetic attraction, and resistance to oxidation or corrosive environments. Wires can be provided as bare or insulated. Most alloys can also be made as flat wire.

Properties of Major Alloys

MATERIAL	COMPOSITION (%)	RESISTIVITY AT 20°C		COEFFICIENT OF LINEAR EXPANSION	TENSILE STRENGTH (KPSI AT 20°C)		DENSITY	SPECIFIC GRAV-ITY	MAGNETIC ATTRACTION	MELTING POINT APPROX
		OHMS/ CMF	TCR (0-100°C)	µm/m (0-100°C)	MIN.	MAX.	lb/in³			(°C)
MWS-875	22.5 Cr, 5.5 Al, .5 Si, .1 C, bal. Fe	875	0.00002	0.000012	105	175	0.256	7.10	Strong	1,520
MWS-800	75 Ni, 20 Cr, 2.5 Al, 2.5 Cu	800	0.00002	0.000014	100	200	0.293	8.10	None	1,350
MWS-675	61 Ni, 15 Cr, bal. Fe	675	0.00013	0.000014	95	175	0.298	8.25	Faint	1,350
MWS-650	80 Ni, 20 Cr	650	0.0001	0.000013	100	200	0.304	8.41	None	1,400
ALLOY 42	42 Ni, bal. Fe	390	0.001	0.000003	70	150	0.295	8.10	Strong	1,425
MWS-294	55 Cu, 45 Ni	294	0.000020*	0.000015	60	135	0.321	8.90	None	1,210
MWS-294R	29 Ni, 17 Co, bal. Fe	294	0.0033	0.000003	65	150	0.302	8.36	Strong	1,450
MANGANIN	13 Mn, 4 Ni, bal. Cu	290	0.000015**	0.000019	40	90	0.296	8.19	None	1,020
ALLOY 52	50.5 Ni, bal. Fe	260	0.0029	0.000005	70	150	0.301	8.25	Strong	1,425
MWS-180	23 Ni., bal. Cu	180	0.00018	0.000016	50	100	0.321	8.90	None	1,100
MWS-120	70 Ni, 30 Fe	120	0.0045	0.000015	70	150	0.305	8.46	Strong	1,425
MWS-90	12 Ni, bal. Cu	90	0.0004	0.000016	35	75	0.321	8.90	None	1,100
MWS-60	6 Ni, bal. Cu	60	0.0005	0.000016	35	70	0.321	8.90	None	1,100
MWS-30	2 Ni, bal. Cu	30	0.0013	0.000017	30	60	0.321	8.90	None	1,100
NICKEL 205	99 Ni	57	0.0048	0.000013	60	135	0.321	8.90	Strong	1,450
NICKEL 270	99.9 Ni	45	0.0067	0.000013	48	95	0.321	8.89	Strong	1,452

*TCR at 25-105°C **TCR at 15-35°C Note: Available bare or insulated. See pages 4 and 5 for available insulations.

Trade Name Cross Reference

MWS WIRE IND.	CARPENTER TECH.	DRIVER-HARRIS	HARRISON	HOSKINS	JELLIFF	KANTHAL	MOLECU
MWS-875	Alchrome 875		HAI-FeCr Al 25	Alloy 875		Kanthal A-I	
MWS-800	Evanohm	Karma	HAI-431	Chromel R	Alloy 800	Nikrothal L	Moleculoy
MWS-675	Tophet C	Nichrome	HAI-NiCr 60	Chromel C	Alloy C	Nikrothal 6	Electroloy
MWS-650	Tophet A	Nichrome V	HAI-NiCr 80	Chromel A	Alloy A	Nikrothal 8	Protoloy
MWS-294	Cupron	Advance	HAI-CuNi 102	Copel	Alloy 45	Cuprothal 294	Neutroloy
MWS-294R	Kovar		HAI-373				
MWS-180	180 Alloy	Midohm	HAI-180	Alloy 380	Alloy 180	Cuprothal 180	
MWS-120	Balco	Hytemco	HAI-380		Alloy 120		Pelcoloy
MWS-90	90 Alloy	#95 Alloy	HAI-90	Alloy 290	Alloy 90	Cuprothal 90	
MWS-60	60 Alloy	Lohm	HAI-60	Alloy 260	Alloy 60	Cuprothal 60	
MWS-30	30 Alloy	#30 Alloy	HAI-30	Alloy 230	Alloy 30	Cuprothal 30	

SIZE (AWG)	DIA. (INCHES)	NOMINAL OHMS											
		NI 270	NI 205	MWS 875	MWS 800	MWS 675	MWS 650	MANGANIN	MWS 294	MWS 120	ALLOY 180	ALLOY 90	ALLOY 30
Resistivity		0.000045	0.000057	0.000875	0.000800	0.000675	0.000650	0.000290	0.000294	0.000120	0.000180	0.000090	0.000030
6	0.1620	0.0017	0.0022	0.0333	0.0305	0.0257	0.0248	0.0111	0.0112	0.0046	0.0069	0.0034	0.0011
7	0.1440	0.0022	0.0027	0.0422	0.0386	0.0326	0.0313	0.0140	0.0142	0.0058	0.0087	0.0043	0.0014
8	0.1280	0.0027	0.0035	0.0534	0.0488	0.0412	0.0397	0.0177	0.0179	0.0073	0.0110	0.0055	0.0018
9	0.1140	0.0035	0.0044	0.0673	0.0616	0.0519	0.0500	0.0223	0.0226	0.0092	0.0139	0.0069	0.0023
10	0.1020	0.0043	0.0055	0.0841	0.0769	0.0649	0.0625	0.0279	0.0283	0.0115	0.0173	0.0087	0.0029
11	0.0910	0.0054	0.0069	0.1057	0.0966	0.0815	0.0785	0.0350	0.0355	0.0145	0.0217	0.0109	0.0036
12	0.0808	0.0069	0.0087	0.1340	0.1225	0.1034	0.0996	0.0444	0.0450	0.0184	0.0276	0.0138	0.0046
13	0.0720	0.0087	0.0110	0.1688	0.1543	0.1302	0.1254	0.0559	0.0567	0.0231	0.0347	0.0174	0.0058
14	0.0641	0.0110	0.0139	0.2130	0.1947	0.1643	0.1582	0.0706	0.0716	0.0292	0.0438	0.0219	0.0073
15	0.0571	0.0138	0.0175	0.2684	0.2454	0.2070	0.1994	0.0889	0.0902	0.0368	0.0552	0.0276	0.0092
16	0.0508	0.0174	0.0221	0.3391	0.3100	0.2616	0.2519	0.1124	0.1139	0.0465	0.0698	0.0349	0.0116
17	0.0453	0.0219	0.0278	0.4264	0.3898	0.3289	0.3168	0.1413	0.1433	0.0585	0.0877	0.0439	0.0146
18	0.0403	0.0277	0.0351	0.5388	0.4926	0.4156	0.4002	0.1786	0.1810	0.0739	0.1108	0.0554	0.0185
19	0.0359	0.0349	0.0442	0.6789	0.6207	0.5237	0.5043	0.2250	0.2281	0.0931	0.1397	0.0698	0.0233
20	0.0320	0.0439	0.0557	0.8545	0.7813	0.6592	0.6348	0.2832	0.2871	0.1172	0.1758	0.0879	0.0293
21	0.0285	0.0554	0.0702	1.0773	0.9849	0.8310	0.8002	0.3570	0.3620	0.1477	0.2216	0.1108	0.0369
22	0.0253	0.0703	0.0890	1.3670	1.2498	1.0545	1.0155	0.4531	0.4593	0.1875	0.2812	0.1406	0.0469
23	0.0226	0.0881	0.1116	1.7131	1.5663	1.3216	1.2726	0.5678	0.5756	0.2349	0.3524	0.1762	0.0587
24	0.0201	0.1114	0.1411	2.1658	1.9801	1.6708	1.6089	0.7178	0.7277	0.2970	0.4455	0.2228	0.0743
25	0.0179	0.1404	0.1779	2.7309	2.4968	2.1067	2.0287	0.9051	0.9176	0.3745	0.5618	0.2809	0.0936
26	0.0159	0.1780	0.2255	3.4611	3.1644	2.6700	2.5711	1.1471	1.1629	0.4747	0.7120	0.3560	0.1187
27	0.0142	0.2232	0.2827	4.3394	3.9675	3.3476	3.2236	1.4382	1.4580	0.5951	0.8927	0.4463	0.1488
28	0.0126	0.2834	0.3590	5.5115	5.0391	4.2517	4.0942	1.8267	1.8519	0.7559	1.1338	0.5669	0.1890
29	0.0113	0.3524	0.4464	6.8525	6.2652	5.2862	5.0905	2.2711	2.3025	0.9398	1.4097	0.7048	0.2349
30	0.0100	0.4500	0.5700	8.7500	8.0000	6.7500	6.5000	2.9000	2.9400	1.2000	1.8000	0.9000	0.3000
31	0.0089	0.5681	0.7196	11.0466	10.0997	8.5217	8.2060	3.6612	3.7117	1.5150	2.2724	1.1362	0.3787
32	0.0080	0.7031	0.8906	13.6719	12.5000	10.5469	10.1563	4.5313	4.5938	1.8750	2.8125	1.4063	0.4688
33	0.0071	0.8927	1.1307	17.3577	15.8699	13.3902	12.8943	5.7528	5.8322	2.3805	3.5707	1.7854	0.5951
34	0.0063	1.1338	1.4361	22.0459	20.1562	17.0068	16.3769	7.3066	7.4074	3.0234	4.5351	2.2676	0.7559
35	0.0056	1.4349	1.8176	27.9018	25.5102	21.5242	20.7270	9.2474	9.3750	3.8265	5.7398	2.8699	0.9566
36	0.0050	1.8000	2.2800	35.0000	32.0000	27.0000	26.0000	11.6000	11.7600	4.8000	7.2000	3.6000	1.2000
37	0.0045	2.2222	2.8148	43.2099	39.5062	33.3333	32.0988	14.3210	14.5185	5.9259	8.8889	4.4444	1.4815
38	0.0040	2.8125	3.5625	54.6875	50.0000	42.1875	40.6250	18.1250	18.3750	7.5000	11.2500	5.6250	1.8750
39	0.0035	3.6735	4.6531	71.4286	65.3061	55.1020	53.0612	23.6735	24.0000	9.7959	14.6939	7.3469	2.4490
40	0.0031	4.6826	5.9313	91.0510	83.2466	70.2393	67.6379	30.1769	30.5931	12.4870	18.7305	9.3652	3.1217
41	0.0028	5.7398	7.2704	111.6071	102.0408	86.0969	82.9082	36.9898	37.5000	15.3061	22.9592	11.4796	3.8265
42	0.0025	7.2000	9.1200	140.0000	128.0000	108.0000	104.0000	46.4000	47.0400	19.2000	28.8000	14.4000	4.8000
43	0.0022	9.2975	11.7769	180.7851	165.2893	139.4628	134.2975	59.9174	60.7438	24.7934	37.1901	18.5950	6.1983
44	0.0020	11.2500	14.2500	218.7500	200.0000	168.7500	162.5000	72.5000	73.5000	30.0000	45.0000	22.5000	7.5000
45	0.0018	14.5274	18.4013	282.4768	258.2645	217.9106	209.8399	93.6209	94.9122	38.7397	58.1095	29.0548	9.6849
46	0.0016	18.2563	23.1247	354.9840	324.5568	273.8448	263.7024	117.6518	119.2746	48.6835	73.0253	36.5126	12.1709
47	0.0014	22.9592	29.0816	446.4286	408.1633	344.3878	331.6327	147.9592	150.0000	61.2245	91.8367	45.9184	15.3061
48	0.0012	29.2664	37.0708	569.0687	520.2914	438.9958	422.7367	188.6056	191.2071	78.0437	117.0656	58.5328	19.5109
49	0.0011	36.5230	46.2625	710.1696	649.2979	547.8451	527.5546	235.3705	238.6170	97.3947	146.0920	73.0460	24.3487
50	0.0010	45.9137	58.1573	892.7660	816.2432	688.7052	663.1976	295.8882	299.9694	122.4365	183.6547	91.8274	30.6091
51	0.0009	58.1095	73.6054	1,129.9070	1,033.0579	871.6426	839.3595	374.4835	379.6488	154.9587	232.4380	116.2190	38.7397
52	0.0008	73.9645	93.6884	1,438.1986	1,314.9244	1,109.4675	1,068.3761	476.6601	483.2347	197.2387	295.8580	147.9290	49.3097
53	0.0007	91.8367	116.3265	1,785.7143	1,632.6531	1,377.5510	1,326.5306	591.8367	600.0000	244.8980	367.3469	183.6735	61.2245
54	0.0006	117.0656	148.2830	2,276.2747	2,081.1655	1,755.9834	1,690.9469	754.4225	764.8283	312.1748	468.2622	234.1311	78.0437
55	0.0006	148.7603	188.4298	2,892.5620	2,644.6281	2,231.4050	2,148.7603	958.6777	971.9008	396.6942	595.0413	297.5207	99.1736

Plated Wire

MWS offers a complete line of electroplated wire in round and ribbon shapes. Wires inventoried include those meeting QQ-W-343, AA59551, Mil Std 1276, ASTM B298, ASTM B355, and ASTM B488 requirements. These wires were developed for applications where severe operating environments may degrade conventional conductor materials. Conventional copper wires are plated with gold, silver, or nickel in a variety of plating thicknesses, and then are film-insulated. At elevated temperatures, these wires can operate for extremely long periods of time, as the plated constructions prevent high-temperature chemical migration and conductor oxidation. Tin and copper plated wires are insulated for lower temperature applications. Sizes 14-56 AWG can be produced in single end, parallel bonded, and twisted constructions. Also offered is braided and stranded constructions.

Plating Finishes - Gold, Silver, Nickel, Tin, Tin/Lead (60/40, 70/30, 90/10)

Surface Conditions and Treatments - Bright, semi-bright, or matte finish

Conductor Materials - Copper, Nickel, Dumet, Copper-Nickel Alloys, Nickel-Iron Alloys, Nickel-Chromium Alloys, Beryllium Copper, Phosphor Bronze, and Brass, along with a variety of other metals and alloys.

Size Range Capabilities - Round: .125" -.0007". Flat/square/rectangular: thickness .0005" and larger, widths up to .125"

Plated Copper Wire Data

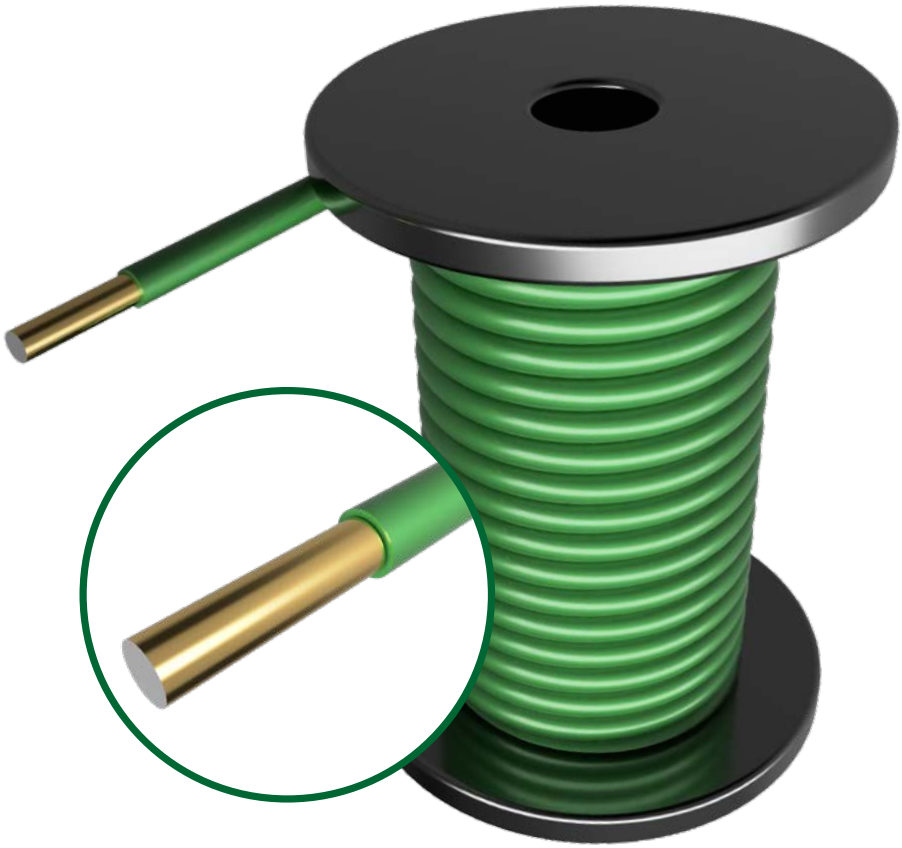
SIZE (AWG)	DIAMETER (INCHES)	CIRCULAR MILS	RESISTANCE (OHMS PER 1000 FT. AT 20°C)	POUNDS PER 1000 FT.	THICKNESS OF COATING (MICROINCHES)											
					SILVER PLATED							NICKEL PLATED				
	NOMINAL	NOMINAL	NOMINAL		1.25%	2%	2.5%	3%	4%	5%	6.1%	2%	4%	7%	10%	27%
14	0.0641	4,110	2.48	12.4	170	272	343	417	551	692	846	322	647	1,142	1,645	4,670
15	0.0571	3,260	3.13	9.87	151	243	305	371	491	617	754	282	577	1,018	1,465	4,160
16	0.0508	2,580	3.95	7.81	135	216	272	330	437	549	671	255	513	905	1,304	3,700
17	0.0453	2,050	4.98	6.21	120	193	242	294	390	489	598	228	458	807	1,162	3,300
18	0.0403	1,620	6.30	4.92	107	171	216	262	347	435	532	202	407	718	1,034	2,930
19	0.0359	1,290	7.91	3.90	95	153	192	233	309	388	474	180	363	640	921	2,610
20	0.0320	1,020	10.0	3.10	85	136	171	208	247	346	422	161	323	570	821	2,330
21	0.0285	812	12.6	2.46	76	121	152	185	245	308	376	143	288	508	731	2,070
22	0.0253	640	15.9	1.94	67	108	135	164	218	273	334	127	255	451	649	1,850
23	0.0226	511	20.0	1.55	60	96	121	147	194	244	293	114	228	403	580	1,640
24	0.0201	404	25.2	1.22	53	85	108	131	173	217	265	101	203	358	516	1,460
25	0.0179	320	31.9	0.970	47	76	96	116	154	193	236	90	181	319	459	1,300
26	0.0159	253	40.3	0.765	42	68	85	103	137	172	210	80	161	283	408	1,160
27	0.0142	202	50.5	0.610	38	60	76	92	122	153	187	71	143	253	364	1,030
28	0.0126	159	64.2	0.481	33	54	67	82	108	136	166	63	127	224	323	920
29	0.0113	128	79.7	0.387	30	48	60	73	97	122	149	57	114	201	290	820
30	0.0100	100	102	0.303	27	43	54	65	86	108	132	50	101	178	256	730
31	0.0089	79.2	129	0.240	24	38	48	58	77	96	117	45	90	159	228	650
32	0.0080	64.0	159	0.194	21	34	43	52	69	86	106	40	81	143	205	580
33	0.0071	50.4	202	0.153	19	30	38	46	61	77	94	36	72	126	182	520
34	0.0063	39.7	257	0.120	17	27	34	41	54	68	83	32	64	112	162	460
35	0.0056	31.4	325	0.0949	15	24	30	36	48	60	74	28	57	100	144	410
36	0.0050	25.0	408	0.0757	13	21	27	33	43	54	66	25	50	89	128	360
37	0.0045	20.2	505	0.0613	12	19	24	29	39	48	59	23	45	80	116	320
38	0.0040	16.0	638	0.0484	11	17	21	26	34	43	53	20	40	71	103	290
39	0.0035	12.2	836	0.0371	9	15	19	23	30	38	46	18	35	62	90	260
40	0.0031	9.61	1061	0.0291	8	13	17	20	27	33	41	16	31	55	80	230

Precious Metals

MWS inventories bare pure gold, silver and platinum from AWG 16 and finer, as well as rolled rectangular sizes. These precious metals can be insulated and produced in Multifilar® and Twistite™ constructions.

Properties of Specialty Metals

METAL	ATOMIC SYMBOL	ELECTRICAL RESISTIVITY (OHMS/CMF AT 20°C)	TEMPERATURE COEFFICIENT of RESISTANCE (0-100°C)	COEFFICIENT OF LINEAR EXPANSION (µm/m AT 20°C)	TENSILE STRENGTH (KPSI) ANNEALED	DENSITY (lb/in³)	MELTING POINT APPROX (°C)
Gold	Au	13.31	0.00372	14.2	30-32	0.698	1,064
Platinum	Pt	63.91	0.00393	8.9	18-24	0.775	1,769
Silver	Ag	9.56	0.00382	18.9	18-27	0.379	962



Copper and Copper Alloys

Copper Wire Data

CDA ALLOY NO.	ALLOY NAME	COMPOSITION	TENSILE STRENGTH		YIELD STRENGTH		ELONGATION		ELECTRICAL CONDUCTIVITY	ELECTRICAL RESISTIVITY	DENSITY	MELTING POINT APPROX
			KPSI		KPSI		%					
		%	Hard	Soft	Hard	Soft	Hard	Soft	IACS (68°F)	OHMS/CMF	lb/in³	°C
C10100	Certified OFHC Copper	Other, 99.99 Cu min.	55	34	50	11	6	36	101	10.3	0.323	1,083
C10200	OFHC Copper	Other, 99.95 Cu min.	55	34	50	11	6	36	101	10.3	0.323	1,083
C11000	ETP Copper	.04 O, 99.90 Cu min.	55	34	50	12	5	36	100	10.3	0.323	1,065
C15000	Zirconium Copper	.15 Zr, 99.85 Cu	64	30	62	13	1.5	30	93	11.2	0.321	980
C17200	Beryllium Copper	1.9 Be, 98.1 Cu	152	68	125	28	1	42	22	46.2	0.298	866
C26000	Cartridge Brass	30 Zn, 70 Cu	109	52	68	21	5	30	28	37.0	0.308	916
C51000	Phosphor Bronze	5.0 Sn, .2 P, 94.8 Cu	110	51	85	21	5	49	15	69.1	0.32	954

Properties are nominal values, and should not be used for specification purposes. Elongation values are generally size dependent.

Certified OFHC Copper (CDA C10100)

This is an unalloyed, high purity copper that has excellent forming and brazing characteristics, as well as resistance to hydrogen embrittlement at elevated temperatures. It has good solderability and corrosion resistance, and may be used in any high current application. Both grades of OFHC copper are available in round and shaped wire and may be substituted for ETP copper wherever optimal properties of copper are desired.

OFHC Copper (CDA C10200)

OFHC copper has 99.95% minimum copper (silver counted as copper) and is produced by converting cathodes in a continuous casting and rolling process into copper rod. Typical uses include bus bars or any electrical conductor, and it may be specified as a special magnet wire conductor.

ETP Copper (CDA C11000)

Electrolytic tough pitch copper is intentionally alloyed with oxygen to achieve the best combination of conductivity, capacity for being cold worked, and economy. This is the most widely used copper for wire conductors and is available in round, square and rectangular shapes.

Zirconium Copper (CDA C15000)

This copper alloy exhibits high conductivity, excellent solderability, and good strength. Unlike ETP and the OFHC coppers, zirconium copper resists softening at higher temperatures. Typical applications include switches, high current interconnects, terminal pins, welding tips, and other applications where high temperatures exist.

Beryllium Copper (CDA C17200)

This alloy is characterized by very high strength and good electrical conductivity. Normally supplied in age-hardenable tempers, beryllium copper has good to excellent cold workability. This alloy is available as bare wire or it can be film insulated. Typical uses include switch parts, springs, fuse clips, connectors, and contacts.

Cartridge Brass (CDA C26000)

Cartridge brass has good conductivity and strength, but poor solderability due to its high zinc content. This copper alloy is widely used for cold-headed products such as machine and wood screws, rivets, and fasteners. It may also be used as an economical spring material.

Phosphor Bronze (CDA C51000)

This alloy is widely used for most types of springs because of its high strength and resistance to corrosion and fatigue. It is also used in switches, relays, contacts, and fasteners.

MWS offers High Performance Wire in Extra (XHTW) and Extreme (EHTW) tensile strength with all insulation types and as bare wire. Most alloys are available with nickel, silver, or gold plating.

MWS High Performance Wire (HPW) products are copper alloy conductors specifically designed for applications with high mechanical stress that also require high conductivity. Through improved characteristics of the wire, lifespan and reliability under dynamic load are increased.

High Strength Wire

METAL		COPPER	BERYLLIUM COPPER	PHOSPHOR BRONZE	XHTW	EHTW
Description		ETP C11000	C17200	C51000	Extra High Tensile Wire	Extreme High Tensile Wire
Density	(lb/cu in)	0.323	0.298	0.32	0.325	0.325
Conductivity	(% IACS-Soft)	100	22	15	89	80
Electrical Resistance	(ohms/cir mil ft)	10.3	46.2	69.1	11.8	12.9
Tensile (Soft)	ksi	34	68	51	50	56
Tensile (Hard)	ksi	55	152	110	62	68
Elongation (a)	%	6 to 36	1 to 42	5 to 49	10 to 25	10 to 30
Solderability		Excellent	Good	Excellent	Good	Good
Weldability		Excellent	Good	Excellent	Good	Good
Bend Test (b)		100			600	1,050

(a) Tensile and elongation values are nominal and generally size dependent

(b) Fatigue strength compared to annealed copper

Wire Properties

- Increased Tensile Strength – over 50% greater than ETP copper
- High Conductivity – up to 89% of ETP copper
- Good Solderability and Weldability – no performance loss compared to copper
- Increased Bending Performance – better fatigue strength results in fewer wire breaks in cable constructions

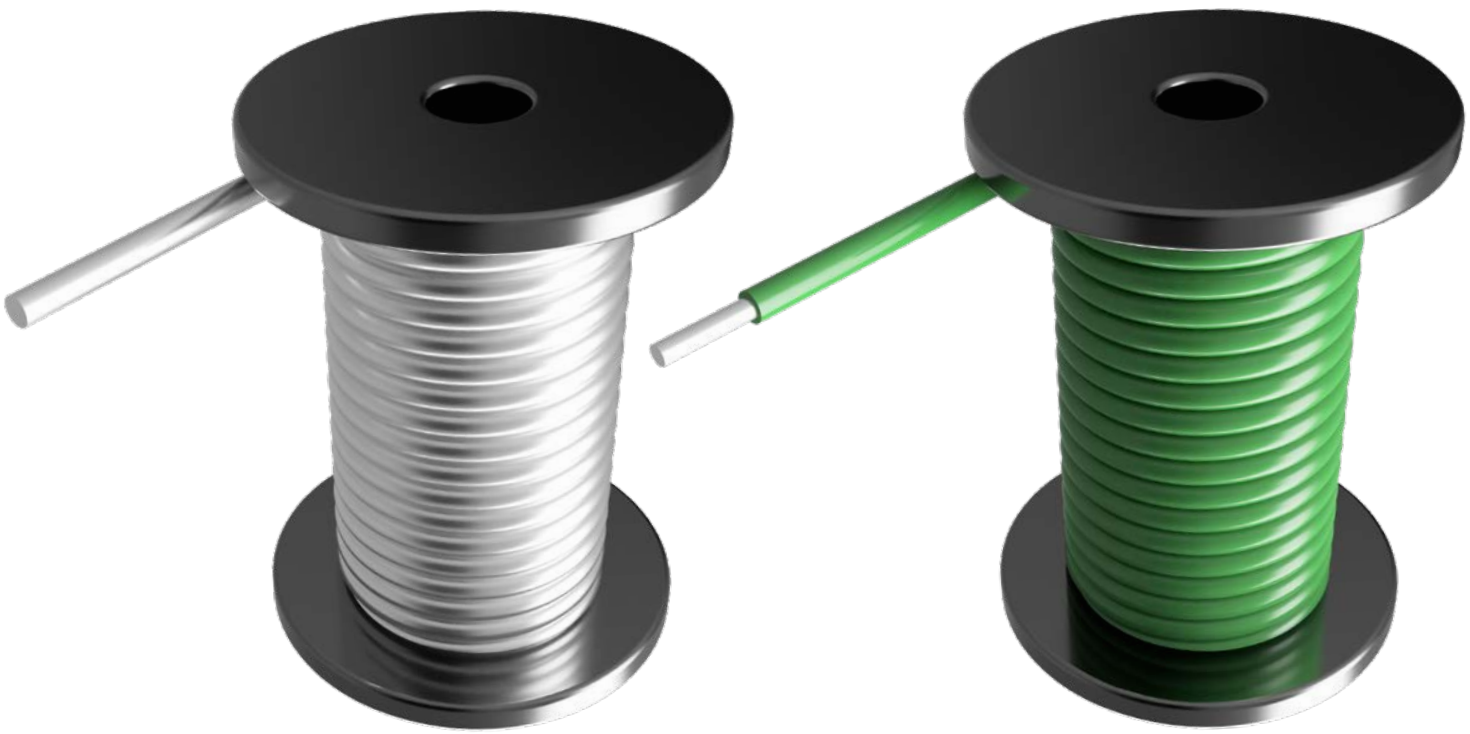
Applications

- Catheter electrode wires
- Severe coil winding applications
- Voice coils
- Miniature cables
- Aerospace applications

Aluminum and Aluminum Alloys

Aluminum's unique combination of properties make it a highly versatile material when alloyed with various metals. Besides light weight, characteristics of aluminum alloys include excellent workability and inherent corrosion resistance due to the inert oxide coat that forms directly after exposure to air. Many alloys in the 1000 through 5000 series are non-heat-treatable, their strength depends on the amount of cold working done. In the case of 5056 alloy, the addition of magnesium as the principal alloying agent increases its initial tensile strength. Alloy 6061 is a heat-treatable alloy supplied in annealed or strain hardened tempers. The end user may achieve maximum tensile strength through a multi-step thermal treatment.

ALLOY	CHEMICAL COMPOSITION (%)	TENSILE STRENGTH (KPSI)	ELECTRICAL CONDUCTIVITY IACS (68°F)	RESISTIVITY (OHMS/CMF)	DENSITY (lb/in³)	SPECIFIC GRAVITY	COEFFICIENT OF LINEAR EXPANSION (µm/m AT 20°C)	MELTING POINT APPROX (°C)
1350(EC)	99.5 Al min.	13	61.8	17	0.098	2.7	23.8	649
1100	.12 Cu, 99 Al min.	13	59	18	0.098	2.71	23.6	646
1199	99.996 Al min.	7	64.9	15	0.0975	2.7	23.6	660
5056	.12 Mn, 5 Mg, .12 Cr, Al bal.	42	29	36	0.095	2.64	24.1	571
6061	.6 Si, .28 Cu, 1 Mg, .2 Cr, Al bal.	17	47	22	0.098	2.7	23.6	582



EC Aluminum Wire Data

Aluminum 1350, also referred to as EC (electrical conductor) aluminum, is the primary alloy utilized in aluminum magnet wire. Its combination of light weight, high thermal conductivity, and high mass electrical conductivity (more than twice that of copper, per pound), make it an ideal alternative to copper for certain winding applications. Most film insulations are available on round aluminum wire. Please contact sales for sizes smaller than 40 AWG.

SIZE (AWG)	DIAMETER (INCHES)			RESISTANCE (OHMS PER 1000 FT. AT 20°C)			FEET PER POUND	POUNDS PER 1000 FT.	CIRCULAR MILS	SIZE (AWG)
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.			NOMINAL	
10	.1009	.1019	.1027	1.612	1.632	1.665	104	9.56	10,380	10
11	.0898	.0907	.0916	2.020	2.060	2.101	132	7.60	8,230	11
12	.0800	.0808	.0816	2.545	2.596	2.648	166	6.03	6,530	12
13	.0713	.0720	.0727	3.206	3.269	3.333	209	4.79	5,190	13
14	.0635	.0641	.0647	4.048	4.124	4.203	264	3.80	4,110	14
15	.0565	.0571	.0577	5.090	5.198	5.308	332	3.01	3,260	15
16	.0503	.0508	.0513	6.439	6.567	6.698	420	2.38	2,580	16
17	.0448	.0453	.0458	8.079	8.258	8.443	528	1.90	2,050	17
18	.0399	.0403	.0407	10.23	10.43	10.64	667	1.50	1,620	18
19	.0355	.0359	.0363	12.86	13.15	13.45	840	1.19	1,290	19
20	.0317	.0320	.0323	16.24	16.55	16.86	1,057	0.946	1,020	20
21	.0282	.0285	.0288	20.43	20.86	21.31	1,333	0.750	812	21
22	.0250	.0253	.0256	25.86	26.47	27.11	1,691	0.591	640	22
23	.0224	.0226	.0228	32.60	33.18	33.77	2,120	0.472	510	23
24	.0199	.0201	.0203	41.12	41.94	42.79	2,680	0.373	404	24
25	.0177	.0179	.0181	51.73	52.89	54.09	3,379	0.296	320	25
26	.0157	.0159	.0161	65.38	67.03	68.75	4,283	0.234	253	26
27	.0141	.0142	.0143	82.87	84.04	85.24	5,369	0.186	202	27
28	.0125	.0126	.0127	105.1	106.7	108.5	6,820	0.1470	159	28
29	.0112	.0113	.0114	130.4	132.7	135.1	8,479	0.1180	128	29
30	.0099	.0100	.0101	166.1	169.5	172.9	10,827	0.0920	100	30
31	.0088	.0089	.0090	209.2	213.9	218.8	13,669	0.0732	79.21	31
32	.0079	.0080	.0081	258.3	264.8	271.5	16,917	0.0591	64.00	32
33	.0070	.0071	.0072	326.9	336.2	345.8	21,478	0.0466	50.41	33
34	.0062	.0063	.0064	413.7	427.0	440.8	27,279	0.0367	39.69	34
35	.0055	.0056	0.0057	521.6	540.4	560.2	34,524	0.0290	31.36	35
36	.0049	.0050	.0051	651.5	677.8	705.8	43,307	0.0231	25.00	36
37	.0044	.0045	.0046	800.9	836.8	875.3	53,466	0.0187	20.25	37
38	.0039	.0040	.0041	1,008	1,059	1,114	67,668	0.0148	16.00	38
39	.0034	.0035	.0036	1,308	1,383	1,466	88,383	0.0113	12.25	39
40	.0030	.0031	.0032	1,655	1,763	1,883	112,663	0.0089	9.61	40

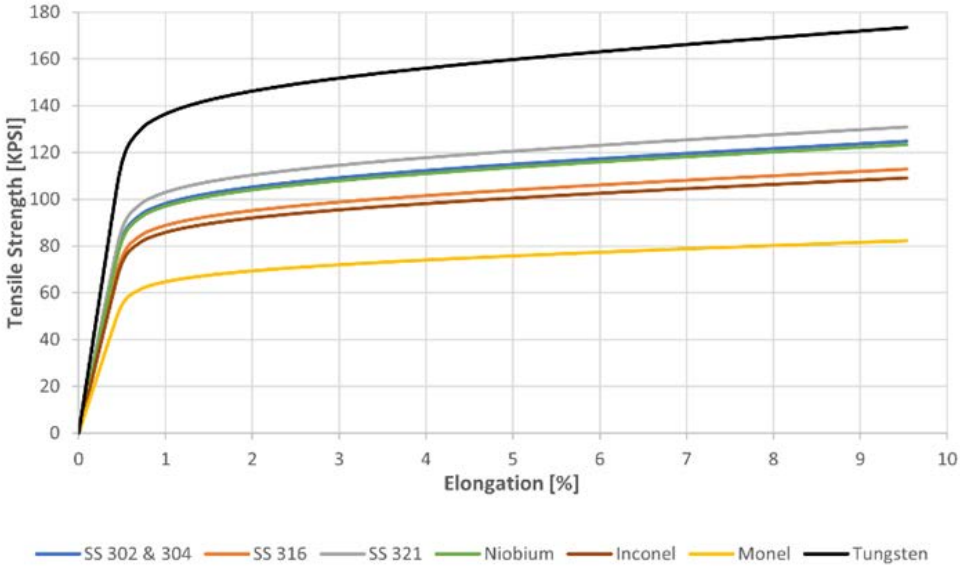
Mechanical Alloys

When selecting wire for mechanical applications there are four classifications from which to choose a specific material or alloy. They are: nickel base lockwires, carbon steels, stainless steels and superalloys. A three-part evaluation procedure is recommended: 1) initial screening based on temperature and corrosion requirements; 2) analysis of physical properties; and 3) final screening on the basis of specific properties, material, and forming costs.

MATERIAL	COMPOSITION (%)	RESISTIVITY	COEFFICIENT OF LINEAR EXPANSION (0-100°C)	TENSILE STRENGTH NOMINAL (KPSI)		DENSITY	MAGNETIC ATTRACTION	MELTING POINT
		OHMS/CMF	µm/m	SOFT	HARD	lb/in³		(°C)
#302 Stainless Steel	Cr 18, Ni 9, Mn 2, Si 1, C .12, N .1, P .045, S .03, Bal Fe	433.1	17.3	125	330	0.290	None	1,410
#304 Stainless Steel	Cr 19, Ni 9.25, Mn 2, Si 1, C .08, N .1, P .045, S .03, Bal Fe	433.1	17.3	125	330	0.290	None	1,425
#316 Stainless Steel	Cr 17.25, Ni 12, Mo 2.25, Mn 2, Si 1, C .07, N 0.1, P .045, S .03, Bal Fe	444.6	15.9	113	260	0.290	None	1,387
#321 Stainless Steel	Cr 18, Ni 10.5, Mn 2, Si 1, Ti .4, C .08, P .045, S .03, Bal Fe	433.1	16.6	130	250	0.290	None	1,387
Inconel* 600	Ni 72, Cr 15.5, Fe 8, Mn 1, Cu .5, Si .5, C .15, S.015	619.6	11.8	110	205	0.306	None	1,384
Inconel* X-750	Ni 70, Cr 15.5, Fe 7, Ti 2.5, Mn 1, Nb .75, Al 0.7, Si .5, Cu .5, C .08, S .01	733.9	12.0	145	225	0.299	None	1,410
Monel* 400	Ni 63-70, Cu 28-34, Fe 2.5, Mn 2, Si .5, C .3, S .024	329.0	13.5	83	163	0.318	Weak	1,325
Niobium	Ta .20, W .05, O .025, Hf .02, C .01, N .01, Al .005, Balance Nb	91.43	7.0	125	240	0.310	Strong	2,477
Tungsten	W 99.95 min, Thorium balance	33.08	4.3	175	500	0.697	Weak	3,410

*Registered trademark of Inco family of companies

Mechanical Alloys Stress-Strain Relation Curve

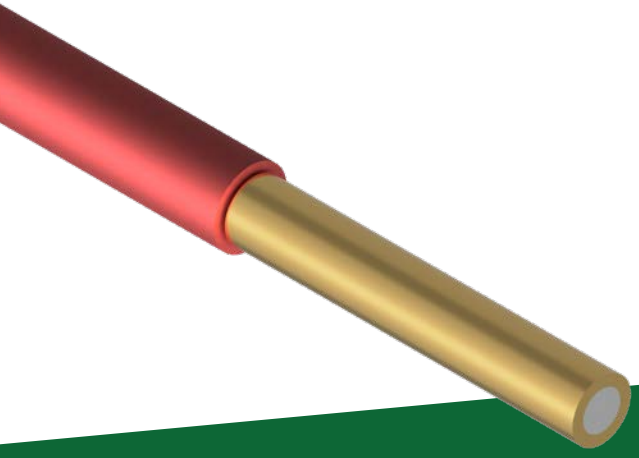


Copper Clad Aluminum and Other Clad Metals

Clad metals are two distinct metals or alloys that are metallurgically bonded together for achieving specific functional properties. It is a composite wire composed of multiple metallic phases and allows greater amount of material in contrast to plating metals. Copper clad aluminum (CCA) is an electrical conductor having a copper sleeve bonded to a solid aluminum core, manufactured in compliance with ASTM B-566. The copper clad accounts for either 10% or 15% of the wire's cross-sectional area and assures excellent conductivity and solderability, whereas the aluminum core contributes to lower weights. CCA exhibits AC conductivity equal to solid copper at frequencies greater than 5 MHz. Another example is copper clad steel (CCS) which is a conductor having a copper sleeve bonded to a solid low-carbon steel core. CCS is a high-strength conductor manufactured in accordance with ASTM B-452, where the cladded copper provides a superior electrical conductivity, and the steel core contributes to greater tensile strength and fatigue resistance. For certain medical applications, these CCS conductors can be made substantially stronger and corrosive-resistant by using a 300 series core instead, referred to as copper-clad stainless steel (CCSS) per ASTM B-910. Nickel clad copper (NCC) accounts for 27% Nickel clad per ASTM B-355 is used in applications where high temperatures, oxidizing, or corrosive atmospheres exist. It has electrical conductivity approximately 70% that of copper and the corrosion resistance of pure nickel. Dumet is a Copper clad Nickel-Iron alloy widely used to obtain hermetic seals in soft glass. This is possible because the thermal expansion of the Ni-Fe alloy closely matches to that of glass, and the material "wets" well to bond with the glass. The copper clad around contributes to its electrical conductivity, solderability, ductility and the ability to be supplied electroplated with gold, tin, or solder. Dumet conforms to ASTM F29-63T and its typical applications include electronic wire leads of all varieties. MWS produces clad metals in insulated and bare sizes from 14 through 44 AWG. For insulation data, see pages 4 and 5.

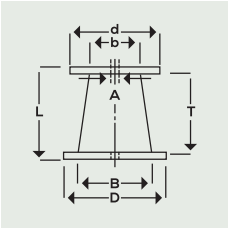
Clad Metals

MATERIAL	RESISTIVITY	CONDUCTIVITY	TENSILE STRENGTH NOMINAL (KPSI)		DENSITY	MAGNETIC ATTRACTION
	Ohms/CMF	IACS	Soft	Hard	lb/in³	
Copper Clad Aluminum 10%	16.50	62.9%	25	30	0.120	Non-Magnetic
Copper Clad Aluminum 15%	16.10	64.4%	25	30	0.131	Non-Magnetic
Nickel Clad Copper	14.61	71%	55	85	0.321	Magnetic
Copper Clad Steel 40%	26.45	40%	50	110	0.294	Magnetic
Copper Clad Stainless Steel (CCSS)	27.97	37%	106	200	0.300	Non-Magnetic
Copper Clad Nickel Iron Alloy (Dumet)	58	17%	80	120	0.298	Magnetic



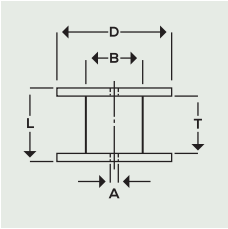
Spool Specifications

Tapered Spools



PACKAGE TYPE	FLANGE		BARREL		TRAVERSE LENGTH (T-IN.)	OVERALL LENGTH (L-IN.)	ARBOR HOLE DIAM. (A-IN.)	TARE WEIGHT (POUNDS)	NOM. NET WEIGHT (POUNDS)	
	TOP (d-IN.)	BOTTOM (B-IN.)	TOP (b-IN.)	BOTTOM (B-IN.)				PLASTIC	COPPER	ALUMINUM
TP1000	18¾	20½	9	10½	18 5/16	36⅞	1½	30	1000	300
TP500	15	16	8	9	24	26	1½	12	500	180
TP250	15	16	8	9	12	14	1½	10	250	90
TP100	10	11	6	7	12	13	1½	3.05	85	30
TP50	8½	9¼	5½	6½	9	10	1½	1.6	5	2

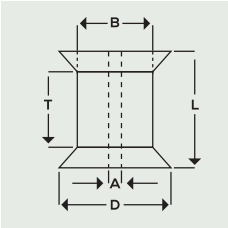
Straight Spools



PACKAGE TYPE	FLANGE		BARREL		TRAVERSE LENGTH (T-IN.)	OVERALL LENGTH (L-IN.)	ARBOR HOLE DIAM. (A-IN.)	TARE WEIGHT (POUNDS)	NOM. NET WEIGHT (POUNDS)	
	TOP (B-IN.)	BOTTOM (B-IN.)	TOP (B-IN.)	BOTTOM (B-IN.)				PLASTIC	COPPER	ALUMINUM
24"	24	24	14	14	6	8⅞	1½	20	250	80
12" x 7"	12	12	6½	6½	7	8	1½	2.8	85	26
12"x 4" WR	11¾	11¾	8¼	8¼	3⅝	4	2	1.8	30	10
8" x 6"	8	8	4½	4½	5⅝	7¼	3	1.5	30	10
6" x 6"	6	6	3¾	3¾	6	7	⅝	.95	12	5
6" DIN *	6¼	6¼	4	4	5	6¼	⅞	1.02	10	3
6" X 3½"*	6	6	3½	3½	3½	4 5/16	⅝	.66	8	3
6" X 3½"	6	6	3½	3½	3½	4	⅝	.43	8	3
6" RB	6	6	4	4	3	4	⅝	.64	8	3
4⅞" DIN*	4⅞	4⅞	3 3/16	3 3/16	4	4⅞	⅝	.55	6	2
4⅞	4⅞	4⅞	3	3	3½	4	⅝	.39	5	2
3"	3	3	1¾	1¾	3½	4	⅝	.17	2	.5
3" DIN *	3⅛	3⅛	2	2	2½	3 5/32	⅝	.15	1	.30
2½"	2½	2½	1¾	1¾	3	3⅜	⅝	.15	.5	.15
2¼"	2¼	2¼	1¾	1¾	1	15/16	⅝	.09	.20	.07

*Thick flange

Taper Flange Spools



PACKAGE TYPE	FLANGE		BARREL		TRAVERSE LENGTH (T-IN.)	OVERALL LENGTH (L-IN.)	ARBOR HOLE DIAM. (A-IN.)	TARE WEIGHT (POUNDS)	NOM. NET WEIGHT (POUNDS)	
	TOP (B-IN.)	BOTTOM (B-IN.)	TOP (B-IN.)	BOTTOM (B-IN.)				PLASTIC	COPPER	ALUMINUM
10" TF	10	11	6	7	8 -11½	12½	1½	3.12	75	20
8" TF	8	8	4	4	3⅝ - 7⅝	8	⅞	.98	22	6
6" TF	6	6	3⅛	3⅛	3 - 5¼	6¼	⅝ - ⅞	.69	8	3
5" TF	4⅞	4⅞	2½	2½	2¼ - 4	4⅞	⅝	.35	5	1.75
4" TF	4	4	2	2	1⅞ - 3¾	4	⅝	.15	3	1
3" TF	3	3	2¾	2	2¾ - 3¾	3⅞	⅝	.19	1.5	.5
2½" TF	2½	2½	1¾	1¾	2⅜ - 3¼	3⅜	⅝	.16	.66	.15

Recommended Winding Tensions

Below are recommended winding tension for round magnet wire with Copper and Aluminum conductors. They are strictly recommendations and it is suggested that you use your own validation tests to ensure that the wire is not stretched during your production process.

RECOMMENDED WINDING TENSIONS FOR ROUND COPPER AND ALUMINUM CONDUCTORS									
	COPPER				ALUMINUM				
SIZE (AWG)	MINIMUM		MAXIMUM		MINIMUM		MAXIMUM		SIZE (AWG)
	lbs	kg	lbs	kg	lbs	kg	lbs	kg	
10	61	28	82	37	12	6	22	10	10
11	48	22	65	29	10	4	18	8	11
12	38	17	51	23	8	3	14	6	12
13	31	14	41	18	6	3	11	5	13
14	24	11	32	15	5	2	9	4	14
15	19	8.7	26	12	4	2	7	3	15
16	15	6.9	20	9.2	3	1	6	3	16
17	12	5.5	16	7.3	2	1	4	2	17
18	10	4.3	13	5.8	2	1	4	2	18
19	8	3.4	10	4.6	2	1	3	1	19
20	6	2.7	8	3.6	1.3	0.6	2	1	20
21	5	2.2	6	2.9	1.0	0.3	1.8	0.8	21
22	4	1.7	5	2.3	0.8	0.3	1.4	0.6	22
23	3	1.4	4	1.8	0.6	0.3	1.1	0.5	23
24	2	1.1	3	1.0	0.5	0.2	0.9	0.4	24
25	2	0.9	3	1.1	0.4	0.2	0.7	0.3	25
26	1	0.7	2	0.9	0.3	0.1	0.5	0.2	26
27	1	0.5	2	0.7	0.2	0.1	0.4	0.2	27
SIZE (AWG)	MINIMUM		MAXIMUM		MINIMUM		MAXIMUM		SIZE (AWG)
	oz	g	oz	g	oz	g	oz	g	
28	15	425	20	565	3	85	6	160	28
29	12	340	16	455	2.5	68	4.5	125	29
30	9	270	13	360	2	54	3.5	99	30
31	7	210	10	280	1.5	42	2.8	78	31
32	6	170	8	290	1.2	34	2.2	63	32
33	5	135	6	180	0.95	27	1.75	49	33
34	4	105	5	140	0.75	21	1.40	39	34
35	3	85	4	110	0.60	17	1.10	31	35
36	2	65	3	90	0.45	13	0.85	24	36
37	2	55	3	70	0.38	11	0.71	20	37
38	2	45	2	55	0.29	8.6	0.56	16	38
39	1.2	35	1.5	45	0.23	6.5	0.42	12	39
40	0.9	25	1.2	35	0.18	5.1	0.33	9	40
41	0.7	20	1.0	28	0.15	4.2	0.27	7.7	41
42	0.6	17	0.8	22	0.12	3.3	0.22	6.1	42
43	0.5	13	0.6	17	0.09	2.6	0.17	4.7	43
44	0.4	10	0.5	13	0.07	2.1	0.14	3.9	44

Maximum value above based on yield strength of fully annealed copper wire.

Winding tensions higher than the stated maximums may cause higher resistance values.

MWS Wire Industries Accreditations

At MWS, the quality system has been certified to the standards of ISO 9001 and ISO 13485. Our mission is to provide quality magnet wire, specialty products and unsurpassed service through a quality system focused on continuous improvement of our products, processes, and customer service.

Gauge to MM Conversion Chart

A.W.G.			WIRE NUMBER	S.W.G.		
INCH	MM	MM²		INCH	MM	MM²
.4600	11,684	107,21	4/0	.4000	10,1600	81,07
.4096	10,404	85,03	3/0	.3720	9,4487	70,12
.3648	9,266	67,43	2/0	.3480	8,8391	61,36
.3249	8,252	53,48	1/0	.3240	8,2295	53,19
.2893	7,348	42,41	1	.3000	7,6200	45,60
.2576	6,543	33,63	2	.2760	7,0103	38,60
.2294	5,827	26,67	3	.2520	6,4008	32,18
.2043	5,189	21,15	4	.2320	5,8972	27,27
.1819	4,621	16,77	5	.2120	5,3847	22,77
.1620	4,115	13,30	6	.1920	4,8768	18,68
.1443	3,665	10,55	7	.1760	4,4703	15,70
.1285	3,264	8,37	8	.1600	4,0640	12,97
.1144	2,906	6,63	9	.1440	3,6576	10,51
.1019	2,588	5,26	10	.1280	3,2512	8,30
.0907	2,304	4,17	11	.1160	2,9463	6,82
.0808	2,052	3,30	12	.1040	2,6416	5,48
.0720	1,829	2,62	13	.0920	2,3368	4,29
.0641	1,628	2,08	14	.0800	2,0320	3,24
.0571	1,450	1,65	15	.0720	1,8288	2,63
.0508	1,291	1,31	16	.0640	1,6256	2,08
.0453	1,150	1,04	17	.0560	1,4224	1,59
.0403	1,024	0,823	18	.0480	1,2192	1,17
.0359	0,9119	0,653	19	.0400	1,0160	0,811
.0320	0,8128	0,518	20	.0360	0,9143	0,657
.0285	0,7239	0,411	21	.0320	0,8128	0,519
.0253	0,6426	0,324	22	.0280	0,7112	0,397
.0226	0,5740	0,258	23	.0240	0,6096	0,292
.0201	0,5106	0,205	24	.0220	0,5588	0,245
.0179	0,4547	0,162	25	.0200	0,5080	0,203
.0159	0,4038	0,129	26	.0180	0,4572	0,164
.0142	0,3606	0,101	27	.0164	0,4166	0,136
.0126	0,3200	0,0810	28	.0148	0,3759	0,111
.0113	0,2870	0,0644	29	.0136	0,3454	0,0937
.0100	0,2540	0,0507	30	.0124	0,3150	0,0779
.0089	0,2261	0,0403	31	.0116	0,2946	0,0682
.0080	0,2032	0,0320	32	.0108	0,2743	0,0591
.0071	0,1803	0,0254	33	.0100	0,2540	0,0507
.0063	0,1601	0,0201	34	.0092	0,2337	0,0429
.0056	0,1422	0,0160	35	.0084	0,2134	0,0358
.0050	0,1270	0,0127	36	.0076	0,1930	0,0293
.0045	0,1143	0,0100	37	.0068	0,1727	0,0234
.0040	0,1016	0,0081	38	.0060	0,1524	0,0182
.0035	0,0889	0,00618	39	.0052	0,1321	0,0137
.0031	0,0787	0,00486	40	.0048	0,1220	0,0117
.0028	0,0711	0,09397	41	.0044	0,1118	0,00981
.0025	0,0635	0,00317	42	.0040	0,1016	0,00811
.0022	0,0559	0,00245	43	.0036	0,0914	0,00657
.0020	0,0508	0,00203	44	.0032	0,0813	0,00519
.0018	0,0457	0,00164	45	.0028	0,0711	0,00397
.0016	0,0406	0,00129	46	.0024	0,0610	0,00292
.0014	0,0350	0,00109	47	.0020	0,0508	0,00203
.0012	0,0305	0,000731	48	.0016	0,0406	0,00129
.0011	0,0279	0,000611	49	.0012	0,0305	0,000731
.0010	0,0254	0,000507	50	.0010	0,0254	0,000507
.00088	0,0224	0,000394	51	-	-	-
.00078	0,0198	0,000308	52	-	-	-
.00070	0,0178	0,000249	53	-	-	-
.00062	0,0158	0,000194	54	-	-	-
.00055	0,0140	0,000154	55	-	-	-
.00049	0,0124	0,000121	56	-	-	-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