Materials Mag!c
Hitachi Metals

HITACHI

Magnet Wire

Selection and Use Directions for Magnet Wire

CONTENTS

What is Magnet Wire?

Wire for winding used in electrical equipment is generally called magnet wire. Simply put, “Magnet wire is used for interchanging electrical energy with magnetic energy”. Magnet wires are broadly divided into enamelled wire (coating insulation), covered conductor wire (fiber/film insulation), other specially formulated wire, and combinations thereof.

Both type and performance of magnet wire are quite varied. The following are the most important features of magnet wire:

(a) Small and uniform insulation thickness

(b) Good electrical characteristics such as dielectric strength and insulation resistance

(c) Tough coating, resistant to external forces such as bending, stretching and friction

(d) Heat-resistance

(e) Resistant to solvents, chemicals and varnishes

(f) Resistant to hydrolytic degradation

(g) Stable when combined with insulating material

(h) Resistant to water and moisture

(i) Easy to use

It is difficult to provide all of these characteristics in one product. Each type of wire has its own advantages and disadvantages. Therefore, it is important to consider operating conditions in order to select the correct product.

Pick up

High-strength, self-lubricating heat-resistant wire

KOMAKI Series

We work to meet current demands.	
	Inserting wires in slots using little force.
	Further reducing external damage during winding.
	Making the coil more compact.
	Maximizing the slot fill factor level.

Advantages

- "KOMAKI® Series" of enameled wire provides a highly compact coil, meeting the demand for high-efficiency compact motors while conserving energy.
- "KOMAKI" wire delivers much stronger adhesion with impregnation varnish compared to conventional self-lubricated enamelled wire.

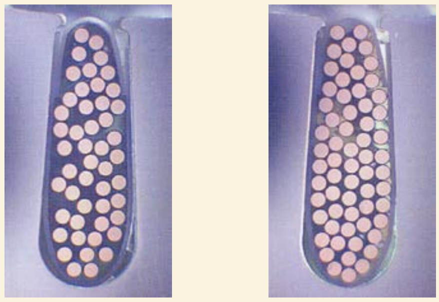
Application

- Motors for general use, electrical equipment, air cooling, and other uses with highly slot fill factor.

Part name	KMK®-20E	KMK®-22A
Coating material	Heat-resistant double coated wire (Polyamide-imide/ Class-H polyester-imide)	Polyamide-imide wire
Heat resistance	200℃	220℃

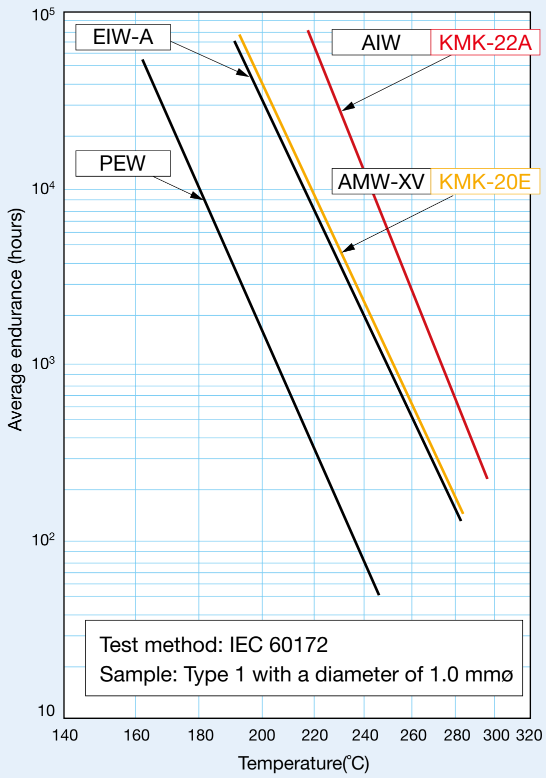
Comparison of slot fill factor

$$\text{Slot fill factor} = \frac{\text{Cross-section of magnet wire in a slot}}{\text{Total area of cross-section of the slot minus total area of the slot liner and wedge}} \times 100$$

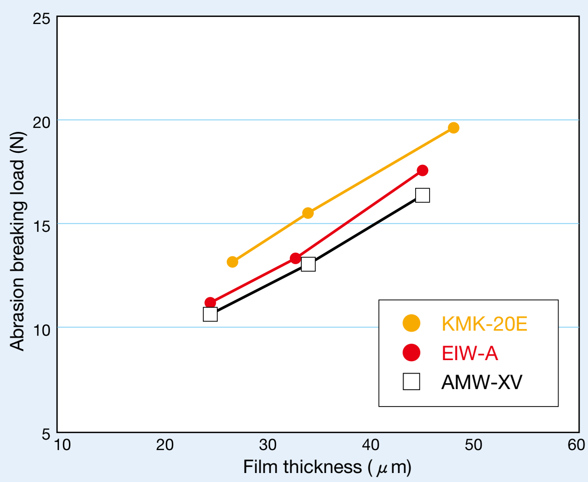


55% 70%

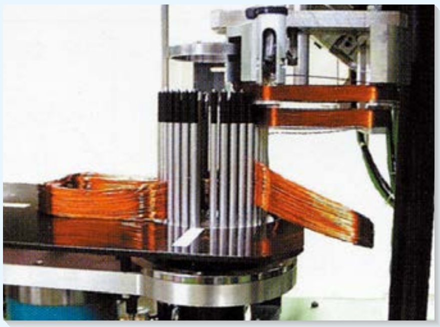
Thermal endurance



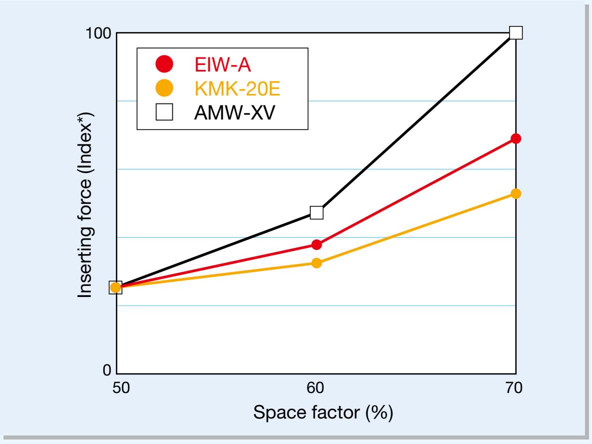
Evaluation of mechanical strength



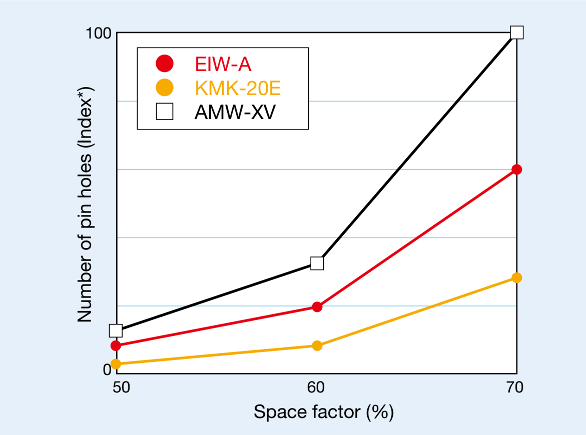
Coil windability evaluation equipment



Coil inserting force



Number of pin holes after inserting coil



* Index when 70% of the AMW-XV space factor is 100.

General properties Example of characteristic (Type 1 with a diameter of 0.85 mmø)

Item		Heat-resistance, double coated wire			Polyamide-imide wire		
		KMK-20E	EIW-A (Self-lubricating, heat-resistant, double coated wire)	AMW-XV (Heat-resistant, double coated wire)	KMK-22A	AIW-A (Self-lubricating polyamide-imide wire)	AIW (Polyamide-imide wire)
Film thickness (mm)		0.032	0.032	0.032	0.032	0.032	0.032
Flexibility	No elongation	1d	1d	1d	1d	1d	1d
	20% elongation	1～2d	1～2d	1～2d	1～2d	1～2d	1～2d
Resistance to cut through [Heating-up method, ˚C]		398	396	398	420	420	420
Abrasion	Reciprocating type (number of times)	532	180	161	1500＜	1500＜	452
	Uni-directional type (N)	15.2	13.3	12.9	16.5	16.1	15.0
Static frictional coefficient		0.045	0.050	0.120	0.045	0.050	0.120
Adhesive strength of varnish (N) (epoxy)		173	127	190	172	128	188
R-22 extraction rate [at 150°C X 24h, %]		0.12	0.11	0.10	0.08	0.07	0.06
Resistance to R-22 [at 150˚CX7d]	Acceptable blister temperature(˚C)	140	140	140	180＜	180＜	180＜
	Retention of breakdown voltage(%)	105	105	106	104	104	106

Pick up

Inverter surge resistant enameled wire

KMKED

We work to meet current demands.

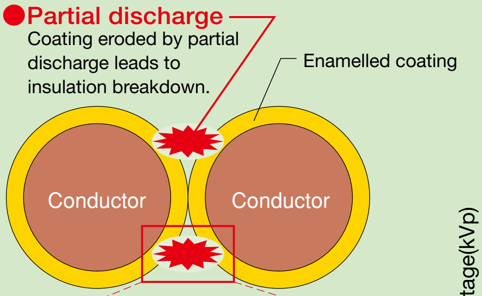
- Reducing the failure rate of inverter-controlled motors.
- Increasing the life span of inverter-controlled motors.
- Designing motors with high resistance to inverter surges.

Have you experienced causes like these?

- The motor breaks down often. (Market failure rate is increasing)
- Saving motor control to save energy shortened the motor's life. (Using inverter control)
- Even though new parts were used in the motor, it soon broke down again. (Failure reoccurrence)

These problems are probably caused by inverter surges.

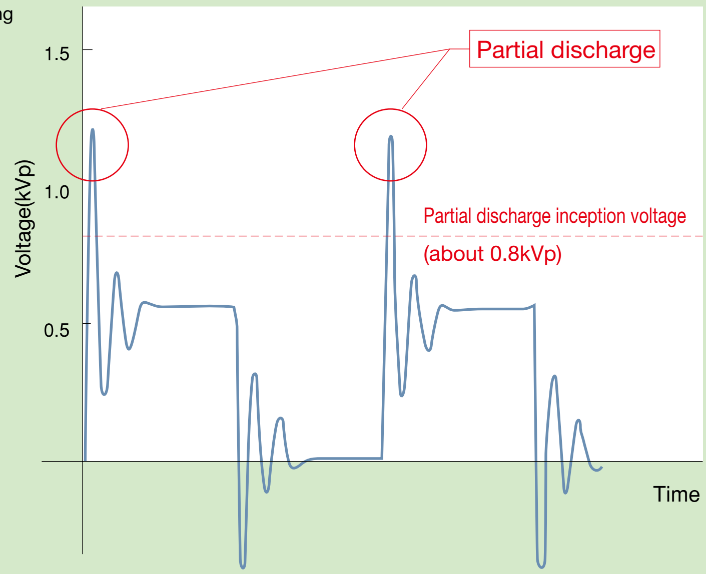
Cross-section view



Erosion caused by partial discharge

General purpose heat-resistant enamelled wire
Appearance after inverter surge application test
(After applying a voltage of 1.1 kVp for 11.2 hours.)

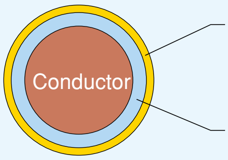
Inverter output waveform (400-volt class)



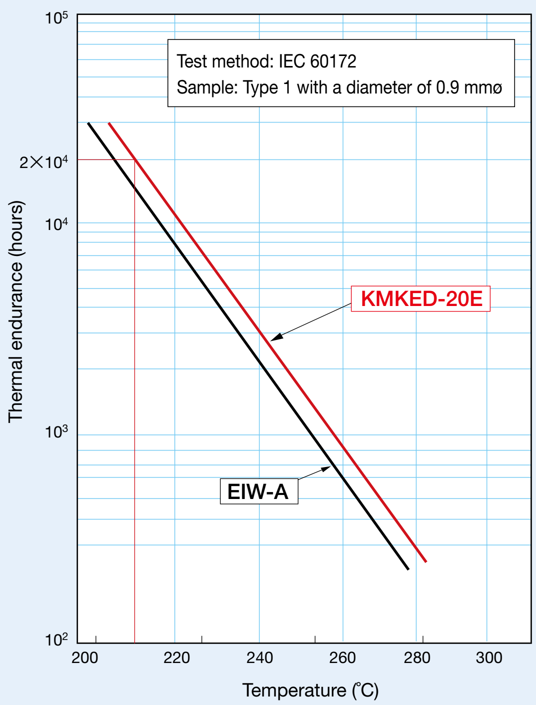
KMKED
Appearance after inverter surge application test
(After applying a voltage of 1.1 kVp for 11.2 hours)

KMKED prevents inverter surges from eroding coatings.
In addition, mechanical properties have been significantly improved.
These features contribute to longer motor life.

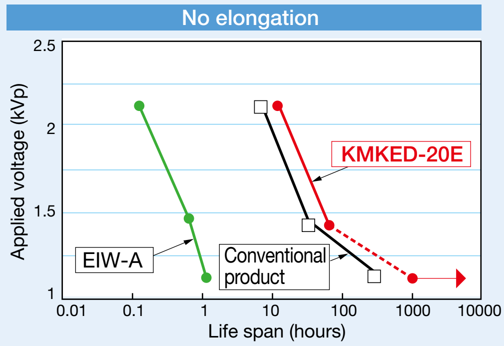
Structure

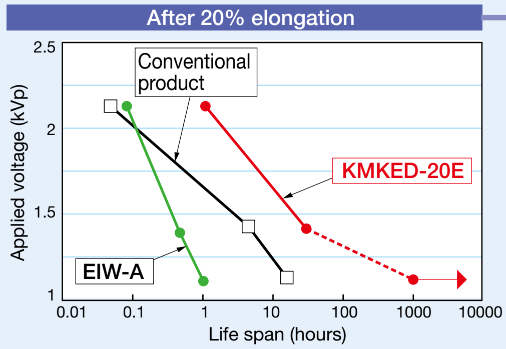


Thermal endurance



Voltage endurance (10 kHz sine wave)





Appearance after 20% elongation

KMKED-20E has no cracking in its partial discharge resistant layer even after elongation, resulting in a small decrease in life span.

General properties

Characteristic example (Type 1 with a diameter of 0.9 mmø)

Item		KMKED-20E	Conventional products (Conventional manufacturing methods)	EIW-A (General self-lubricating heat-resistant wire)
Film thickness (mm)		0.031	0.032	0.032
Flexibility	Entire layers	1dOK	1dOK	1dOK
	Partially discharge-resistant layer	1dOK	3dOK	—
Heat shock [at 200℃ for one hour]	No elongation	1dOK	2dOK	1dOK
	20% elongation	3dOK	6dOK	2dOK
Abrasion (N)	Uni-directional type (N)	13.7	11.3	12.6
	Reciprocating type (number of times)	351	150	180
Static frictional coefficient		0.048	0.061	0.055
Partial discharge inception voltage (Vp)		854	740	848
Inverter surge resistance after 20% elongation (hour) [1.1 kVp carrier frequency: 10kHz]		6500＜	1886	11.2
Adhesive strength of varnish (N) (Epoxy-based)		173	120	125
Temperature index (℃)		200	200	200

Pick up

High heat-resistant enamelled wire

IMWAD

We work to meet current demands.

- Need to have enamelled wire with excellent heat resistance.
- Polyimide wire is not resistant enough.
- Ceramic wire is not worth the cost.

Thermal index

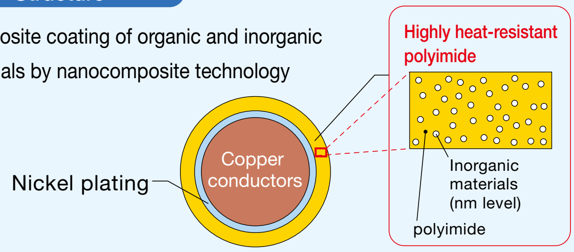
- 280℃

Application

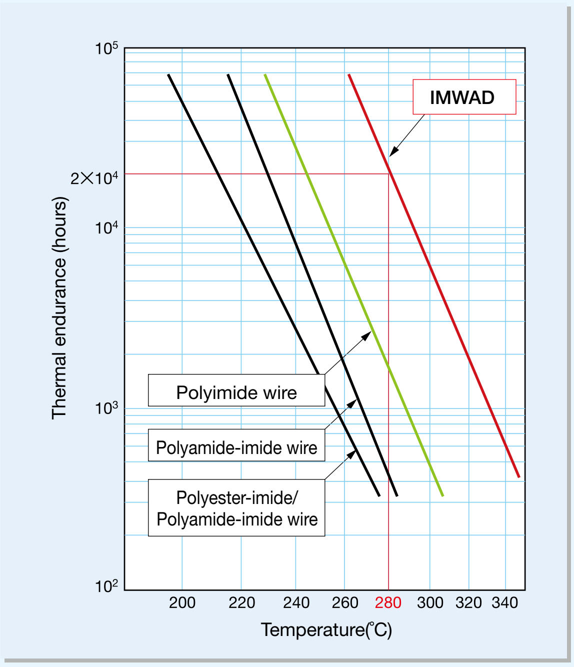
- Motors for electrical equipment
- Motors for special pumps
- Induction heating coils
- Motors and electrical equipment used under high temperatures

Structure

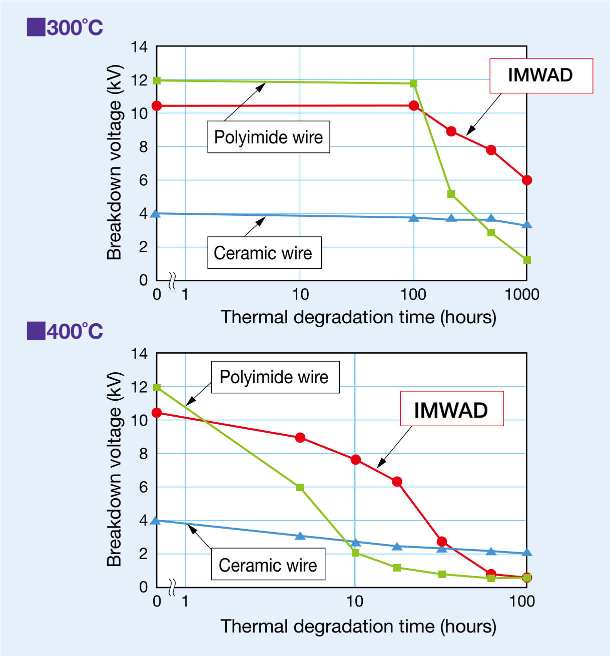
- Composite coating of organic and inorganic materials by nanocomposite technology



Thermal endurance



Thermal degradation



Test method: IEC60172
Sample: Type 1 with a diameter of 1.1 mmø

General properties

Characteristic example (Type 1 with a diameter of 1.0 mmø)

Item		IMWAD	CEW (Ceramic wire)	IMW (Polyimide wire)
Structure	Conductor	Nickel plating copper	Nickel plating copper	Copper
	Coating	Highly heat-resistant polyimide	Ceramic + polyimide	Polyimide
Film thickness (mm)		0.036	0.035 (0.023)	0.035
Temperature index (℃)		280	400	240
Flexibility [No elongation or winding]		1d	1d	1d
Adherence [sudden jerk]		OK	OK	OK
Abrasion	Uni-directional type (N)	9.9	9.4	9.5
	Reciprocating type (number of times)	95	12	96
Breakdown voltage (kV)		10.5	3.9	12.0

Value in parentheses: thickness of ceramic layer

Pick up

High reliability rectangular enamelled wire

AIW rectangular wires

We work to meet current demands.

- Maximizing the space factor.
- Downsizing the equipment further.
- Improving equipment reliability.

Advantages

- Excellent flexibility
- Uniform coating, including at the corners, provides good insulation
- Much more compact stacking for high space factor, compare to round enamelled wire

  [Comparative space factors]

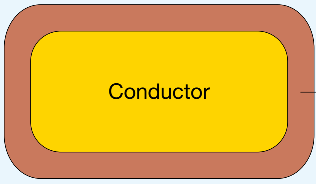
  Round enamelled wire: Approximately 78%

  Rectangular enamelled wire: Approximately 91%

Thermal index

220℃

Structure

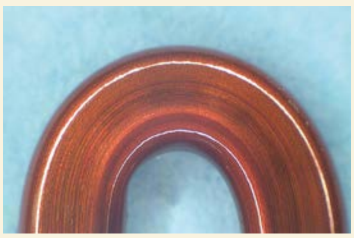
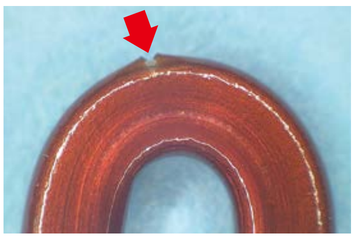


Application

- Motors for electrical equipment/generators
- Other motors and electric equipments requiring high efficiency and reliability

General properties

Characteristic example (1.6X2.3 mm)

Item	AIW (High reliability fine rectangular enamelled wire)	AIW (General enamelled rectangular wire)	Notes
Film thickness (mm)	0.045×0.045 (0.040)	0.045×0.045 (0.030)	Value in parentheses: minimum film thickness at corners
Flexibility	No Crack 	Crack 	When bent edgewise 180° with a bending diameter equal to the conduct diameter
Adherence (mm)	4.6	9.8	Length of wire generating coating flakes at breakpoint during tensile test
Breakdown voltage (V)	9,000	5,400	Metallic foil method
Resistance to cut through (°C)	430	430	

Enamelled wire: Type, symbol, standard and feature

Series name	Type	Symbol	Standard	Coating type	Size range (mm)	Tempe-rature index*1(℃)	Advantages	Operational precautions	Applications
Formal series	Formal wire	PVF	SP70-90001	Class 0 Class 1 Class 2	0.1～3.2 0.1～1.0	105	●Mechanically strong coating and good flexibility ●Good thermal shock resistance ●Strong in hydrolytic degradation	●Crazing prone (Preheating prevents crazing from developing.)	1.Transformer
	Formal rectangular wire	PVF	SP70-90101	—	Shown in Table 22 (on page 33)				
Polyurethane enamelled wire series (Polyurethane wires)	Polyurethane enamelled wire	UEW	— (Overseas product) *2	Class 1 Class 2	0.1～1.0	130	●Soldering is possible without stripping off coating ●Excellent electrical characteristics with high frequency	●Coating is mechanically weak. ●Vulnerable to aromatic solvents. ●Crazing prone. (Preheating prevents crazing from developing.)	1.Coils for electronic equipment 2.Coils for communication equipment 3.Coils for electrical meters 4.Micromotors 5.Magnet coils
Polyester enamelled wire series (polyester wires)	Polyester enamelled wire	PEW	SP70-90010	Class 0 Class 1 Class 2	0.1～3.2 0.1～1.0	155	●Good electrical characteristics ●Good heat resistance ●Good solvent resistance	●Mediocre resistance to thermal shock. ●Poor resistance to hydrolytic degradation; care must be taken when used in sealed equipment.	1.General purpose motors 2.Magnet coils
	Polyester enamelled rectangular wire	PEW	SP70-90110	—	Shown in Table 22 (on page 33)				
	Polyester enamelled/N wire (Polyester/nylon wire)	PEW-N	SP70-90013	Class 0 Class 1 Class 2	0.1～1.0	155	●Good surface slip characteristics; suited for high-speed machine winding ●Good thermal shock resistance ●Similar advantages to PEW	●Poor resistance to hydrolytic degradation; care must be taken when used in sealed equipment.	1.General purpose motors 2.Small motors
Aromester series (polyester-imide wires)	Aromester XV wire (Polyester-imide / polyamide-imide wire)	AMW-XV®	SP70-90056 (Refrigerant proof) SP70-90058 (General purpose)	Class 0 Class 1 Class 2	0.2～3.2 0.2～1.0	200	●Good heat resistance ●Good thermal shock resistance ●Mechanically strong coating ●Excellent resistance to hydrolytic degradation ●Excellent resistance to refrigerants	●Film detachment is difficult.	1.Class-F motors 2.Freon motors 3.Microwave oven transformers 4.Magnet coils for heat-resistant components 5.Motors for electrical equipment
	Aromester XV rectangular wire	AMW-XV	SP70-90156	—	Shown in Table 22 (on page 33)				
	Polyester-imide/A wire (Polyester-imide / Self-lubricating polyamide-imide wire)	EIW-A	SP70-90059	Class 0 Class 1 Class 2	0.2～1.2 0.2～1.0		●Good surface slip characteristics; suited for high-speed machine winding ●Similar advantages to AMW-XV	Same with above	
Polyamide-imide enamelled wire series (polyamide-imide wires)	Polyamide-imide enamelled wire	AIW	SP70-90070	Class 0 Class 1 Class 2	0.1～3.2 0.1～1.0	220	●Mechanically strong coating ●Good heat resistance ●Good overload characteristics just below IMW	●Coating flexibility is slightly inferior to PEW.	1.Transformers for heat-resistance equipment 2.Motors for electric tools 3.Hermetic motors 4.Motors for electrical equipment
	Polyamide-imide enamelled rectangular wire	AIW	SP70-90170	—	Shown in Table 22 (on page 33)				
	Polyamide-imide enamelled/A wire (Self-lubricating polyamide-imide wire)	AIW-A	SP70-90074	Class 0 Class 1 Class 2	0.2～0.75		●Good surface slip characteristics; suited for winding process ●Similar advantages to AIW	Same with above	

Series name	Type	Symbol	Standard	Coating type	Size range (mm)	Temperature index*1(°C)	Advantages	Operational precautions	Applications
Image series (polyimide wires)	Image wire	IMW	SP70-90080	Class 0 Class 1 Class 2	0.1～3.2 (Class 0, Class 1) 0.1～1.0 (Class 2)	240	●Top-level heat resistance among enamelled wire. ●Excellent overload characteristic ●Good resistance to chemical solvents	●Coating is somewhat weak mechanically.	1.Motors for heat-resistant equipment 2.Equipment for airplanes
	Image rectangular wire	IMW	SP70-90180	—	Shown in Table 22 (on page 33)				
	High heat-resistant enamelled wire	IMWAD	SP70-90081	Class 0 Class 1	0.6～1.2	280	●Heat resistance is superior to IMW due to composite coating of organic and inorganic materials. ●Similar advantages as IMWS		1.Motors for electrical equipment 2.Motors for special pumps 3.Induction heating coils
KOMAKI series	Heat-resistant double coated wire (Self-lubricating Polyester-imide / polyamide-imide wire)	KMK-20E	SP70-90062	Class 0 Class 1 Class 2	0.32～2.0 (Class 0, Class 1) 0.32～1.0 (Class 2)	200	●Excellent surface slip characteristics and mechanical strength; suited for high space-factor motors ●Similar advantages to AMW-XV	●Film detachment is difficult.	1.High space factor motor 2.Freon motors 3.Motors for electrical equipment
	Polyamide-imide wire	KMK-22A	SP70-90063	Class 0 Class 1 Class 2	0.32～2.0 (Class 0, Class 1) 0.32～1.0 (Class 2)	220	●Excellent surface slip characteristics and mechanical strength; suited for high space-factor motors ●Similar advantages to AMW		1.High space-factor motors 2.Freon motors 3.Motors for electrical equipment 4.Motors for electric tools
	Heat-resistant double coated Inverter surge resistant enamelled wire	KMKED -20E	SP70-90064	Class 0 Class 1	0.6～1.6	200	●Excellent resistance to inverter surges ●Excellent surface slip characteristics and mechanical strength	●Coating flexibility is slightly inferior to KMK-20E.	1.Inverter-driven motors 2.High voltage motors
	Polyamide-imide Inverter surge resistant enamelled wire	KMKED -22A	—	Class 0 Class 1	0.6～1.6	220	●Excellent resistance to inverter surges ●Similar advantages to AIW	●Coating flexibility is slightly inferior to KMK-22A.	1.Inverter-driven motors 2.Motors for electrical equipment
Highbon series (self-bonding wires)	Alcohol-bonding highbon wires	BN-PEW	SP70-91095	Class 1 Class 2	0.2～1.0	155	●Coils can be fixed without varnishing. ●Coil winding is possible while applying methanol and ethanol. ●Solder reflow after coil winding causes very slight coil deformation, due to heat from reflow furnace.	●Store wires in a cool, dark place away from heat and moisture.	1.Coils for flat motors 2.Clutch coils
		BN-AMW-X	SP70-91099			180			
	Class-F highbon wires	BF-AMW-X	SP70-91090	Class 0 Class 1	0.2～1.0	180	●Coils can be fixed without varnishing. ●Wires can be bonded tightly together by heat, produced with current flow or by heating in a thermostatic chamber. ●Class-F heat resistance	●Store wires in a cool, dark place away from heat and moisture. ●Alcohol bonding is difficult.	1.Coils
		BF-AIW	SP70-90098			220			

*1 shows the index of insulation layer
*2 Manufactured at Thai Hitachi Enamel Wire Co., Ltd. etc.

[Contents of standard] SP: Hitachi Metals standard specifications
[Size range] Standard manufacturable size

Performance comparison of enamelled wires

The space factors of magnet wires are compared in the right figure. The space factors of enamelled wires are superior to those of other wires for winding, as are their electrical properties. However, more careful examination must be made of the following properties as compared with other wires.

$$\text{Space factor}(\%)=\frac{d^2}{D^2}\times100$$

(d:Conductor diameter
D:Over all diameter)

(1) Heat resistance
(2) Resistance to solvents, chemicals and varnishes
(3) Resistance to hydrolytic degradation
(4) Stability when combined with insulating materials
(5) Resistance to water and moisture
(6) Ease of use

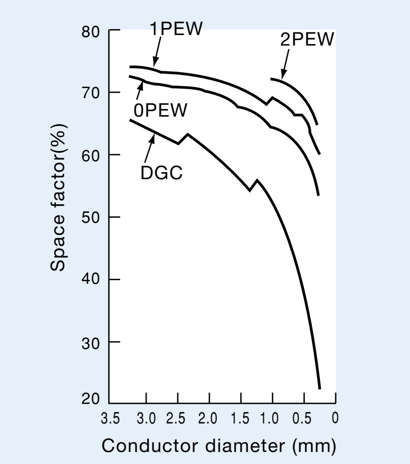


Figure 1: Comparison of magnet wire space factor

Table 1 shows the comparison of the general performances of enamelled wires.

Table 1: Comparison of general enamelled wire performance

Test items \ Product type			PVF	UEW	PEW	PEW-P	AMW-XV	EIW-A	KMK-20E	KMKED-20E	AIW	KMK-22A	IMW	Notes
Physical properties	Dimensions (mm)	Conductor diameter	1.000	0.997	1.002	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	
		Film thickness	0.041	0.044	0.041	0.039	0.041	0.041	0.040	0.040	0.043	0.043	0.044	
		Over all diameter	1.082	1.084	1.083	1.078	1.082	1.082	1.080	1.080	1.086	1.086	1.081	
	Elongation(%)		38	37	36	39	39	40	40	39	38	40	39	
	Flexibility	diameter	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	Denominator: Number of samples Numerator: Number of defective cracks
	Abrasion	Uni-directional type (N)	13.90	9.78	11.63	11.90	13.46	14.50	15.90	14.95	15.46	16.80	11.22	
		Reciprocating type (number of times)	72	34	41	118	162	157	510	343	411	1000<	26	Load of 6N
	Peel Test (number of times)		88	101	100	80	80	80	81	74	71	72	87	Gauge length 200mm
Thermal properties	Heat resistance degradation	Temperature, time	160℃,6h	160℃,6h	200℃,6h	200℃,6h	200℃,6h	200℃,6h	200℃,6h	200℃,6h	200℃,6h	200℃,6h	250℃,6h	Denominator: Number of samples Numerator: Number of defective cracks
		1 diameter	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	1/5	0/5	
		2 diameter	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	
	Cut through(℃)		262	238	330	328	395	392	396	398	413	413	450	Load of 7N
	Heat shock	Temperature, time	150℃,1h	150℃,1h	150℃,1h	150℃,1h	200℃,1h	200℃,1h	200℃,1h	200℃,1h	200℃,1h	200℃,1h	250℃,1h	×1~4 Diameter magnification of conductor diameter
		diameter	×1、OK	×3、OK	×3、OK	×2、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	
Electrical properties	Pin hole (number/5m)		0	0	0	0	0	0	0	0	0	0	0	
	Breakdown voltage(V)		9,780	9,990	10,970	10,800	10,900	11,700	11,600	11,600	11,600	11,700	12,780	The method of twist pair
Chemical properties	Xylene		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	At 60℃×30 minutes
	Sulfuric acid(S.G1.2)		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	Immersion at normal temperature for 24 hours Determination using a nail.
	Sodium hydroxide(10%)		◎	◎	○	○	◎	◎	◎	◎	◎	◎	○	
	Transformer oil		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	Deter-mination {◎Good ○Partly discolored
	Styrol	Untreated	6H	5H	4H	4H	6H	6H	6H	6H	6H	6H	5H	Pencil hardness
		At normal temperature for 24 hours	6H	3H	4H	4H	6H	6H	6H	6H	6H	6H	5H	
		100℃30min	2B	F	B	B	6H	6H	6H	6H	6H	6H	5H	

1 Pin hole and crazing

Enamelled wires develop a few pin holes as film thickness decreases, in rare cases. For PVF and UEW, however, contact with water or solvents when coatings are strained by bending or stretching may cause minute cracking, resulting in the formation of numerous pin holes. This phenomenon is generally called crazing. Applying heat (curing) prior to contact with water or solvents causes pin holes to disappear. Table 2 shows wet (water) crazing and solvent (dispersing agent) crazing.
It is advised that crazing-prone enamelled wire be heat treated after winding at a temperature above the grass transportation temperature.

2 Flexibility

A winding test judges coating flexibility and is usually applied to round wire with a diameter of 0.37 mm or more.

●Figure 2: Winding Test

3 Elongation

A stretching test judges coating flexibility. Wires demonstrate very similar tendencies.
For round wire with a diameter of 0.35 mm and under, and for rectangular wire, coating flexibility is usually judged using the stretching test.

4 Breakdown voltage

One of the advantages of enamelled wire is its high dielectric strength depending on film thickness.
Although absolute values vary depending on the measurement method, all types of wire have similar dielectric strength values in a normal state.

5 Abrasion

An abrasion test judges the mechanical strength of the coating. A uni-directional abrasion test and a reciprocating abrasion test are generally conducted.
In both tests, AIW shows the best results, followed by PVF. On the other hand, UEW and IMW have low abrasion resistance; special care must be taken during the winding process. In recent years, it has become necessary to improve the workability of winding wires.
Self-lubricating enamelled wire, of which the upper layer is baking-finished with a thin layer of lubricant with a superior lubricity, is excellent in abrasion resistance. Thus, the coating is difficult to be scratched from damage during the winding process. Accordingly, self-lubricating enamelled wire is variously used. See pages 16 and 17 for self-lubricating enamelled wire.

●Table 2: Wet crazing and solvent crazing phenomena and recoverability (Example)

Conditions / Product type	Wet crazing			Solvent crazing: Methyl alcohol			Ethyl alcohol			Xylene			Acetone			Toluene			Styrol		
	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min	Untreated	130℃ × 30min	150℃ × 30min
PVF	×	○	–	○	–	–	×	△	○	×	○	–	×	○	–	×	△	△	×	×	× (●)
UEW	×	○	–	×	△	○	×	○	–	×	○	–	×	○	–	×	△	△	×	△	○
PEW	○	–	–	○	–	–	○	–	–	×	○	–	○	–	–	×	△	△	×	○	–
EIW-A	○	–	–	△	△	△	△	△	△	△	△	△	×	×	×	×	×	×	×	×	×
AMW-XV	○	–	–	○	–	–	○	–	–	○	–	–	×	×	×	×	×	×	×	×	×
KMK-20E	○	–	–	○	–	–	○	–	–	○	–	–	×	×	×	×	×	×	×	×	×
AIW	○	–	–	○	–	–	○	–	–	○	–	–	×	×	×	○	–	–	○	–	–
KMK-22A	○	–	–	○	–	–	○	–	–	○	–	–	×	×	×	○	–	–	○	–	–
IMW	○	–	–	○	–	–	○	–	–	○	–	–	×	×	×	○	–	–	○	–	–

Remarks

(1) Elongation percentage is 5%.
(2) Wet crazing: ①Untreated products shall be left alone at normal temperature after elongation and the number of pin holes shall be counted within 10 seconds.
②In measuring recoverability, apply heat to wires at a given temperature for a given time after elongation, remove the wires, and count the number of pin holes.
(3) Solvent crazing: ①Untreated wires shall be solvent-treated within 30 seconds for 5 minutes after elongation. Then, count the number of pin holes.
②In measuring recoverability, wires shall be solvent-treated within 30 seconds for 5 minutes after elongation. Remove the wires, heat-treat them at a given temperature for a given time, and count the number of pin holes.
③(●) denotes that recovery is made by heat-treating at 180℃ for 30 minutes.
(4)○: No crazing occurs. △: Crazing occurs in some degree. ×: Crazing occurs.

Glass transition temperature (℃)

PVF	90～115
UEW	110～135
PEW	110～130
AIW	230～280
IMW	350～370
AMW-X*	180～190

* Base layer of AMW-XV

6 Resistance to solvents, chemicals, and oil

IMW and AIW have the best solvent resistance and remain unaltered by solvents in most cases.
UEW tends to be slightly eroded by alcohol solvents.
IMW and PEW are not alkali-resistant but are stable with respect to other chemicals.
Table 3 shows solvent resistance. It's necessary to select the varnish of wire with consideration of for these solvents.
There is almost no difference in oil resistance in the insulation coating.

7 Hydrolyzability

An enamelled wire film is an organic polymer material with which wires are baking-finished. Some types are prone to hydrolytic degradation. A sealed hydrothermal degradation test is an accelerated test for evaluating hydrolytic degradation of enamelled wire. In this method, an enamelled wire and water are put together in a sealed container and heated at 100℃ or more in order to obtain the retention of breakdown voltage, with which the hydrolyzability of the wire is evaluated.
For the breakdown voltage properties of enamelled wire after sealed hydrothermal degradation, as shown in Figure 3, PEW is the most prone to hydrolytic degradation and thus exhibits the largest decrease in breakdown voltage, followed by IMW. On the other hand, AIW and KMK-22A are far superior in resistance to hydrolytic degradation.

8 Water resistance under electric charging

Adhesion of salt water or dust particles to an enamelled wire during the passage of a current accelerates charge degradation of its coating. A water resistance test under electric charging is a method for evaluating this property.
As shown in Table 4, AIW and KMK-22A have the best charge water resistance, followed by AMW-XV and KMK-20E respectively.
When an enamelled wire is used in equipment subject to salt water or dust particles, special care must be taken in selecting thereof.

Figure 3: Example of breakdown voltage after sealed hydrothermal degradation (120℃)

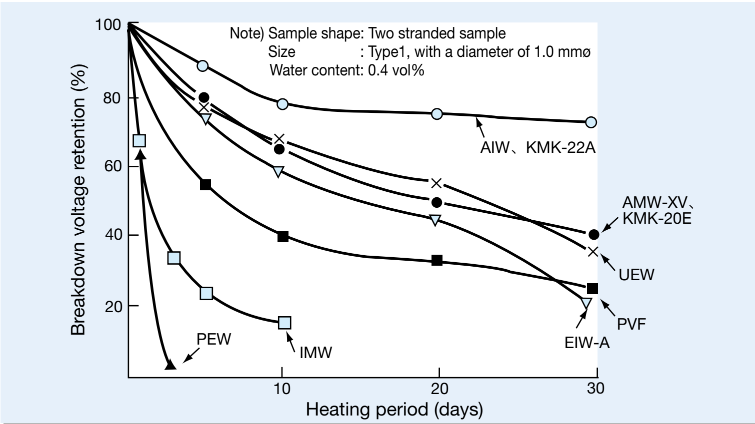


Table 4: Example of charge water resistance (Type1, with a diameter of 1.0 mm)

Product type	PEW	EIW-A	AMW-XV KMK-20E	AIW KMK-22A	Remarks
Charge water resistance (h)	160	680	1,050	2,050	0.4% saline Voltage:200AC Precure:150℃X10min.

Note) Test method

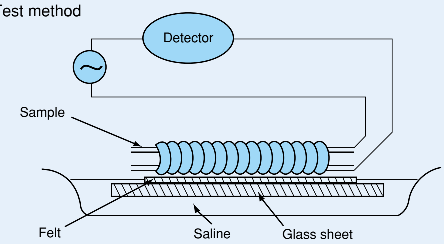


Table 3: Solvent resistance of enamelled wire

Condition / Product type		PVF		UEW		PEW PEW-P		EIW-A		AMW-XV KMK-20E		AIW KMK-22A		IMW	
		Cloth	Nail	Cloth	Nail	Cloth	Nail	Cloth	Nail	Cloth	Nail	Cloth	Nail	Cloth	Nail
20 ℃	Methanol	◎	◎	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Ethanol	◎	◎	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Butanol	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Naphtha	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Kerosene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Terpene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Gasoline	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Benzole	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Cresol	×	×	○	△	○	△	○	△	○	△	N.T	N.T	N.T	N.T
65 ℃	Methanol	◎	○	◎	△	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Ethanol	◎	○	◎	△	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Butanol	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Naphtha	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Kerosene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Terpene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Gasoline	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Benzole	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Cresol	×	×	×	×	×	×	×	×	×	×	N.T	N.T	N.T	N.T

Note) (1) Symbol◎: Good with no change ○: Coating peels off slightly △: Coating peels off somewhat easily ×: Coating peels off naturally
(2) After 24 hours of dipping (3) Type 1 with a film thickness of 0.5 mm (4) N.T: Not tested

9 Heat shock

Applying heat to a distorted film may cause the development of cracks. This phenomenon is generally called thermal shock, which is an important characteristic for determining bend radius and dry temperature during coil forming.

In comparison at the same temperature, IMW, AIW, KMK-22A, KMK-20E, AMW-XV, EIW-A and PVF show excellent thermal shock resistance and develop no cracking when bent with a bending diameter equal to the conductor width. IMW and AIW in particular show satisfactory results under high temperature conditions of 350℃. PEW is inferior to these wires; care must be taken with application. (See Table 1 on page 11.)

10 Thermal endurance

It is desirable to determine the life span of enamelled wires through a test in line with actual usage conditions. The test method and judgment criteria require examination in many aspects. A number of study results have been reported on this.

Figure 4 shows the test result of a comparison of life spans of enamelled wire with no varnishing applied in accordance with IEC60172. Based on the combination, coil-varnished enamelled wire will not necessarily have a better life span than untreated enamelled wire.

A combination of an enamelled wire and a varnish with a higher heat resistance generally results in an improved heat life. Some heat-resistance enamelled wires higher than Class-F, however, have a large impact on the life span depending on the type of varnish. Due consideration must be given in selecting the varnish.

11 Allowable overload characteristics

Enamelled wire is used for wound coil of motor or transformer. Equipment may be overloaded temporarily for some reason. Some enamelled wires resist overcurrents, while others do not.

An allowable overload test is conducted to evaluate the allowable overload characteristics.

Figure 5 shows the allowable overload characteristics of enamelled wire, indicating that in general enamelled wire, with higher resistant temperature, show better performance.

Figure 4: Example of thermal endurance of enamelled wire

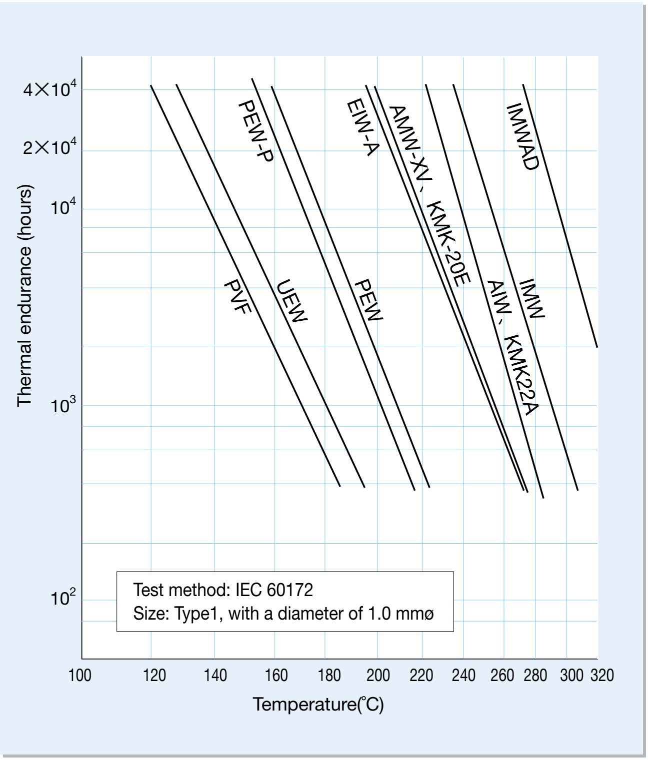
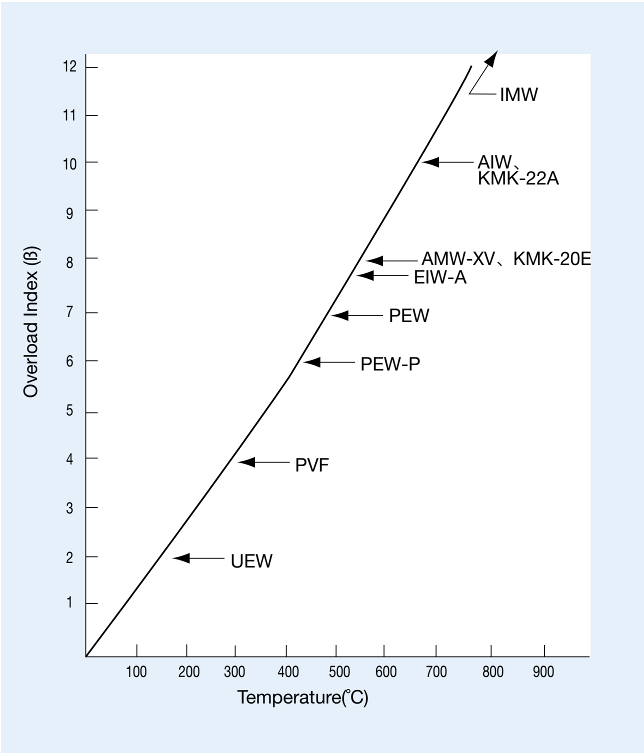


Figure 5: Example of allowable overload characteristic of enamelled wire (NEMA method)



12 Solderability

When soldering coil terminals during electrical work, coatings are generally separated before soldering. However, UEW allows you to generally perform soldering without separating coatings.

13 Resistance to refrigerants

The refrigerant can penetrate easily into the enamel wire, so sufficient caution is required during use.

Table 5 shows the resistance of enamelled wire to refrigerants as obtained in breakdown voltage tests, pencil hardness tests, and blister tests, indicating that IMW, AIW and KMK-22A are best, followed by AMW-XV, KMK-20E, and EIW-A respectively.

●Table 5: Example of resistance to refrigerants

Test / Product type	Untreated		R-134a						R-22					
			Ordinary temperature			125℃			Ordinary temperature			125℃		
	Pencil hardness	Breakdown voltage (V)	Blister	Pencil hardness	Breakdown voltage (V)	Blister	Pencil hardness	Breakdown voltage (V)	Blister	Pencil hardness	Breakdown voltage (V)	Blister	Pencil hardness	Breakdown voltage (V)
0 PVF	6H	13,500	Good	5H	14,200	Good	5H	14,100	Good	H	7,400	Good	H	7,300
0 PEW	4H	16,500	Good	4H	14,600	Good	4H	14,400	Foaming	H	7,600	Foaming	H	7,000
0 EIW-A	6H	14,800	Good	6H	15,100	Good	6H	15,300	Good	6H	14,900	Good	6H	15,100
0 AMW-XV	6H	14,200	Good	6H	14,000	Good	6H	15,800	Good	6H	14,700	Good	6H	14,500
0 KMK-20E	6H	14,600	Good	6H	14,800	Good	6H	15,500	Good	6H	14,900	Good	6H	14,900
0 AIW	6H	14,600	Good	6H	15,200	Good	6H	15,300	Good	6H	14,900	Good	6H	14,800
0 KMK-22A	6H	14,900	Good	6H	15,100	Good	6H	15,000	Good	6H	15,000	Good	6H	15,000
0 IMW	5H	13,800	Good	5H	14,000	Good	5H	13,800	Good	5H	12,600	Good	5H	12,600

Test method: Freon/Refrigerator oil =1/1, processing time =7d, Blister: Measured after heating at 130˚C for 10 minutes, Pencil hardness: Measured immediately after removal, Breakdown voltage: Measured after heating at 130˚C for one hour

14 Resistance to varnish

Recently, electrical equipment is decreasing in size and weight and increasing in capacity in terms of a single machine while promoting high reliability and safety. Therefore, insulation systems with high reliability and economic efficiency are needed.
To meet this demand, accurate evaluation is required of whether an insulation system using electrical insulating materials such as enamelled wire, treatment varnishes, and tapes can deliver substantial performance intended under the usage conditions. New heat-resistance enamelled wire particularly tends to show deterioration in heat life as an insulation system depending on the type of treatment varnish (particularly epoxy system varnish). Thus, the evaluation of compatibility between an enamelled wire and a treatment varnish is the most important functional evaluation test.
On the other hand, in the coil manufacturing process for electronics manufacturers, enamelled wire is wound around coils while being elongated, twisted, bent, or abraded. After preliminary drying at a given temperature, the wire is varnish-treated by means of impregnation or dropping. Enamel films deteriorated in the machining process, however, are susceptible to thermal stress at high temperatures during varnish hardening and to chemical attacks by varnish solvents and varnish components. Due to the recent rationalization of electrical work, the conditions of use for enamelled wire are becoming harsher than ever with respect to processes and materials. Greater importance is being placed on the evaluation of compatibility between enamelled wire and treatment varnishe - not only heat life evaluation with the assumption about the compatibility during equipment operation but also the evaluation of compatibility during varnish treatment.
As for the combination of an enamelled wire and a treatment varnish, the results of compatibility evaluations greatly differ depending on the hardening temperature of the treatment varnish, blending quantity of the curing agent, presence of preliminary heating, as well as the application purpose of the equipment. Therefore, compatibility must be checked before designing an insulation system.

15 Self-lubricating enamelled wires

As electrical equipment grows more sophisticated and smaller in size and weight, recent years have seen advances in the area of coil space factor. In addition, the rationalization of the winding process has led to high-speed winding of enamelled wire. Therefore, enamelled wire is becoming more susceptible to greater damage than ever during winding. On the other hand, as coil-wound end product is required to have high reliability, the need for enamelled wire that can endure under harsh winding conditions has been growing.
Self-lubricating enamelled wire can meet such needs, as it has excellent lubricating properties and abrasion resistance.
As Figure 6 shows, self-lubricating enamelled wire comes in three types, of which usage is determined depending on the application. Table 6 shows typical application examples.

Figure 6: Structure of self-lubricating enamelled wire

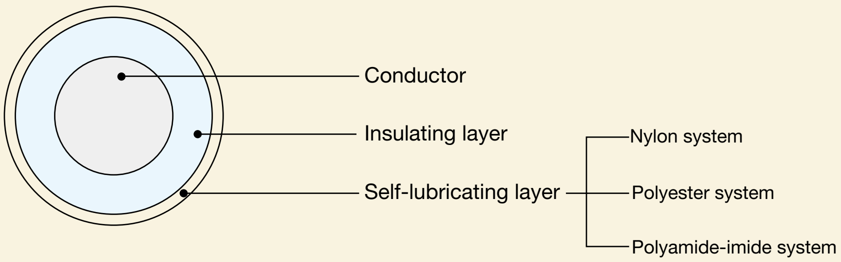


Table 6: Example: Applications of self-lubricating enamelled wire

Insulating layer	Type	Product name	Application example
PEW	Nylon	PEW-P	General purpose motors Fan motors
	Polyester	PEW-E	General purpose motors Fan motors
EIW	Polyamide-imide	EIW-A	General purpose motors Hermetic motors Motors for electrical equipment
		KMK-20E※	
AIW	Polyamide-imide	AIW-A	Motors for electrical equipment Small generators
		KMK-22A※	

*KOMAKI Series products have excellent adhesive properties with impregnated varnish

Table 7: Example: Coefficient of static friction of self-lubricating enamelled wires

Nylon	Polyester	Polyamide-imide	Standard enamelled wire
0.03～0.05	0.04～0.06	0.04～0.06	0.10～0.15

Figure 7 shows examples of coil inserting force of polyamide-imide self-lubricating enamelled wires. KMK-20E has a smaller inserting force than that of EIW-A and is thus superior. As Figure 8 shows, there are fewer pin holes after coil insertion.
Therefore, KMK-20E is suitable for improving reliability of coil-wound end products.

As the coefficient of static friction decreases, the wettability with impregnated varnish becomes inferior. Careful consideration must be given to compatibility with treatment varnishes under usage conditions when adopting the enamelled wire. KOMAKI Series products have significantly improved the adhesive properties of impregnated varnish.

Figure 7: Example of coil inserting force

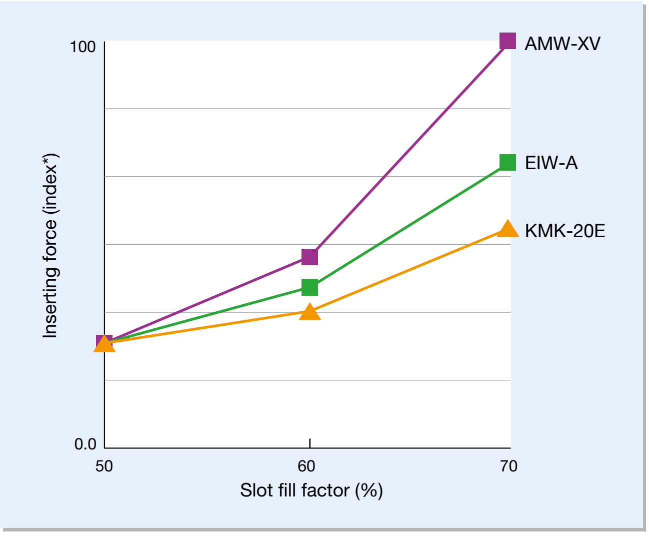
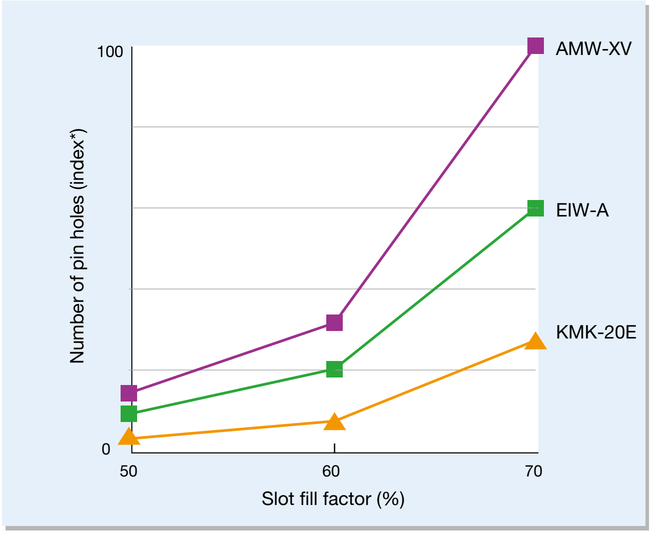


Figure 8: Example of the number of pin holes after coil insertion

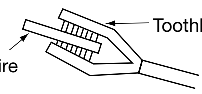
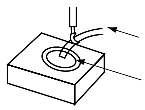


*Index when 70% of the AMW-XV space factor is 100.

16 Methods for removing film on enamelled wire

Table 8 shows methods for removing films on enamelled wire.

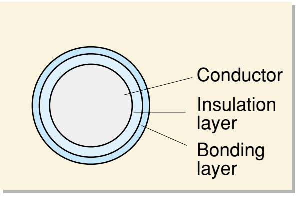
Table 8: Example: Methods for removing films on enamelled wire

Method	Type	Specification	Applicable product type
Use of chemicals	Several types of chemicals for removing films	Several specifications	All product types
Use of tool	Mechanical removing		All product types
	Gas burner	Burning with gas burner. Soaked alcohol water solution (1 to 5%) after combustion.	All product types
	Knife	Peel with a knife	All product types
Direct connecting method without peeling coating	Fusing machine	Spot welding method	All product types
	Water welder	Small welding method (connecting wire, lead wire connection)	All product types
	Silver lot pot	Making connections by melting silver brazing at about 700℃. 	All product types

17 Self-bonding enamelled wire

Self-bonding enamelled wire is enamelled wire that allow coils to be adhered by heating or applying solvent during or after coil winding. As Figure 9 shows, a self-bonding enamelled wire has an internal insulation layer and a bonding layer as the outside periphery.

Figure 9: Structure example of bonding wire



Self-bonding enamelled wire is provided with insulation properties at the insulation layer and bonding functionality for coil at the bonding layer.

Table 9 shows self-bonding enamelled wire fusion methods while Table 10 shows bonding strength test methods.

The properties of fusion wire are as given below. Please select appropriate magnet wire based on the usage.

(1) Example of bonding characteristic by heat activation

For electrical equipment or induction cooker, the wire is heat activated for bonding in a thermostatic chamber or similar device after coil winding.

Figure 10 on page 19 shows the bonding properties of the wire by heat activation.

(2) Bonding strength at high temperatures

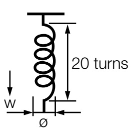
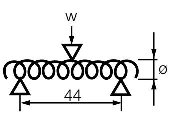
Figure 11 on page 19 shows the bonding strength of self-bonding enamelled wire in high temperature environments.

Table 9: Bonding method of self-bonding enamelled wire

Fusion method	Contents	Applicable types	Applications
Alcohol bonding method	●Method in which alcohol is applied onto wires immediately before coil winding or coils are soaked into alcohol after the winding process. ●Further heating after applying alcohol improves adhesive strength. Be aware of foam formation caused by rapid heating.	B N	Electrical equipment Brush-less motors
Oven bonding method	●Oven bonding is achieved by heat-sealing coils in a heat chamber. ●Suitable for fusion of narrow wires that cannot be electrified due to excessively high resistance or thick wire coils that require a large current.	B F	Electrical equipment Induction cooker
Resistance heating method	●Method in which Joule heat caused by an electric current melts and fuses bonding films. ●In the resistance heating method, the temperature increase depends on the radiation effect as influenced by the conductor diameter, film thickness, wire turns, coil shape, and surrounding environment. Energizing conditions must be determined after examining the test results.	B F	Electrical equipment Induction cooker

* Bonding films shall be fused at approximately the temperatures below.(Element wire end-point temperature)
BF type: 180 to 220°C (epoxy system)
Heating time depends on the coil size, shape, and fusion method.

Table 10: Test method of adhesive strength for self-bonding enamelled wire

Test methods	Sample shapes	Related standards	Methods
Line separation method		JISC3003	Average adhesive strength shall be measured when a 20-turn helical coil is peeled up to two thirds of the way.
Bend strength method		NEMA MW-1000	The breaking strength shall be measured by bending a 75 mm long helical coil with the specified inside diameter at a span of 44 mm.

ø : Depending on the size

Figure 10: Bonding characteristics of self-bonding wire by heat activation at each temperatures

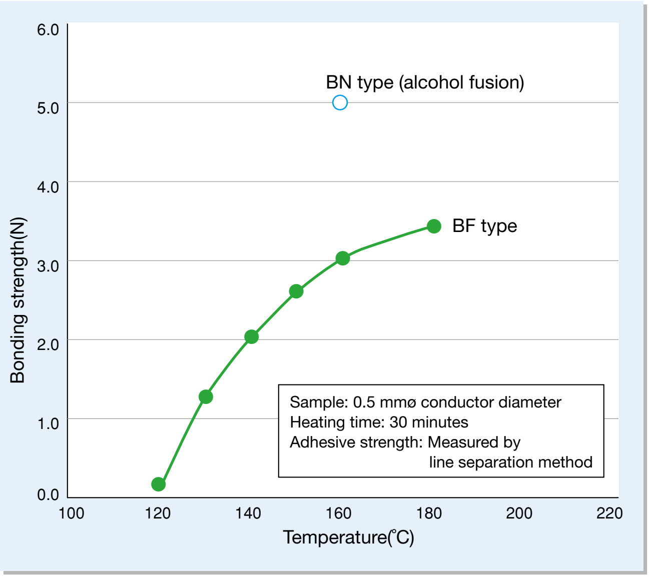
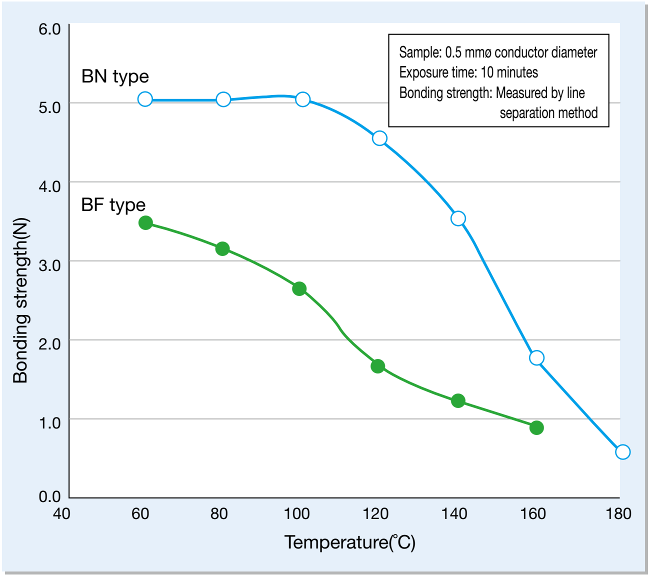


Figure 11: Bonding characteristics of self-bonding wire in high temperatures



Covered conductor wire: Type, symbol, standard, and feature

Type	Symbol	Standard	Size range (mm)	Maximum allowable temperature(°C)	Advantages	Operational precautions	Applications
Glass fiber covered wire	SGC,DGC	JIS C 3204-3	(SGC)0.6〜2.0 (DGC)0.6〜6.0	155 180	●Good and stable heat resistance ●Excellent humidity resistance ●Excellent corona resistance	●Mediocre flexibility	1.Large rotating machines 2.Vehicle motors 3.Small dry transformers
Glass fiber covered rectangular wire	DGC	JIS C 3204-4	Shown in Table 24 (on page35)				
Paper-covered rectangular wire	tKC	JCS 2241	—	105	●Inexpensive ●Good electrical characteristics in oil	●Bending characteristics are limited as paper is not flexible.	1.Oil-filled, large-sized transformer 2.Switch
Heat-resistance, paper-covered rectangular wire	(HL)n KC	SP70-90741	—	115	●Good heat resistance ●Good electrical characteristics in oil		
Transposed wire (Continuous transposed conductor)	TRWm(a×b) tKC	SP70-90790	(element wire size) Thickness: 1.2〜3.0 Width: 4.0〜10 (Number of element wires) 5〜29 (Only odd numbers)	105	●Simplified coil winding process ●Small stray loss in winding wires ●Better space factor than standard paper-covered wires	●Minimum bend diameter =D D (cm) =0.6×element wire conductor width (mm) × number of element wires	1.Oil-filled, large-sized transformers
Mica tape-covered wire	DMPC	SP70-90784	—	155	●Good heat resistance	●Coating is more susceptible to damage than glass-fiber covered wires	1.Small rotating machines 2.Small to medium generators
Aromatic polyamide paper-covered wire	nNPC 2XC	SP70-90742 SP70-90748	—	200	●Good heat resistance ●Good space factor	●Coating is more susceptible to damage than glass-fiber covered wires ●Inferior to SIC in flexibility	1.Dry-type transformer 2.Vehicle motors 3.Heat-resistance equipment
Aromatic polyimide tape-covered wire	nIC	SP70-90780	—	240	●Good heat resistance ●Good space factor ●Excellent dielectric strength	●Coating is more susceptible to damage than glass-fiber covered wires	1.Vehicle motors 2.Heat-resistance equipment

[Content of standards]
JIS : Japanese Industrial Standards
JCS: Japanese Cable Makers' Association Standard
SP : Hitachi Meatals Standard Specifications

[Content of symbols]
n : Number of paper or tape wrappings
m: Number of conductors
t : Insulation thickness on each side
a: Conductor thickness
b: Conductor width

[Size range]
Standard manufacturable range

Performance comparison of covered conductor wire

Magnet wire excluding enamelled wire is also required to have the properties listed in the preceding paragraph.
Tables 11 and 12 show the general properties of covered conductor wire.

●Table 11: Example: Characteristic of covered conductor wire (round wire with a diameter of 1.6mmø)

Properties / Product type (symbol)	Coating thickness (mm)	Breakdown voltage (V)	Breakdown voltage after heating and 6d bend(V)	Bendability (Presence of cracks)						Short circuit temperature(°C)
				2 d	4 d	6 d	8d	10d	12d	
Class F glassfiber covered wire(F-DGC)	0.150	880 (590)	720 (480)	△	△	△	△	△	○	500<
Class H glassfiber covered wire(H-DGC)	0.145	920 (630)	760 (520)	△	△	△	○	○	◎	500<
Polyamide imide/Polyester glass fiber wound wire (1AIW-SGTC)	0.107 (SGTC:0.071)	4,600 (4,300)	4,500 (4,210)	○	◎	◎	◎	◎	◎	500<
Polyester(PEW)	0.068	5,900 (8,680)	5,700 (8,380)	◎	◎	◎	◎	◎	◎	328
Remarks		Metal foil method Value in parentheses: V/0.1mm	59 Metal foil method F-DGC: 180°C for 6 hours H-DGC: 210°C for 6 hours Other : 150°C for 6 hours	◎ Good ○ Small crack △ Medium crack × Crack from which substrate is visible Bending angle =180°						W=10N

Table 12: Example : Characteristic of covered conductor wire (rectangular wire 2×5mm)

Properties / Product type (symbol)	Coating thickness (mm)	Breakdown voltage (V)			Bendability [appearance, breakdown voltage (V)]			
		Ordinary state	150℃	200℃	2 W	4 W	6 W	8 W
Class F glassfiber covered wire（F-DGC）	0.191×0.134	940	950	940	× —	△ 710	○ 730	◎ 730
Class H glassfiber covered wire（H-DGC）	0.196×0.143	830	840	830	× —	△ 690	○ 690	◎ 690
Aromatic polyamide paper-covered wire (2mil butt lapping, double winding) (2XC)	0.138×0.13	2,300	2,200	2,200	× —	○ 1,200	○ 1,400	◎ 1,600
Mica tape-covered wire (0.065 mm butt lapping, double winding)(DMPC)	0.154×0.156	6,400	6,300	6,000	○ 4,500	◎ 5,000	◎ 5,000	◎ 5,800
Aromatic polyimide tape-covered wire (1.5 mil 1/2 lap, single lapping) (SIC)	0.105×0.088	9,340	9,800	9,600	◎ 6,370	◎ 6.570	◎ 6,780	◎ 7,170
Polyester（PEW）	0.064×0.065	5,200	5,400	4,750	◎ 4,800	◎ 4,800	◎ 5,100	◎ 5,600
Remarks		Metal foil method After heating for 24 hours			Appearance { ◎Good, ○Small crack, △Medium crack, ×Crack from which substrate is visible W: Conductor width Bent edgewise 180 degrees			

1 Glass-fiber covered wire

Glass-fiber covered wire used to have weak coating strength (abrasion resistance, shock resistance, and flexibility). However, that disadvantage has been significantly improved recently by refining material selection and manufacturing methods. The demand for glass-fiber covered wire is increasing as the wires have excellent uniformity and electrical properties under high temperatures and humidity. Figures 12 and 13 show the mechanical strength of glass-fiber covered wire.

Figure 12: Change in abrasion resistance under continuous heating at 200℃

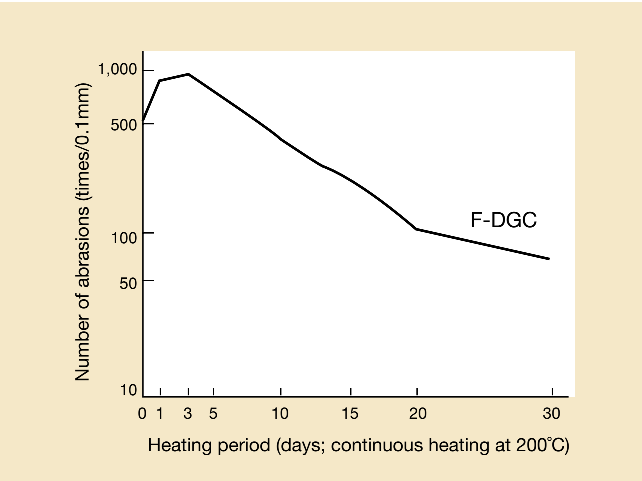
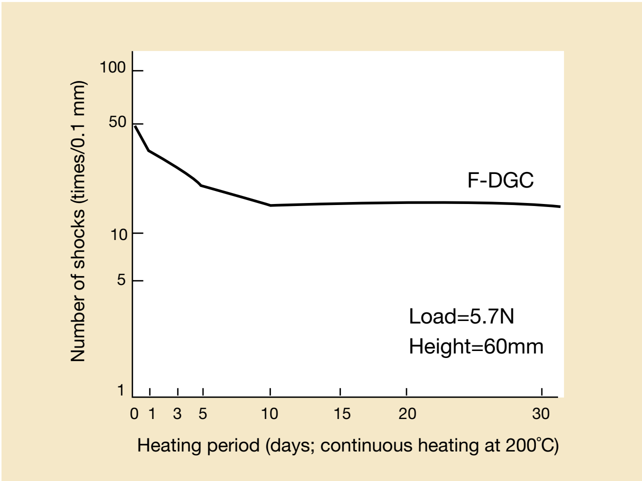


Figure 13: Changes in shock resistance under continuous heating at 200℃



2 Paper-covered wire

Paper-covered wire deliver excellent performance when used with oil such as transformer oil. A paper with a small hygroscopicity, mechanical strength, good permeability for oil, and high dielectric strength should be selected.

3 Aromatic polyimide tape-covered wire

For Aromatic polyimide tape-covered wire, after the wire is taped with a tape that is 1.5 mm thick with 1.0 mm of this thickness being polyimide film and the remaining 0.5 mm being fluoroplastic, it is heated and heat-sealed.
Aromatic polyimide tape-covered wire has a higher space factor than that of glass-fiber covered wire and fully satisfy class-H heat resistance requirements. When Aromatic polyimide tape-covered wire is used as substitute for these glass-fiber covered wire, electrical equipment can be expected to be reduced in size and weight. Aromatic polyimide tape-covered wire has electrical characteristics and coating flexibility far superior to those of glass-fiber covered wire. Aromatic polyimide tape-covered wire is primarily used for electric motors in vehicles, large direct current machines, and dry-transformers. However, the wire is more costly than other winding wires. It is recommended, therefore, to use them when, there are problems in terms of space factor in particular. The wire is inferior to glass-fiber covered wire in corona resistance. When using the wire in high-pressure equipment, special consideration must be given to insulation design.
Table 12 on page 21 shows the property comparison with glass-fiber covered wire.

4 Aromatic polyamide paper-covered wire

Aromatic polyamide paper-covered wire is manufactured by taping heat-resistance polyamide paper around wire. The wire is inferior to Aromatic polyimide tape-covered wire in terms of space factor but are superior to glass-fiber covered wire. The wire fully satisfy Class H heat resistance requirement and enable the miniaturization of electrical equipment.
The wire is almost equal to glass-fiber covered wire in electrical characteristics and coating flexibility. There is no difference with Aromatic polyimide tape-covered wire in other characteristics. Table 12 on page 21 shows the properties of each type.

5 Mica tape-covered wire

Mica tape-covered wire is manufactured by taping a tape (with a thickness of 0.065 mm, 0.040 mm of which is mica thickness) in which reconstituted mica is glued to one side of a polyester tape (with a thickness of 0.025 mm). The wire is superior to glass-fiber covered wire in terms of space factor and is excellent in delivery and price; that is mainly used in small-sized rotating machines as substitutes for glass-fiber covered wire.
This wire is inferior to glass-fiber covered wire in high-pressure corona resistance. When using the wire in high-pressure equipment, special consideration must be given to insulation design.
Table 12 on page 21 shows the properties in comparison with those of glass-fiber covered wire.

6 Transposed wire (Continuous transposed conductor)

For winding wire used for large-sized transformers, it is important that conductors are finely divided and dislocated to reduce losses caused by the skin effect and eddy current.
The transposed wire is wire in which several or several dozens of formal rectangular wires are twisted while being continuously dislocated.
The wires are covered entirely by paper to provide insulation. When used in winding wire of high voltage and large capacity transformer, the wire is expected to reduce the man-hours needed for coil winding and to improve the characteristics and reliability of transformer.
Figure 14 shows the cross section structure of a transposed wire, Figure 15 the appearance thereof, and Table 13 the standard specifications thereof.

Table 13: Standard specifications of Transposed wire

Item		Standard specifications
Element wire conductor dimension	Thickness	1.2～3.0mm
	Width	4.0～10mm
	Width/thickness	2～5
Element wire insulation	Material	Polyvinyl formal paint
	Film thickness	See Table 22 (on page 33)
Element wire weight		Maximum approx. 150kg
Number of element wire		5～29(Always odd numbers)
Dislocation pitch		14 to 22 times of element wire conductor width
Separator paper thickness		0.125mm
Paper-covered insulation	Paper thickness	0.055～0.125mm
	Wrap	Matching or 1/2～1/4 wrap
	Number of wrappings	Minimum of four
Packing		Drum winding
Minimum bend diameter = D (Reference value)		D(cm)＝0.6× Element wire conductor width (mm) × number of element wires
Strand-to-strand short circuit test voltage		DC 30V
Display method		Example TRW15 (↑ Number of element wires) (1.8×6) (↑ Conductor size) 0.75KC (↑ Insulation thickness on each side)

Figure 14: Cross section structure of Transposed wire

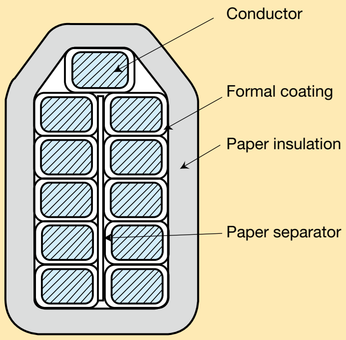
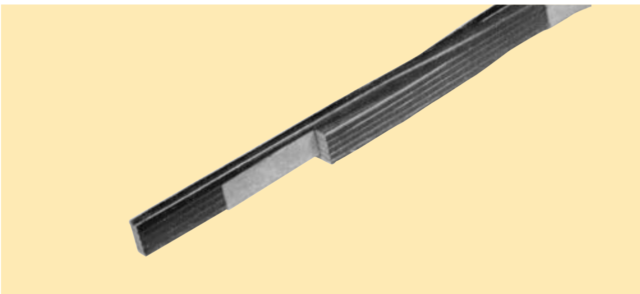


Figure 15: Appearance of Transposed wire



Combination wire: Type, symbol, standard, and feature

Type	Symbol	Standard	Film thickness	Size range (mm)	Temperature index (℃)	Advantages	Operational precautions	Applications
Aromester XV Glass-fiber covered rectangular wire	AMW-XV-SGC AMW-XV-DGC	SP70-90723 SP70-90722	—	—	Class F 155 Class H 180	●High mechanical strength ●Good electrical characteristics	●Poor space factor	1.Large generators 2.Large electric motors
Imec glassfiber covered wire	AIW-SGC AIW-DGC	SP70-90615	Class 0 Class 1	0.6～3.2 0.6～3.2	155	Same with above	Same with above	Same with above
Imec glassfiber covered rectangular wire	AIW-SGC AIW-DGC	SP70-90716 SP70-90715	—	—	Class F 155 Class H 180	Same with above	Same with above	Same with above

[Contents of standard] SP: Hitachi Metals standard specifications
[Size range] Standard manufacturable size

Permissible current of magnet wire

Magnet wire is generally used as coil. Accordingly, the permissible current depends on the coil shape and operating temperature conditions. Although there is no standardization, the current is generally estimated according to the formula below.
In performing estimation, consideration must be given so that the internal coil temperature does not exceed the maximum allowable insulation coating temperature.
Generally, the current value is about 5A/mm2 (per conductor cross sectional area).

Note) Permissible current calculation formula

$$I=\sqrt{\frac{k\cdot\pi\cdot D\cdot\theta}{\beta\cdot R\times10^{-5}}}$$

I :Permissible current (A)
K: Coefficient of heat emission (W/℃･cm)
D: Conductor diameter (cm)
θ : Temperature rise (℃)
ß: AC resistance/DC resistance
R: Conductor resistance in usage state (Ω/cm)

Coil winding: Operational precautions

General precautions

For winding operation using magnet wire, the treatment and operational precautions based on the properties thereof are described below.

1 Do dimensions (thickness and width) conform to the specifications?

Wire undergoes dimensional inspection at time of manufacture, however, taking into consideration the improper use by management, storage and other processes, it is important to measure outside diameter, width and thickness again immediately before use to confirm that the dimensions conform to the intended purpose.

2 Are many oxide films left on bare wire surfaces?

Especially when winding a bare wire around a coil, the presence of an oxide film on the wire surface may pose a problem in soldering or the oxide film may come off as a fine powder and get into the coil insulation. Thus, when using a wire with a substantial oxide film, it is better to perform acid pickling, neutralization, and rinsing before use.

3 Are flaws or frictions checked for?

Wires may have been damaged due to poor handling during transport or storage. Accordingly, after inspecting the wires carefully, small flaws are repaired and significant flaws removed. Aluminum conductors are soft and easily deform; special care is needed during handling.

4 How to handle excess wires

After the coil winding process, excess wires shall be stored away from dust particles (metal powder in particular), moisture, and direct sunlight.

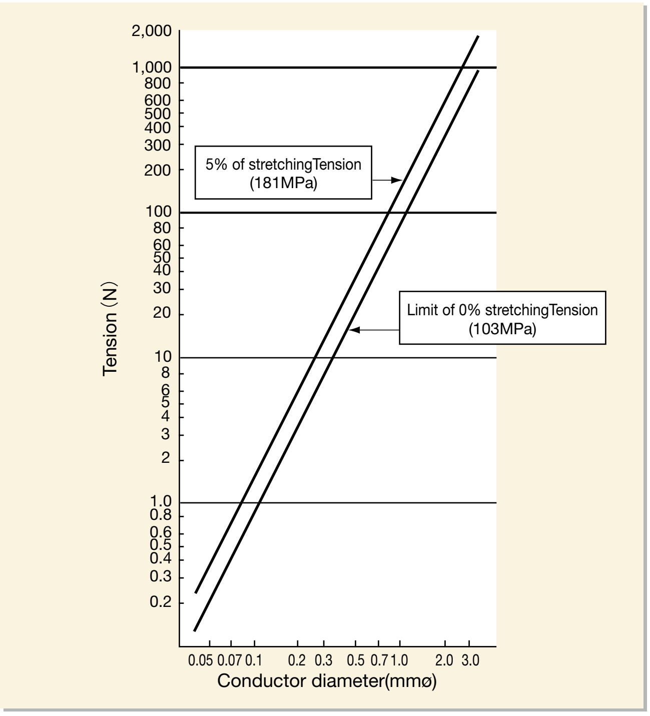
Precautions for enamelled wire

The insulation properties of enamelled wire are generally ensured with a very thin coating. Therefore, take special note that the wire is susceptible to external damage by sharp-edged.

1 Minimize stretching during the coil winding process!

Wire stretching shall be minimized during coil winding process. Stretching decreases the film thickness, leading to deterioration in properties. The smaller the stretching, the better. If stretching is limited to less than 5%, the property degradation of enamelled wire, except for thin wire, will generally be lessened. For reference, Figure 16 shows the tensions at which a wire is stretched by 5% and the wire starts to stretch.

Figure 16: Coil winding tension on enamelled wire



2 Exercise care in selecting treatment varnish!

Generally, coils are varnish-treated after the coil winding process. However, various types of coil varnishes have been developed and are in use. Great care shall be exercised in combining these varnishes.

3 No releasing agent shall be dispersed!

When using a chemical release agent to remove film before performing terminal soldering, special care must be exercised so that the release agent does not adhere to other portions of the coil. It is also important to neutralize the release agent and rinse it thoroughly with water after film removal.

Failure to do so may cause narrow wire to become corroded and disconnected; due care must be exercised. When peeling a film, be sure to wear protective gear such as goggles to prevent chemicals and separated chips from getting into the eyes.

For reference, Table 8 on page 17 shows methods for removing film on enamelled wire.

Coil forming: Operational precautions

Considerations for forming

Dies are used for forming coils in many cases. A flaw on a die surface causes damage to the wire coating; die surfaces shall be checked before use.

Precautions about brake

When winding a coil by a coil winding machine, appropriate tension must be given to a magnet wire. Therefore, a brake, which also serves as a corrector of wire bending, is put into use. It is desirable that the pressure surface should not be a slide surface but a role surface and is important that the brake strength be selected to minimize the magnet wire stretching.
Special care must be taken with narrow wires.

Automatic machine winding

When direct coil winding to electrical equipment using an automatic coil winding machine, first consider whether or not the coil will be damaged or the dimensions reduced after mechanical winding.

Repairing at corner

In some cases, coating wire is bent with a few millimeters of bend radius by using the coil of a rotating machine. It is inevitable that the coating is damaged to some extent at the bends. It is desirable for repair materials to be identical to those of coating. In cases of inevitable situation, materials with similar mechanical, electrical and thermal properties should be selected.

Handling after coil forming

Formed coils as mentioned above will become finished products through further stages - insulating, drying, and varnishing. These coils are assembled to stators or rotors. Extra care must be exercised to check for deformed coil shape and damaged coating during transportation or other handling processes down to the wire mounting process.
Coils shall be stored away from dust particles (particularly metal powder) and moisture.
However, due to the presence of strain, sweat, or moisture from enamel coatings in winding wires, preliminary drying is recommended.

For aluminum conductor magnet wire

1 Precautions about brakes

Since aluminum conductor has a low tensile strength, the brake strength for this conductor should be about 30% or less than that of copper wire. A higher brake strength increases stretching, thereby deteriorating the properties.

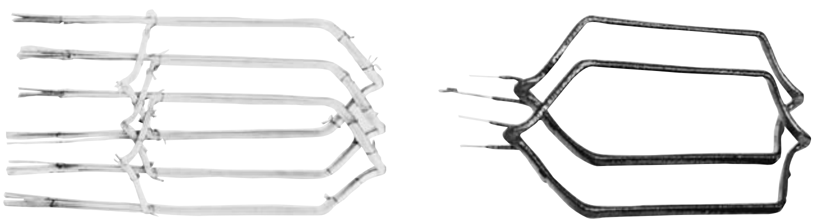
2 Precaution in automatic machine winding

Aluminum conductor may be stretched locally by 10% or more due to impact force during machine winding; special care must be exercised.

3 Precaution in molding process

An aluminum conductor is soft and may deform before its coating is damaged; special care must be taken with pressurizing method during coil molding.

Figure 17: Stator coil of induction electric motor using glass-fiber covered wire



After molding After insulation treatment

Storage of magnet wire

Please pay attention to the following points when storing magnet wire for a long period of time.

(1) Never store wire in an area exposed to direct sunlight.

(2) Avoid high-humidity environments.

(3) Avoid special environments (gasses).

(4) Be sure that no magnet wire will hit other articles or other magnet wires.

(5) Never store wire in a dusty area.

Storage period

If magnet wire is stored properly in accordance with paragraph 1, there will be no deterioration in properties even after 10 years or more have passed.

However, for magnet wire that is not stored properly, if 3 years have passed since delivery, check the characteristics before use to confirm there is no problems.

If you have any question, please contact us.

Dimensional table of magnet wire

The dimensional tables of magnet wire are as shown in Tables 14 to 24.

Table 14: Dimensional table of enamelled wire (Class 0)

Conductor		Minimum film thickness (mm)	Overall diameter		Estimated weight (kg/km)		Conductor resistance 20℃ (/km)			
Diameter (mm)	Tolerance (mm)		Nominal (mm)	Maximum (mm)	Copper	Aluminum	Copper		Aluminum	
							Nominal	Maximum	Nominal	Maximum
3.20	±0.04	0.049	3.342	3.388	72.4	22.6	2.144	2.198	3.458	3.546
3.00	±0.03	0.049	3.138	3.178	63.7	19.9	2.439	2.489	3.935	4.015
2.90	±0.03	0.049	3.038	3.078	59.5	18.7	2.610	2.665	4.211	4.299
2.80	±0.03	0.049	2.938	2.978	55.5	17.4	2.800	2.861	4.517	4.615
2.70	±0.03	0.049	2.838	2.878	51.7	16.3	3.011	3.079	4.858	4.968
2.60	±0.03	0.049	2.738	2.778	47.9	15.1	3.247	3.324	5.239	5.362
2.50	±0.03	0.049	2.638	2.678	44.3	14.0	3.512	3.598	5.666	5.805
2.40	±0.03	0.048	2.536	2.574	40.9	12.9	3.811	3.908	6.148	6.305
2.30	±0.03	0.046	2.430	2.468	37.6	11.8	4.150	4.260	6.694	6.872
2.20	±0.03	0.046	2.330	2.368	34.4	10.9	4.536	4.662	7.317	7.520
2.10	±0.03	0.045	2.228	2.266	31.3	9.91	4.978	5.123	8.030	8.265
2.00	±0.03	0.044	2.126	2.162	28.4	9.00	5.488	5.656	8.853	9.125
1.90	±0.03	0.044	2.026	2.062	25.7	8.15	6.081	6.278	9.810	10.13
1.80	±0.03	0.042	1.920	1.956	23.1	7.32	6.775	7.007	10.93	11.30
1.70	±0.03	0.042	1.820	1.856	20.6	6.55	7.596	7.871	12.25	12.70
1.60	±0.03	0.041	1.718	1.754	18.3	5.82	8.575	8.906	13.83	14.37
1.50	±0.03	0.041	1.618	1.654	16.1	5.14	9.756	10.16	15.74	16.39
1.40	±0.03	0.039	1.514	1.548	14.0	4.49	11.20	11.70	18.07	18.87
1.30	±0.03	0.039	1.414	1.448	12.1	3.89	12.99	13.61	20.95	21.96
1.20	±0.03	0.037	1.308	1.342	10.3	3.33	15.24	16.04	24.59	25.87
1.10	±0.03	0.037	1.208	1.242	8.70	2.82	18.14	19.17	29.27	30.93
1.00	±0.03	0.036	1.106	1.138	7.21	2.34	21.95	23.33	35.41	37.64
0.95	±0.02	0.034	1.046	1.072	6.49	2.11	24.32	25.38	39.24	40.95
0.90	±0.02	0.033	0.994	1.020	5.83	1.90	27.10	28.35	43.72	45.73
0.85	±0.02	0.032	0.942	0.966	5.21	1.70	30.38	31.87	49.01	51.41
0.80	±0.02	0.031	0.888	0.914	4.62	1.51	34.30	36.08	55.33	58.21
0.75	±0.02	0.030	0.836	0.860	4.06	1.33	39.03	41.19	62.96	66.45
0.70	±0.02	0.028	0.780	0.804	3.54	1.16	44.80	47.47	72.27	76.59
0.65	±0.02	0.027	0.728	0.752	3.06	1.00	51.96	55.31	83.92	89.22
0.60	±0.02	0.026	0.676	0.698	2.61	0.86	60.98	65.26	98.37	105.3
0.55	±0.02	0.025	0.624	0.646	2.20	0.73	72.57	78.15	117.1	126.1
0.50	±0.01	0.025	0.568	0.586	1.82	0.60	87.81	91.43	141.7	147.5
0.45	±0.01	0.024	0.516	0.532	1.48	0.49	109.2	114.2	174.9	182.9
0.40	±0.01	0.023	0.464	0.480	1.17	0.39	138.2	145.3	221.3	232.8
0.37	±0.01	0.022	0.430	0.446	1.00	0.34	161.5	170.6	258.7	273.2
0.35	±0.01	0.021	0.408	0.424	0.90	0.30	180.5	191.2	289.1	306.3
0.32	±0.01	0.021	0.378	0.394	0.76	0.26	215.9	230.0	345.8	368.5
0.30	±0.01	0.021	0.358	0.374	0.67	0.23	245.6	262.9	393.5	421.1
0.29	±0.01	0.020	0.346	0.360	0.62	0.21	266.3	285.7	421.1	451.7
0.28	±0.01	0.020	0.336	0.350	0.58	0.20	285.7	307.3	451.7	485.8
0.27	±0.01	0.020	0.326	0.340	0.54	0.19	307.3	331.4	485.8	523.9
0.26	±0.01	0.020	0.316	0.330	0.50	0.18	331.4	358.4	523.9	566.6
0.25	±0.008	0.020	0.304	0.318	0.47	0.16	358.4	382.5	566.6	605.4
0.24	±0.008	0.020	0.294	0.308	0.43	0.15	388.9	416.2	614.8	658.2
0.23	±0.008	0.020	0.284	0.298	0.40	0.14	423.4	454.5	669.4	719.8
0.22	±0.008	0.019	0.272	0.286	0.36	0.13	462.8	498.4	731.7	788.7
0.21	±0.008	0.019	0.262	0.276	0.33	0.12	507.9	549.0	803.0	868.0
0.20	±0.008	0.019	0.252	0.266	0.30	0.11	560.0	607.6	885.3	962.3
0.19	±0.008	0.019	0.242	0.256	0.27	—	620.5	676.2	—	—
0.18	±0.008	0.019	0.232	0.246	0.25	—	691.4	757.2	—	—
0.17	±0.008	0.018	0.220	0.232	0.22	—	775.1	853.5	—	—
0.16	±0.008	0.018	0.210	0.222	0.20	—	875.0	969.5	—	—
0.15	±0.008	0.017	0.198	0.210	0.17	—	995.6	1,111	—	—
0.14	±0.008	0.017	0.188	0.200	0.15	—	1,143	1,286	—	—
0.13	±0.008	0.017	0.178	0.190	0.13	—	1,325	1,505	—	—
0.12	±0.008	0.017	0.168	0.180	0.12	—	1,556	1,786	—	—
0.11	±0.008	0.016	0.154	0.166	0.096	—	1,851	2,153	—	—
0.10	±0.008	0.016	0.144	0.156	0.081	—	2,240	2,647	—	—

Table 15: Dimensional table of enamelled wire (Class 1)

Conductor		Minimum film thickness (mm)	Overall diameter		Estimated weight (kg/km)		Conductor resistance 20°C (/km)			
Diameter (mm)	Tolerance (mm)		Nominal (mm)	Maximum (mm)	Copper	Aluminum	Copper		Aluminum	
							Nominal	Maximum	Nominal	Maximum
3.20	±0.04	0.034	3.304	3.338	72.2	22.4	2.144	2.198	3.458	3.546
3.00	±0.03	0.034	3.098	3.128	63.4	19.7	2.439	2.489	3.935	4.015
2.90	±0.03	0.034	2.998	3.028	59.3	18.4	2.610	2.665	4.211	4.299
2.80	±0.03	0.034	2.898	2.928	55.3	17.2	2.800	2.861	4.517	4.615
2.70	±0.03	0.034	2.798	2.828	51.4	16.0	3.011	3.079	4.858	4.968
2.60	±0.03	0.034	2.698	2.728	47.7	14.9	3.247	3.324	5.239	5.362
2.50	±0.03	0.034	2.598	2.628	44.1	13.8	3.512	3.598	5.666	5.805
2.40	±0.03	0.033	2.496	2.526	40.7	12.7	3.811	3.908	6.148	6.305
2.30	±0.03	0.032	2.394	2.422	37.4	11.7	4.150	4.260	6.694	6.872
2.20	±0.03	0.032	2.294	2.322	34.2	10.7	4.536	4.662	7.317	7.520
2.10	±0.03	0.031	2.192	2.220	31.2	9.75	4.978	5.123	8.030	8.265
2.00	±0.03	0.030	2.090	2.118	28.3	8.85	5.488	5.656	8.853	9.125
1.90	±0.03	0.030	1.990	2.018	25.6	8.01	6.081	6.278	9.810	10.13
1.80	±0.03	0.029	1.886	1.914	22.9	7.19	6.775	7.007	10.93	11.30
1.70	±0.03	0.029	1.786	1.814	20.5	6.43	7.596	7.871	12.25	12.70
1.60	±0.03	0.028	1.684	1.712	18.2	5.71	8.575	8.906	13.83	14.37
1.50	±0.03	0.028	1.584	1.612	16.0	5.03	9.756	10.16	15.74	16.39
1.40	±0.03	0.027	1.482	1.508	13.9	4.39	11.20	11.70	18.07	18.87
1.30	±0.03	0.027	1.382	1.408	12.0	3.80	12.99	13.61	20.95	21.96
1.20	±0.03	0.026	1.278	1.304	10.2	3.25	15.24	16.04	24.59	25.87
1.10	±0.03	0.026	1.178	1.204	8.63	2.74	18.14	19.17	29.27	30.93
1.00	±0.03	0.025	1.076	1.102	7.14	2.28	21.95	23.33	35.41	37.64
0.95	±0.02	0.024	1.018	1.038	6.44	2.05	24.32	25.38	39.24	40.95
0.90	±0.02	0.023	0.966	0.986	5.78	1.84	27.10	28.35	43.72	45.73
0.85	±0.02	0.022	0.914	0.934	5.16	1.65	30.38	31.87	49.01	51.41
0.80	±0.02	0.021	0.862	0.882	4.57	1.46	34.30	36.08	55.33	58.21
0.75	±0.02	0.020	0.810	0.830	4.02	1.29	39.03	41.19	62.96	66.45
0.70	±0.02	0.019	0.758	0.776	3.51	1.12	44.80	47.47	72.27	76.59
0.65	±0.02	0.018	0.706	0.724	3.03	0.97	51.96	55.31	83.92	89.22
0.60	±0.02	0.017	0.654	0.672	2.58	0.83	60.98	65.26	98.37	105.3
0.55	±0.02	0.017	0.602	0.620	2.17	0.70	72.57	78.15	117.1	126.1
0.50	±0.01	0.017	0.548	0.560	1.80	0.58	87.81	91.43	141.7	147.5
0.45	±0.01	0.016	0.496	0.508	1.46	0.47	109.2	114.2	174.9	182.9
0.40	±0.01	0.015	0.444	0.456	1.15	0.38	138.2	145.3	221.3	232.8
0.37	±0.01	0.014	0.412	0.424	0.99	0.32	161.5	170.6	258.7	273.2
0.35	±0.01	0.014	0.390	0.402	0.89	0.29	180.5	191.2	289.1	306.3
0.32	±0.01	0.014	0.360	0.372	0.74	0.24	215.9	230.0	345.8	368.5
0.30	±0.01	0.014	0.340	0.352	0.65	0.22	245.6	262.9	393.5	421.1
0.29	±0.01	0.013	0.328	0.340	0.61	0.20	266.3	285.7	421.1	451.7
0.28	±0.01	0.013	0.318	0.330	0.57	0.19	285.7	307.3	451.7	485.8
0.27	±0.01	0.013	0.308	0.320	0.53	0.18	307.3	331.4	485.8	523.9
0.26	±0.01	0.013	0.298	0.310	0.49	0.16	331.4	358.4	523.9	566.6
0.25	±0.008	0.013	0.288	0.298	0.46	0.15	358.4	382.5	566.6	605.4
0.24	±0.008	0.013	0.278	0.288	0.42	0.14	388.9	416.2	614.8	658.2
0.23	±0.008	0.013	0.268	0.278	0.39	0.13	423.4	454.5	669.4	719.8
0.22	±0.008	0.012	0.256	0.266	0.36	0.12	462.8	498.4	731.7	788.7
0.21	±0.008	0.012	0.246	0.256	0.32	0.11	507.9	549.0	803.0	868.0
0.20	±0.008	0.012	0.236	0.246	0.30	0.10	560.5	607.6	885.3	962.3
0.19	±0.008	0.012	0.226	0.236	0.27	—	620.5	676.2	—	—
0.18	±0.008	0.012	0.216	0.226	0.24	—	691.4	757.2	—	—
0.17	±0.008	0.011	0.204	0.214	0.22	—	775.1	853.5	—	—
0.16	±0.008	0.011	0.194	0.204	0.19	—	875.0	969.5	—	—
0.15	±0.008	0.010	0.182	0.192	0.17	—	995.6	1,111	—	—
0.14	±0.008	0.010	0.172	0.182	0.15	—	1,143	1,286	—	—
0.13	±0.008	0.010	0.162	0.172	0.13	—	1,325	1,505	—	—
0.12	±0.008	0.010	0.152	0.162	0.11	—	1,556	1,786	—	—
0.11	±0.008	0.009	0.138	0.150	0.091	—	1,851	2,153	—	—
0.10	±0.008	0.009	0.128	0.140	0.076	—	2,240	2,647	—	—

Table 16: Dimensional table of enamelled wire (Class 2 and 3)

Conductor		Class 2				Class 3				Conductor resistance 20℃ (/km)	
Diameter (mm)	Tolerance (mm)	Minimum film thickness (mm)	Overall diameter Nominal(mm)	Overall diameter Maximum(mm)	Estimated weight (kg/km)	Minimum film thickness (mm)	Overall diameter Nominal(mm)	Overall diameter Maximum(mm)	Estimated weight (kg/km)	Nominal	Maximum
1.00	±0.012	0.017	1.048	1.062	7.08	–	–	–	–	21.95	22.49
0.95	±0.010	0.017	0.996	1.008	6.39	–	–	–	–	24.32	24.84
0.90	±0.010	0.016	0.944	0.956	5.74	–	–	–	–	27.10	27.71
0.85	±0.010	0.015	0.892	0.904	5.12	–	–	–	–	30.38	31.11
0.80	±0.010	0.015	0.842	0.852	4.54	–	–	–	–	34.30	35.17
0.75	±0.008	0.014	0.788	0.798	3.99	–	–	–	–	39.03	39.87
0.70	±0.008	0.013	0.736	0.746	3.47	–	–	–	–	44.80	45.84
0.65	±0.008	0.012	0.684	0.694	3.00	–	–	–	–	51.96	53.26
0.60	±0.008	0.012	0.634	0.644	2.56	0.008	0.624	0.632	2.54	60.98	62.64
0.55	±0.006	0.012	0.584	0.592	2.15	0.008	0.574	0.581	2.14	72.57	74.18
0.50	±0.006	0.012	0.534	0.542	1.78	0.008	0.524	0.531	1.77	87.81	89.95
0.45	±0.006	0.011	0.482	0.490	1.44	0.007	0.472	0.479	1.43	109.2	112.1
0.40	±0.005	0.011	0.430	0.439	1.14	0.007	0.420	0.429	1.13	138.2	141.7
0.37	±0.005	0.010	0.398	0.407	0.98	0.007	0.390	0.397	0.97	161.5	165.9
0.35	±0.005	0.010	0.378	0.387	0.88	0.007	0.370	0.377	0.87	180.5	185.7
0.32	±0.005	0.010	0.348	0.357	0.73	0.007	0.340	0.347	0.73	215.9	222.8
0.30	±0.005	0.010	0.328	0.337	0.65	0.007	0.320	0.327	0.64	245.6	254.0
0.29	±0.004	0.009	0.316	0.324	0.60	0.006	0.308	0.315	0.60	266.3	273.9
0.28	±0.004	0.009	0.306	0.314	0.56	0.006	0.298	0.305	0.56	285.7	294.4
0.27	±0.004	0.009	0.296	0.304	0.52	0.006	0.288	0.295	0.52	307.3	316.6
0.26	±0.004	0.009	0.286	0.294	0.49	0.006	0.278	0.285	0.48	331.4	341.8
0.25	±0.004	0.009	0.276	0.284	0.45	0.006	0.268	0.275	0.45	358.4	370.2
0.24	±0.004	0.009	0.266	0.274	0.42	0.006	0.258	0.265	0.41	388.9	402.2
0.23	±0.004	0.009	0.256	0.264	0.38	0.006	0.248	0.255	0.38	423.4	438.6
0.22	±0.004	0.008	0.244	0.252	0.35	0.005	0.236	0.243	0.35	462.8	480.1
0.21	±0.003	0.008	0.234	0.241	0.32	0.005	0.226	0.232	0.32	507.9	522.8
0.20	±0.003	0.008	0.224	0.231	0.29	0.005	0.216	0.222	0.29	560.0	577.2
0.19	±0.003	0.008	0.214	0.221	0.26	0.005	0.206	0.212	0.26	620.5	640.6
0.18	±0.003	0.008	0.204	0.211	0.24	0.005	0.196	0.202	0.23	691.4	715.0
0.17	±0.003	0.007	0.192	0.199	0.21	0.005	0.186	0.191	0.21	775.1	803.2
0.16	±0.003	0.007	0.182	0.189	0.19	0.005	0.176	0.181	0.18	875.0	908.8
0.15	±0.003	0.006	0.170	0.177	0.16	0.004	0.164	0.169	0.16	995.6	1,037
0.14	±0.003	0.006	0.160	0.167	0.14	0.004	0.154	0.159	0.14	1,143	1,193
0.13	±0.003	0.006	0.150	0.157	0.12	0.004	0.144	0.149	0.12	1,325	1,389
0.12	±0.003	0.006	0.140	0.147	0.11	0.004	0.134	0.139	0.11	1,556	1,636
0.11	±0.003	0.005	0.128	0.135	0.088	0.003	0.122	0.128	0.087	1,851	1,957
0.10	±0.003	0.005	0.118	0.125	0.074	0.003	0.112	0.118	0.073	2,240	2,381

Table 17: Dimensional table of enamelled wire (Self-bonding wire) [In the case of finish Class 0, insulation layer Class 1]

Conductor		Insulation layer (Class 1)				Self-bonding layer (Class 0)		Nominal overall diameter (mm)	Maximum overall diameter (mm)
Diameter (mm)	Tolerance (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)	Nominal overall diameter (mm)	Maximum overall diameter (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)		
2.0	±0.03	0.030	0.045	2.090	2.118	0.014	0.018	2.126	2.162
1.9	±0.03	0.030	0.045	1.990	2.018	0.014	0.018	2.026	2.062
1.8	±0.03	0.029	0.043	1.886	1.914	0.013	0.017	1.920	1.956
1.7	±0.03	0.029	0.043	1.786	1.814	0.013	0.017	1.820	1.856
1.6	±0.03	0.028	0.042	1.684	1.712	0.013	0.017	1.718	1.754
1.5	±0.03	0.028	0.042	1.584	1.612	0.013	0.017	1.618	1.654
1.4	±0.03	0.027	0.041	1.482	1.508	0.012	0.016	1.514	1.548
1.3	±0.03	0.027	0.041	1.382	1.408	0.012	0.016	1.414	1.448
1.2	±0.03	0.026	0.039	1.278	1.304	0.011	0.015	1.308	1.342
1.1	±0.03	0.026	0.039	1.178	1.204	0.011	0.015	1.208	1.242
1.0	±0.03	0.025	0.038	1.076	1.102	0.011	0.015	1.106	1.138
0.95	±0.02	0.024	0.034	1.018	1.038	0.010	0.014	1.046	1.072
0.90	±0.02	0.023	0.033	0.966	0.986	0.010	0.014	0.994	1.020
0.85	±0.02	0.022	0.032	0.914	0.934	0.010	0.014	0.942	0.966
0.80	±0.02	0.021	0.031	0.862	0.882	0.010	0.013	0.888	0.914
0.75	±0.02	0.020	0.030	0.810	0.830	0.010	0.013	0.836	0.860
0.70	±0.02	0.019	0.029	0.758	0.776	0.009	0.011	0.780	0.804
0.65	±0.02	0.018	0.028	0.706	0.724	0.009	0.011	0.728	0.752
0.60	±0.02	0.017	0.027	0.654	0.672	0.009	0.011	0.676	0.698
0.55	±0.02	0.017	0.026	0.602	0.620	0.008	0.011	0.624	0.646
0.50	±0.01	0.017	0.024	0.548	0.560	0.008	0.010	0.568	0.586
0.45	±0.01	0.016	0.023	0.496	0.508	0.008	0.010	0.516	0.532
0.40	±0.01	0.015	0.022	0.444	0.456	0.008	0.010	0.464	0.480
0.37	±0.01	0.014	0.021	0.412	0.424	0.008	0.009	0.430	0.446
0.35	±0.01	0.014	0.020	0.390	0.402	0.007	0.009	0.408	0.424
0.32	±0.01	0.014	0.020	0.360	0.372	0.007	0.009	0.378	0.394
0.30	±0.01	0.014	0.020	0.340	0.352	0.007	0.009	0.358	0.374
0.29	±0.01	0.013	0.019	0.328	0.340	0.007	0.009	0.346	0.360
0.28	±0.01	0.013	0.019	0.318	0.330	0.007	0.009	0.336	0.350
0.27	±0.01	0.013	0.019	0.308	0.320	0.007	0.009	0.326	0.340
0.26	±0.01	0.013	0.019	0.298	0.310	0.007	0.009	0.316	0.330
0.25	±0.008	0.013	0.019	0.288	0.298	0.007	0.008	0.304	0.318
0.24	±0.008	0.013	0.019	0.278	0.288	0.007	0.008	0.294	0.308
0.23	±0.008	0.013	0.019	0.268	0.278	0.007	0.008	0.284	0.298
0.22	±0.008	0.012	0.018	0.256	0.266	0.007	0.008	0.272	0.286
0.21	±0.008	0.012	0.018	0.246	0.256	0.007	0.008	0.262	0.276
0.20	±0.008	0.012	0.018	0.236	0.246	0.007	0.008	0.252	0.266
0.19	±0.008	0.012	0.018	0.226	0.236	0.007	0.008	0.242	0.256
0.18	±0.008	0.012	0.018	0.216	0.226	0.007	0.008	0.232	0.246
0.17	±0.008	0.011	0.017	0.204	0.214	0.007	0.008	0.220	0.232
0.16	±0.008	0.011	0.017	0.194	0.204	0.007	0.008	0.210	0.222
0.15	±0.008	0.010	0.016	0.182	0.192	0.007	0.008	0.198	0.210
0.14	±0.008	0.010	0.016	0.172	0.182	0.007	0.008	0.188	0.200
0.13	±0.008	0.010	0.016	0.162	0.172	0.007	0.008	0.178	0.190
0.12	±0.008	0.010	0.016	0.152	0.162	0.007	0.008	0.168	0.180
0.11	±0.008	0.009	0.014	0.138	0.150	0.007	0.008	0.154	0.166
0.10	±0.008	0.009	0.014	0.128	0.140	0.007	0.008	0.144	0.156

Table 18: Dimensional table of enamelled wire (Self-bonding wire) [in the case of finish Class 1, insulation layer Class 2]

Conductor		Insulation layer (Class 2)				Self-bonding layer (Class 1)		Nominal overall diameter (mm)	Maximum overall diameter (mm)
Diameter (mm)	Tolerance (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)	Nominal overall diameter (mm)	Maximum overall diameter (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)		
1.0	±0.03	0.017	0.024	1.048	1.062	0.008	0.014	1.076	1.102
0.95	±0.02	0.017	0.023	0.996	1.008	0.007	0.011	1.018	1.038
0.90	±0.02	0.016	0.022	0.944	0.956	0.007	0.011	0.966	0.986
0.85	±0.02	0.015	0.021	0.892	0.904	0.007	0.011	0.914	0.934
0.80	±0.02	0.015	0.020	0.840	0.852	0.006	0.011	0.862	0.882
0.75	±0.02	0.014	0.019	0.788	0.798	0.006	0.011	0.810	0.830
0.70	±0.02	0.013	0.018	0.736	0.746	0.006	0.011	0.758	0.776
0.65	±0.02	0.012	0.017	0.684	0.694	0.006	0.011	0.706	0.724
0.60	±0.02	0.012	0.017	0.634	0.644	0.005	0.010	0.654	0.672
0.55	±0.02	0.012	0.017	0.584	0.592	0.005	0.009	0.602	0.620
0.50	±0.01	0.012	0.017	0.533	0.542	0.005	0.007	0.548	0.560
0.45	±0.01	0.011	0.016	0.482	0.490	0.005	0.007	0.496	0.508
0.40	±0.01	0.011	0.015	0.430	0.439	0.004	0.007	0.444	0.456
0.37	±0.01	0.010	0.014	0.398	0.407	0.004	0.007	0.412	0.424
0.35	±0.01	0.010	0.014	0.378	0.387	0.004	0.006	0.390	0.402
0.32	±0.01	0.010	0.014	0.348	0.357	0.004	0.006	0.360	0.372
0.30	±0.01	0.010	0.014	0.328	0.337	0.004	0.006	0.340	0.352
0.29	±0.01	0.009	0.013	0.316	0.324	0.004	0.006	0.328	0.340
0.28	±0.01	0.009	0.013	0.306	0.314	0.004	0.006	0.318	0.330
0.27	±0.01	0.009	0.013	0.296	0.304	0.004	0.006	0.308	0.320
0.26	±0.01	0.009	0.013	0.286	0.294	0.004	0.006	0.298	0.310
0.25	±0.008	0.009	0.013	0.276	0.284	0.004	0.006	0.288	0.298
0.24	±0.008	0.009	0.013	0.266	0.274	0.004	0.006	0.278	0.288
0.23	±0.008	0.009	0.013	0.256	0.264	0.004	0.006	0.268	0.278
0.22	±0.008	0.008	0.012	0.244	0.252	0.004	0.006	0.256	0.266
0.21	±0.008	0.008	0.012	0.234	0.241	0.004	0.006	0.246	0.256
0.20	±0.008	0.008	0.012	0.224	0.231	0.004	0.006	0.236	0.246
0.19	±0.008	0.008	0.012	0.214	0.221	0.004	0.006	0.226	0.236
0.18	±0.008	0.008	0.012	0.204	0.211	0.004	0.006	0.216	0.226
0.17	±0.008	0.007	0.011	0.192	0.199	0.004	0.006	0.204	0.214
0.16	±0.008	0.007	0.011	0.182	0.189	0.004	0.006	0.194	0.204
0.15	±0.008	0.006	0.010	0.170	0.177	0.004	0.006	0.182	0.192
0.14	±0.008	0.006	0.010	0.160	0.167	0.004	0.006	0.172	0.182
0.13	±0.008	0.006	0.010	0.150	0.157	0.004	0.006	0.162	0.172
0.12	±0.008	0.006	0.010	0.140	0.147	0.004	0.006	0.152	0.162
0.11	±0.008	0.005	0.009	0.128	0.135	0.004	0.005	0.138	0.150
0.10	±0.008	0.005	0.009	0.118	0.125	0.004	0.005	0.128	0.140

Table 19: Dimensional table of enamelled wire (Self-bonding wire) [in the case of finish Class 2, insulation layer Class 3]

Conductor		Insulation layer (Class 3)				Self-bonding layer (Class 2)		Nominal overall diameter (mm)	Maximum overall diameter (mm)
Diameter (mm)	Tolerance (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)	Nominal overall diameter (mm)	Maximum overall diameter (mm)	Minimum film thickness (mm)	Nominal film thickness (mm)		
0.60	±0.008	0.008	0.012	0.624	0.632	0.004	0.005	0.634	0.644
0.55	±0.006	0.008	0.011	0.574	0.581	0.004	0.005	0.584	0.592
0.50	±0.006	0.008	0.012	0.524	0.531	0.004	0.005	0.534	0.542
0.45	±0.006	0.007	0.011	0.472	0.479	0.004	0.005	0.482	0.490
0.40	±0.005	0.007	0.010	0.420	0.429	0.004	0.005	0.430	0.439
0.37	±0.005	0.007	0.010	0.390	0.397	0.003	0.004	0.398	0.407
0.35	±0.005	0.007	0.010	0.370	0.377	0.003	0.004	0.378	0.387
0.32	±0.005	0.007	0.010	0.340	0.347	0.003	0.004	0.348	0.357
0.30	±0.005	0.007	0.010	0.320	0.327	0.003	0.004	0.328	0.337
0.29	±0.004	0.006	0.009	0.308	0.315	0.003	0.004	0.316	0.324
0.28	±0.004	0.006	0.009	0.298	0.305	0.003	0.004	0.306	0.314
0.27	±0.004	0.006	0.009	0.288	0.295	0.003	0.004	0.296	0.304
0.26	±0.004	0.006	0.009	0.278	0.285	0.003	0.004	0.286	0.294
0.25	±0.004	0.006	0.009	0.268	0.275	0.003	0.004	0.276	0.284
0.24	±0.004	0.006	0.009	0.258	0.265	0.003	0.004	0.266	0.274
0.23	±0.004	0.006	0.009	0.248	0.255	0.003	0.004	0.256	0.264
0.22	±0.004	0.005	0.008	0.236	0.243	0.003	0.004	0.244	0.252
0.21	±0.003	0.005	0.008	0.226	0.232	0.003	0.004	0.234	0.241
0.20	±0.003	0.005	0.008	0.216	0.222	0.003	0.004	0.224	0.231
0.19	±0.003	0.005	0.008	0.206	0.212	0.003	0.004	0.214	0.221
0.18	±0.003	0.005	0.008	0.196	0.202	0.003	0.004	0.204	0.211
0.17	±0.003	0.005	0.008	0.186	0.191	0.002	0.003	0.192	0.199
0.16	±0.003	0.005	0.008	0.176	0.181	0.002	0.003	0.182	0.189
0.15	±0.003	0.004	0.007	0.164	0.169	0.002	0.003	0.170	0.177
0.14	±0.003	0.004	0.007	0.154	0.159	0.002	0.003	0.160	0.167
0.13	±0.003	0.004	0.007	0.144	0.149	0.002	0.003	0.150	0.157
0.12	±0.003	0.004	0.007	0.134	0.139	0.002	0.003	0.140	0.147
0.11	±0.003	0.003	0.006	0.122	0.128	0.002	0.003	0.128	0.135
0.10	±0.003	0.003	0.006	0.112	0.118	0.002	0.003	0.118	0.125

Table 20: Dimensional tolerances and corner radii of rectangular copper wire

Dimensional tolerances (JIS C 3104)

corner radii (JIS C 3104)

Thickness or width	Tolerance(mm)	Thickness(mm)	corner radius (approximate)(mm)
0.50<1.2.	±0.035	0.50<0.80	1/2 of thickness
1.2<2.6.	±0.05	0.80<1.2	0.4
2.6<5.0	±0.07	1.2<2.6	0.6
5.0<10.0	±0.10	2.6<4.0	0.8
10.0<20.0	±0.15	4.0<6.0	1.2
20.0<32.0	±0.25	6.0<10.0	1.6

Table 21: Maximum conductor resistance of rectangular copper wire

Unit /km(20°C)

Conductor width mm / Conductor thickness mm	2.0	2..2	2.4	2.6	2.8	3.0	3.2	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10	11	12	13	14	15	16
0.8		11.438	10.384	9.588	8.837	8.194	7.639	6.934	6.009	5.302	4.774	4.317	3.940														
0.9	11.127	10.010	9.096	8.406	7.752	7.192	6.708	6.093	5.285	4.667	4.204	3.803	3.472														
1.0	9.884	8.899	8.093	7.483	6.904	6.409	5.980	5.434	4.717	4.167	3.755	3.398	3.103	2.855	2.644	2.462	2.303										
1.2	8.917	7.969	7.203	6.630	6.091	5.633	5.240	4.742	4.095	3.603	3.237	2.922	2.662	2.445	2.261	2.102	1.965	1.844	1.737	1.642							
1.4	7.420	6.648	6.021	5.550	5.106	4.728	4.402	3.990	3.451	3.040	2.734	2.470	2.252	2.070	1.914	1.781	1.665	1.563	1.473	1.393	1.327	1.202	1.099	1.012	0.938	0.873	0.818
1.6	6.354	5.702	5.172	4.773	4.395	4.074	3.796	3.443	2.982	2.629	2.366	2.139	1.951	1.794	1.660	1.545	1.444	1.356	1.278	1.209	1.153	1.044	0.955	0.879	0.815	0.759	0.711
1.8	5.555	4.992	4.533	4.186	3.858	3.578	3.336	3.028	2.625	2.316	2.086	1.886	1.721	1.583	1.465	1.364	1.276	1.198	1.129	1.068	1.018	0.923	0.844	0.777	0.721	0.671	0.629
2.0		4.440	4.034	3.728	3.438	3.190	2.975	2.703	2.344	2.070	1.865	1.687	1.540	1.417	1.312	1.221	1.142	1.073	1.011	0.957	0.912	0.827	0.756	0.697	0.646	0.602	0.563
2.2			3.635	3.361	3.101	2.878	2.685	2.440	2.118	1.871	1.686	1.526	1.393	1.282	1.187	1.105	1.034	0.971	0.916	0.866	0.826	0.749	0.685	0.631	0.585	0.545	0.511
2.4				3.059	2.823	2.622	2.447	2.224	1.931	1.707	1.539	1.393	1.272	1.170	1.084	1.009	0.944	0.887	0.837	0.792	0.755	0.684	0.626	0.577	0.535	0.498	0.467
2.6					2.712	2.512	2.339	2.121	1.835	1.618	1.455	1.315	1.199	1.102	1.020	0.949	0.887	0.833	0.785	0.742	0.707	0.641	0.586	0.539	0.500	0.466	0.436
2.8						2.314	2.156	1.956	1.694	1.493	1.344	1.215	1.108	1.019	0.943	0.877	0.820	0.770	0.726	0.687	0.655	0.593	0.542	0.499	0.463	0.431	0.404
3.0							2.000	1.815	1.572	1.387	1.249	1.129	1.030	0.947	0.877	0.816	0.763	0.717	0.675	0.639	0.609	0.552	0.505	0.465	0.431	0.401	0.376
3.2								1.693	1.467	1.295	1.166	1.054	0.962	0.885	0.819	0.762	0.713	0.670	0.631	0.597	0.569	0.516	0.472	0.435	0.403	0.375	0.351
3.5									1.333	1.177	1.060	0.959	0.876	0806	0.746	0.694	0.649	0.610	0.575	0.544	0.519	0.470	0.430	0.396	0.367	0.342	0.320
4.0										1.066	0.957	0.863	0.785	0.721	0.666	0.619	0.578	0.543	0.511	0.483	0.460	0.416	0.380	0.350	0.324	0.302	0.282
4.5											0.842	0.760	0.692	0.636	0.588	0.547	0.511	0.479	0.451	0.427	0.407	0.368	0.336	0.310	0.287	0.627	0.250

Note) Conductivity is calculated as 100%.

Table 22: Dimensional table of enamel rectangular wire
(maximum finish thickness, minimum film thickness in width and thickness direction of enamel rectangular copper wire)

Unit mm

Conductor thickness and tolerance / Conductor width and tolerance		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10	11	12	13	14	15	16	Minimum film thickness in width direction (one side)
		±0.05			±0.07							±0.10										±0.15							
0.8	±0.035						1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01															0.02
0.9			1.09	1.09	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11															
1.0		1.19	1.19	1.19	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.21	1.21	1.21	1.21	1.21	1.21	1.21											
1.2	±0.05	1.40	1.40	1.40	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42								0.025
1.4		1.60	1.60	1.60	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.63	1.63	1.63	1.63	1.63	1.63	1.63	
1.6		1.80	1.80	1.80	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.83	1.83	1.83	1.83	1.83	1.83	1.83	
1.8			2.00	2.00	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.03	2.03	2.03	2.03	2.03	2.03	2.03	
2.0					2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.22	2.23	2.23	2.23	2.23	2.23	2.23	2.23	
2.2						2.41	2.41	2.41	2.41	2.41	2.41	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.43	2.43	2.43	2.43	2.43	2.43	2.43	
2.4							2.61	2.61	2.61	2.61	2.61	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.62	2.63	2.63	2.63	2.63	2.63	2.63	2.63	
2.6	±0.07						2.83	2.83	2.83	2.83	2.83	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.84	2.85	2.85	2.85	2.85	2.85	2.85	2.85	0.03
2.8								3.03	3.03	3.03	3.03	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.05	3.05	3.05	3.05	3.05	3.05	3.05	
3.0										3.23	3.23	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.25	3.25	3.25	3.25	3.25	3.25	3.25	
3.2										3.43	3.43	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.45	3.45	3.45	3.45	3.45	3.45	3.45	
3.5												3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.74	3.75	3.75	3.75	3.75	3.75	3.75	3.75	
Minimum film thickness in thickness direction (one side)		0.03																				0.035							

Table 23: Dimensional table of glassfiber covered wire [standard: JIS C 3204-3]

Conductor		Single glassfiber covered wire (SGC)				Double glassfiber covered wire (DGC)				Maximum conductor resistance 20℃(Ω/km)	
Diameter (mm)	Tolerance (mm)	Minimum insulation thickness (mm)	Maximum overall diameter (mm)	Estimated weight (kg/km)		Minimum insulation thickness (mm)	Maximum overall diameter (mm)	Estimated weight (kg/km)			
				Copper	Aluminum			Copper	Aluminum	Copper	Aluminum
3.20	±0.04	—	—	—	—	0.14	3.58	74.6	24.9	2.198	3.546
3.00	±0.03	—	—	—	—	0.14	3.37	65.7	22.0	2.489	4.015
2.90	±0.03	—	—	—	—	0.14	3.27	61.5	20.7	2.665	4.299
2.80	±0.03	—	—	—	—	0.14	3.17	57.5	19.4	2.861	4.615
2.70	±0.03	—	—	—	—	0.14	3.07	53.5	18.1	3.079	4.968
2.60	±0.03	—	—	—	—	0.14	2.97	49.7	16.9	3.324	5.362
2.50	±0.03	—	—	—	—	0.14	2.87	46.1	15.7	3.598	5.805
2.40	±0.03	—	—	—	—	0.14	2.77	42.6	14.6	3.908	6.305
2.30	±0.03	—	—	—	—	0.12	2.63	38.9	13.2	4.260	6.872
2.20	±0.03	—	—	—	—	0.12	2.53	35.6	12.2	4.662	7.520
2.10	±0.03	—	—	—	—	0.12	2.43	32.5	11.2	5.123	8.265
2.00	±0.03	0.06	2.19	28.7	9.30	0.12	2.33	29.6	10.2	5.656	9.125
1.90	±0.03	0.06	2.09	26.0	8.43	0.12	2.23	26.8	9.26	6.278	10.13
1.80	±0.03	0.06	1.99	23.4	7.61	0.12	2.13	24.1	8.40	7.007	11.30
1.70	±0.03	0.06	1.89	20.9	6.83	0.12	2.03	21.6	7.58	7.871	12.70
1.60	±0.03	0.06	1.79	17.9	6.09	0.12	1.93	19.2	6.80	8.906	14.37
1.50	±0.03	0.06	1.69	16.3	5.39	0.12	1.83	17.0	6.06	10.16	16.39
1.40	±0.03	0.06	1.59	14.3	4.73	0.12	1.73	14.9	5.37	11.70	18.87
1.30	±0.03	0.06	1.49	12.3	4.12	0.12	1.63	12.9	4.71	13.61	21.96
1.20	±0.03	0.06	1.37	10.5	3.53	0.10	1.49	11.0	3.96	16.04	25.87
1.10	±0.03	0.06	1.27	8.88	3.01	0.10	1.39	9.28	3.41	19.17	30.93
1.00	±0.03	0.06	1.17	7.38	2.53	0.10	1.29	7.75	2.89	23.33	37.64
0.95	±0.02	0.06	1.11	6.68	—	0.10	1.23	7.03	—	25.38	—
0.90	±0.02	0.06	1.06	6.02	—	0.10	1.18	6.35	—	28.35	—
0.85	±0.02	0.06	1.01	5.39	—	0.10	1.13	5.71	—	31.87	—
0.80	±0.02	0.06	0.96	4.79	—	0.10	1.08	5.10	—	36.08	—
0.75	±0.02	0.06	0.91	4.23	—	0.10	1.03	4.52	—	41.19	—
0.70	±0.02	0.06	0.86	3.71	—	0.10	0.98	3.98	—	47.47	—
0.65	±0.02	0.06	0.81	3.22	—	0.10	0.93	3.47	—	55.31	—
0.60	±0.02	0.06	0.76	2.76	—	0.10	0.88	3.00	—	65.26	—
0.55	±0.02	0.06	0.71	2.34	—	0.10	0.83	2.57	—	78.15	—
0.50	±0.01	0.06	0.65	1.96	—	0.10	0.75	2.14	—	91.43	—
0.45	±0.01	0.06	0.60	1.60	—	0.10	0.70	1.78	—	114.2	—
0.40	±0.01	0.06	0.55	1.29	—	0.10	0.65	1.45	—	145.3	—

Table 24: Dimensional table of double glassfiber covered rectangular wire (DGC) (conductor dimensions, tolerances, insulation thickness in conductor thickness direction [minimum value] and overall thickness [maximum value]) (Standard: JIS C 3204-4)

Unit mm

Conductor thickness and tolerance \ Conductor width and tolerance		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10	11	12	13	14	15	16
		±0.05			±0.07							±0.10										±0.15						
0.8	±0.035		1.15	1.15	1.15	1.15	1.18	1.18	1.18	1.18	1.18	1.23	1.23	1.23														
0.9		1.25	1.25	1.25	1.25	1.25	1.28	1.28	1.28	1.28	1.28	1.33	1.33	1.33														
1.0		1.35	1.35	1.35	1.35	1.35	1.38	1.38	1.38	1.38	1.38	1.43	1.43	1.43	1.43	1.43	1.43	1.48										
1.2	±0.05	1.56	1.56	1.56	1.56	1.56	1.59	1.59	1.59	1.59	1.59	1.64	1.64	1.64	1.64	1.64	1.64	1.69	1.69	1.69	1.69	1.69	1.69	1.69				
1.4		1.76	1.76	1.76	1.76	1.76	1.79	1.79	1.79	1.79	1.79	1.84	1.84	1.84	1.84	1.84	1.84	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.94	1.94	1.94	1.94
1.6		1.96	1.96	1.96	1.96	1.96	1.99	1.99	1.99	1.99	1.99	2.04	2.04	2.04	2.04	2.04	2.04	2.09	2.09	2.09	2.09	2.09	2.09	2.09	2.14	2.14	2.14	2.14
1.8		2.16	2.16	2.16	2.16	2.16	2.19	2.19	2.19	2.19	2.19	2.24	2.24	2.24	2.24	2.24	2.24	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.34	2.34	2.34	2.34
2.0			2.36	2.36	2.36	2.36	2.39	2.39	2.39	2.39	2.39	2.44	2.44	2.44	2.44	2.44	2.44	2.49	2.49	2.49	2.49	2.49	2.49	2.49	2.54	2.54	2.54	2.54
2.2				2.56	2.56	2.56	2.59	2.59	2.59	2.59	2.59	2.64	2.64	2.64	2.64	2.64	2.64	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.74	2.74	2.74	2.74
2.4					2.76	2.76	2.79	2.79	2.79	2.79	2.79	2.84	2.84	2.84	2.84	2.84	2.84	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.94	2.94	2.94	2.94
2.6	±0.07					2.97	3.00	3.00	3.00	3.00	3.00	3.05	3.05	3.05	3.05	3.05	3.05	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.15	3.15	3.15	3.15
2.8							3.20	3.20	3.20	3.20	3.20	3.25	3.25	3.25	3.25	3.25	3.25	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.35	3.35	3.35	3.35
3.0								3.40	3.40	3.40	3.40	3.45	3.45	3.45	3.45	3.45	3.45	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.55	3.55	3.55	3.55
3.2									3.60	3.60	3.60	3.65	3.65	3.65	3.65	3.65	3.65	3.70	3.70	3.70	3.70	3.70	3.70	3.70	3.75	3.75	3.75	3.75
3.5										3.90	3.90	3.95	3.95	3.95	3.95	3.95	3.95	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.05	4.05	4.05	4.05
4.0											4.40	4.45	4.45	4.45	4.45	4.45	4.45	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.55	4.55	4.55	4.55
4.5												4.95	4.95	4.95	4.95	4.95	4.95	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.05	5.05	5.05	5.05
Minimum insulation thickness (one side)		0.09					0.10					0.12						0.14							0.16			

Bobbin or pack of magnet wire

Tables 25 to 28 show the standard bobbin or pack of magnet wire

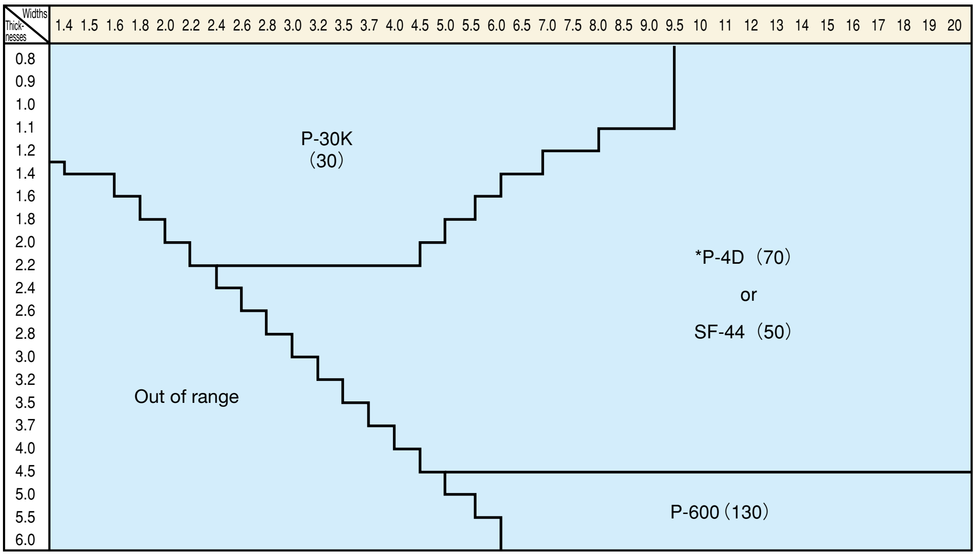
● Table 25: Standard bobbin or pack and standard wire weight (round wire)

Conductor diameter (mm)	Enamelled wire: Bobbin	Enamelled wire: Pack	Covered conductor wire
0.1～0.12	PT-15 (15)		
0.13～0.30	PT-25 (25), PT-15 (15)		
0.32～0.50	PT-25 (25)		
0.55～0.70	PT-25 (25), PT-90 (90), PT-60 (60)		
0.75～0.95	PT-25 (25), PT-270 (250), PT-90 (90), PT-60 (60)	LMP (100)	P-30 (20)
1.0～1.5	P-30 (30), PT-270 (250), PT-90 (90), PT-60 (60)	LMP (100)	P-30 (20)
1.6～2.0	P-30 (30)	LMP (100)	P-30 (20)
2.1～3.0	P-40 (40)	LMP (100)	P-40 (30)
3.2～4.0	SF-44 (50)		SF-44 (50)

Note) 1. Value in parentheses: Standard wire weight (unit: kg)
2. The tolerance of standard wire weight shall be 30%.
3. Standard wire weight is value when conductor is made of copper. For aluminum conductor, the value shall be 1/3.3.

● Table 26: Standard bobbin or pack and standard wire weight (rectangular wire)

1.All rectangular wires except for paper-covered wire



Note) 1. Value in parentheses: Standard wire weight (unit: kg)
2. For sections marked with an asterisk (*), P-4D shall be Hitachi metal standard. When P-4D is too heavy, the standard shall be SF-44. If the order quantity is 50kg and under, SF-44 shall be adopted.
3. The tolerance of standard wire weight shall be 30%.
4. Standard wire weight is value when conductor is made of copper. For aluminum conductor, the value shall be 1/3.3.

2. Paper-covered rectangular wire

Conductor thickness (mm)	Drum No.	Standard wire weight (kg)
<5.0	P-4D	70
5.0<	P-600	130

Note) 1. Standard tolerance of wire weight shall be 30%.
2. For paper-covered wire, the standard wire weight differs slightly depending on the number of paper.
3. Standard wire weight is value when conductor is made of copper. For aluminum conductor, the value shall be 1/3.3.

Table 27: Dimensional table of packaging for standard wire

Unit mm

	Types	Flange diameter D		Barrel diameter d		Inside width W	Flange thickness a	Bore diameter h
Plastic bobbin	P-30K(For rectangular wire) P-30	300		130		130	15	30
Plastic bobbin	P-40（P-35）	350		150		130	18	32
Plastic drum	SF-44	440		300		190	16	50
Plastic drum	P-4D	500		300		190	30	50
Plastic drum	P-600	600		400		220	30	50
Tapered long bobbin		D_1	D_2	d_1	d_2			
Tapered long bobbin	PT-10	160	180	96	110	200	15	30
Tapered long bobbin	PT-15	180	200	96	110	200	15	30
Tapered long bobbin	PT-25	215	230	110	130	250	15	30
Tapered long bobbin	PT-60	270	300	150	180	350	25	45
Tapered long bobbin	PT-90	300	315	180	200	425	38	100
Tapered long bobbin	PT-270	435	460	255	280	530	50	100

Figure 18: Bobbin

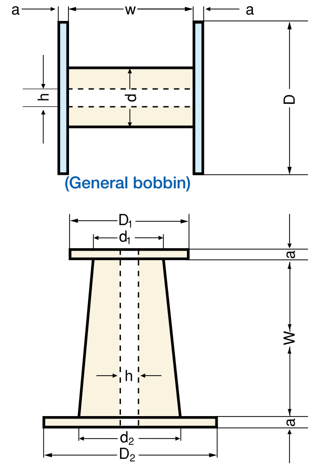
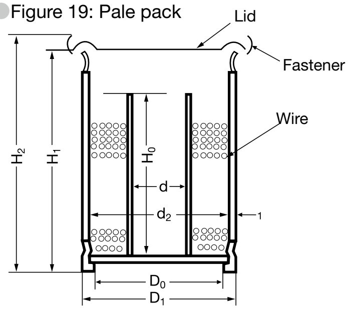


Table 28: Standard pale pack dimensions

Types	H_0	H_1	H_2	d_1	d_2	D_0	D_1	t
LMP	525	560	560	300	500	480	515	5.0 ≤
LP-500	715	767	770	399	650	626	662	5.0 ≤

Figure 19: Pale pack

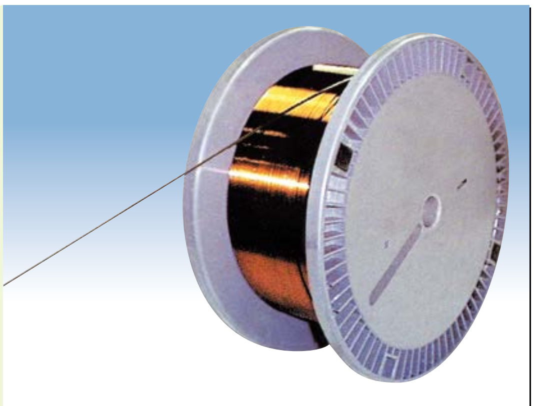


We provide you with usability.

Regular winding enamelled wire

- It is not necessary to realign the wire because there is no slight bending.
- No need to correct small bending; The wire will not be hard.

Regular winding enamelled wire contributes to improvement in the efficiency of coil winding work for extra wide enamelled wire (having a diameter of 2.0 to 3.2 mm ø) that is difficult to process.



Regular winding products

General winding products

Regular winding enamelled wire in stock

Product type	Size (mm)	Bobbin or pack	Standard
Class 1 polyester wire (1PEW)	2.0 2.1, 2.2, 2.3, 2.4, 2.5 2.6, 2.7, 2.8, 2.9, 3.0 3.2	P-35S	SP70-90010
Class 1 polyamide-imide wire (1AIW)	2.1, 2.2, 2.3, 2.4, 2.5 2.6, 2.7, 2.8, 2.9, 3.0 3.2	P-35S	SP70-90070

*Standard wire weight: 35kg

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