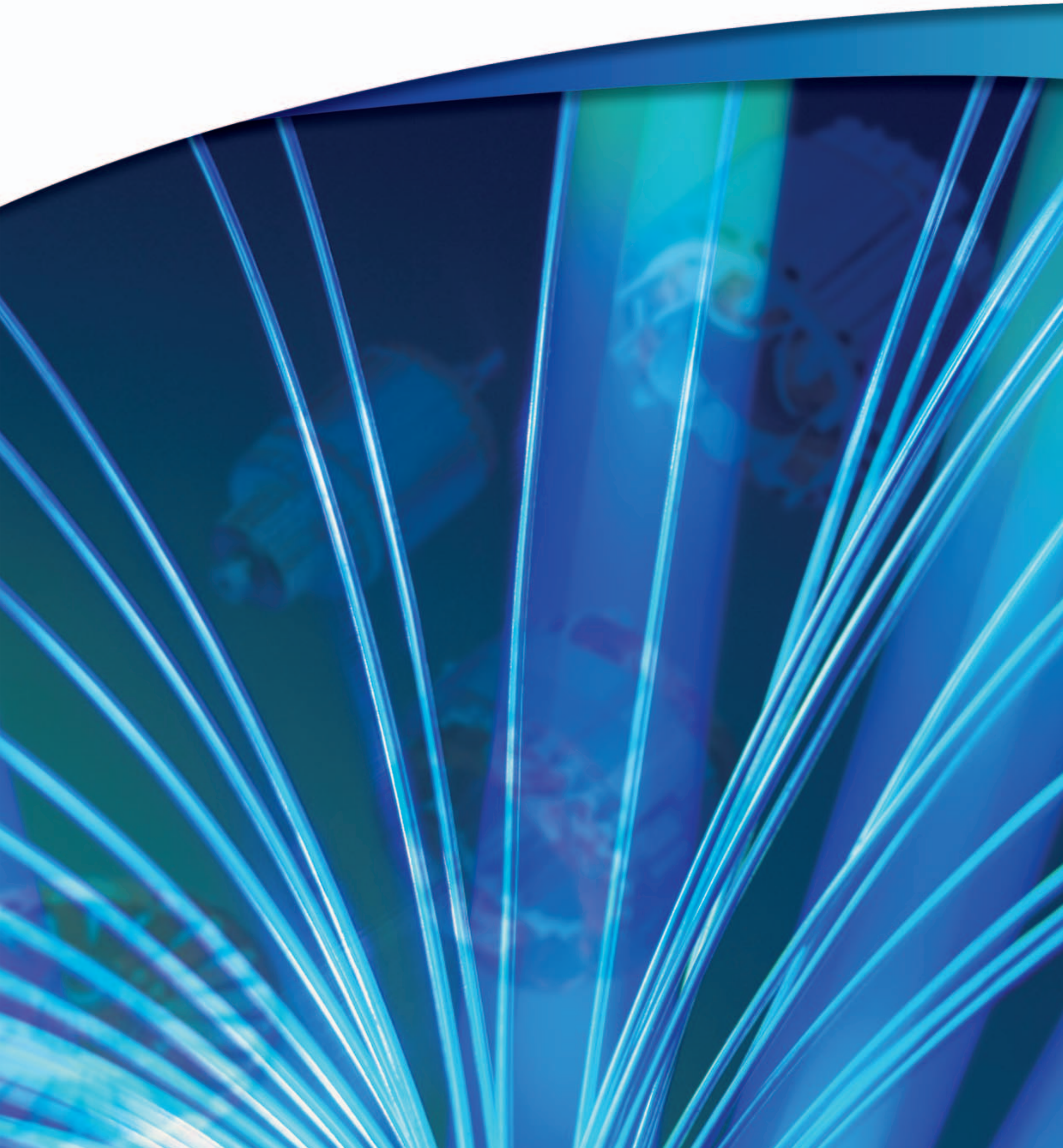
Hitachi Magnet Wire

Selection and Use Directions of Magnet Wires



For our customers, we are working toward improving performance under an integrated system that covers development, manufacturing method, and usage of better materials.

In electric equipment, winding wires play a very important role as they are likened to the nerves and veins of the equipment. It is a must, therefore, to select wires for winding or magnet wires and use them properly in order to reduce the size and weight of electric equipment and to improve its lifetime and reliability.

Recent progress made in synthetic chemistry has caused the advent of new insulating materials one after another, resulting in a very wide variety of magnet wires with significantly improved performance. However, under present circumstances, this creates confusion as to which products to choose.

In close liaison with the Electric Division and the Insulating Materials Manufacturing Division of Hitachi, Ltd., we have engaged over the years in a series of studies and examinations on the development of better materials and the manufacturing and usage of better magnet wires under an integrated system from copper casting. In this way, we have always worked to improve technology and performance, which thereby has contributed to development in electric equipment.

We always examine products in a careful manner from the user's standpoint from all angles and conduct trials to a satisfactory extent before supplying products to the market. This is one of our unique features rarely seen elsewhere. We therefore are confident that you will be satisfied with our products.

The following is an explanation of the types and performances of a number of magnet wires, an overview and selection methods thereof, as well as handling precautions during the manufacturing of electric equipment.

CONTENTS

What are Magnet Wires?

Wires for winding used in electric equipment are generally called magnet wires. Simply put, magnet wires are used for interchanging electric energy with magnetic energy. Magnet wires are broadly divided into enamelled wires (coating insulation), spiral shielded wires (fiber/film insulation), other specially formulated wires, and combinations thereof.

Both the types and performance of magnet wires are quite varied. In the document, we describe the electric and mechanical performances of these wires and the appropriate usage thereof so that it can serve as a guide for selecting products.
The following are the most important features of magnet wires:

(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 materials.
(h) Resistant to water and moisture.
(i) Easy to use.

All of these characteristics are essential. It is difficult, however, to provide all these performances in the same product. Each wire has its own advantages and disadvantages. Therefore, it is important to select products properly in consideration of operating conditions.

Pick up

Hitachi's high-strength, self-lubricating heat-resistance wires

KOMAKI Series

We work to meet the needs of the times

- Inserting wires in slots using little force.
- Further reducing external damage during winding.
- Making the coil more compact.
- Maximizing the space factor level.

Environmental performance

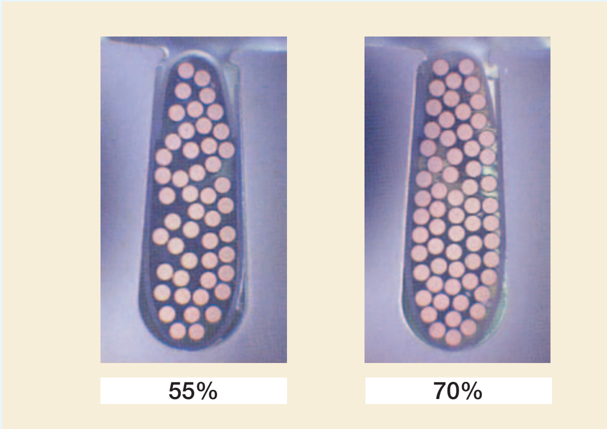
- "KOMAKI Series" of enamelled wires provide a coil with high space factor, and so meets the demand for high-efficiency compact motors while conserving energy.
- "KOMAKI" wires deliver much stronger adhesion with impregnation vanish compared to conventional self-lubricated enamelled wires.

Application

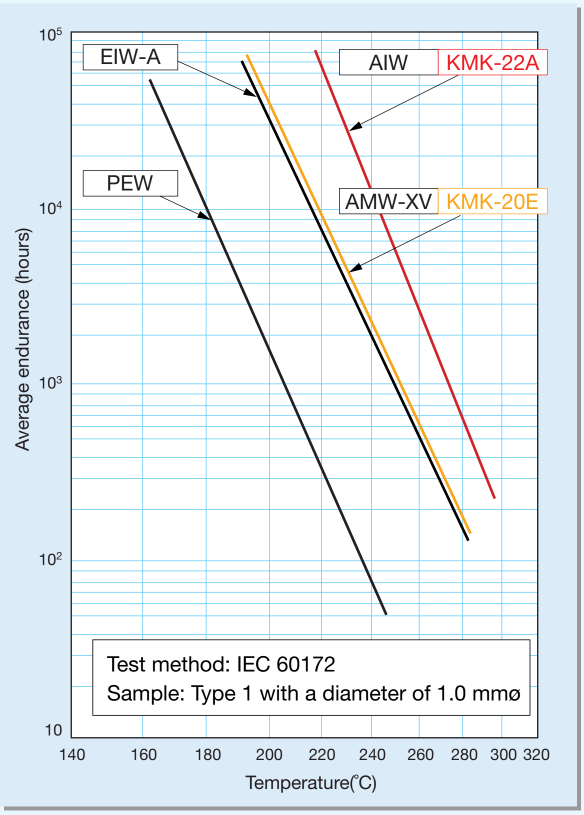
- Motors for general use, electrical equipment, air cooling, and other motors used under a high space factor.

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

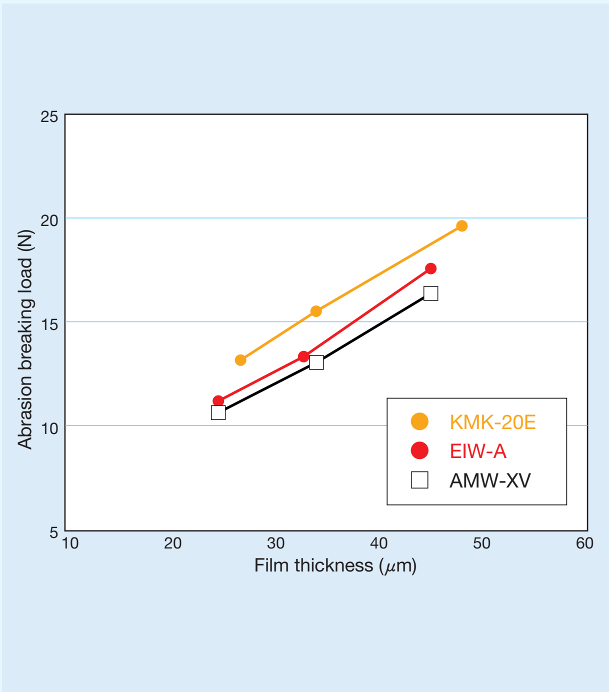
Comparison of space factor



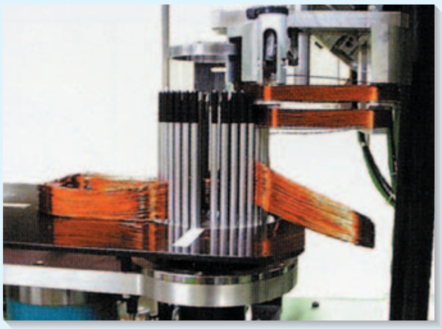
Thermal endurance



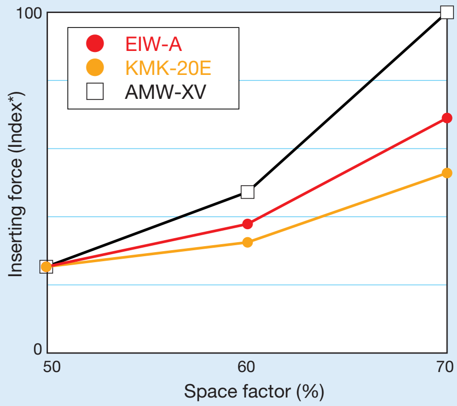
Evaluation of mechanical strength



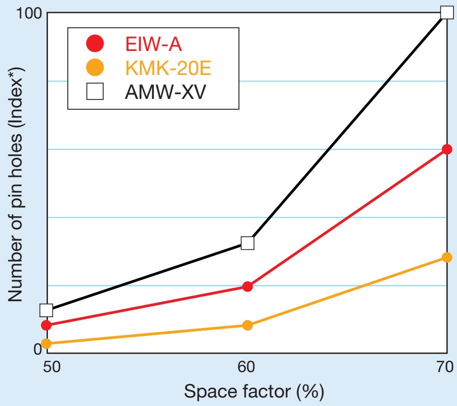
Coil windability evaluation equipment



Coil inserting force



Number of pin holes after inserting coil



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

General properties

Characteristic example (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-resistance, double coated wire)	AMW-XV (Heat-resistance, 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
Cut through [Heating-up method, ˚C]		398	396	398	420	420	420
Abration	Reciprocating type (number of times)	532	180	161	1500<	1500<	452
	Unidirectional type (N)	15.2	13.3	12.9	16.5	16.1	15.0
Static friction coefficient		0.045	0.050	0.120	0.045	0.050	0.120
Varnish adhesive strength (N) (epoxy)		173	127	190	172	128	188
R-22 extraction rate [at 150−C for 24 hours,%]		0.12	0.11	0.10	0.08	0.07	0.06
Resistance to R-22 [at 150˚CX7d]	Acceptable blister temperature(℃)	140	140	140	180<	180<	180<
	Retention of breakdown voltage(%)	105	105	106	104	104	106

Pick up

Hitachi's inverter surge resistant enamelled wires

KMKED

We work to meet the needs of the times

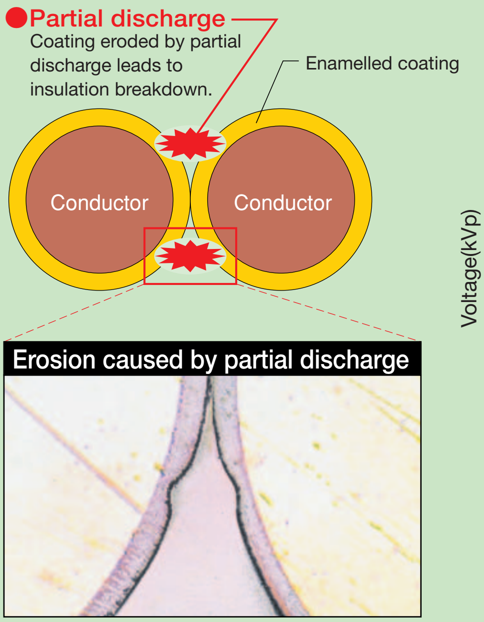
- Reducing the failure rate of inverter-controlled motors.
- Increasing the life span of inverter-controlled motors.
- Designing motors with high resistance to inverter surges.

Environmental performance

- "KMKED" has insulation film that is hardly eroded by inverter surges.
- "KMKED" also provides much higher mechanical strength than conventional products.
- These features contribute to the longer life of Motors.

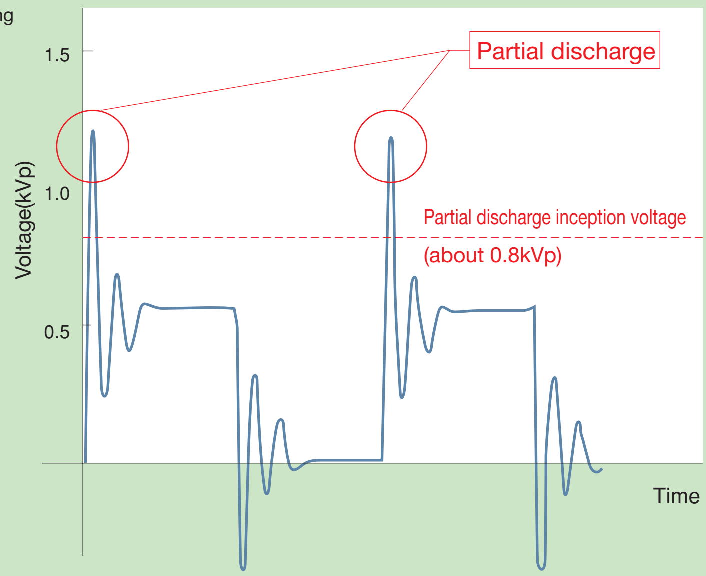
These problems are probably caused by inverter surges.

Cross-section view



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

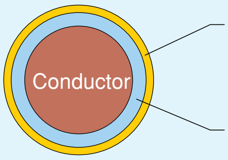
Inverter output waveform (400a-volt class)



●**KMKED-20E**
Appearance after inverter surge application test
(After applying a voltage of 1.1 kVp for 11.2 hours)

KMKED-20E prevents inverter surges from eroding coatings.
In addition, mechanical properties have been significantly improved.
These features contribute to the longer motor life.

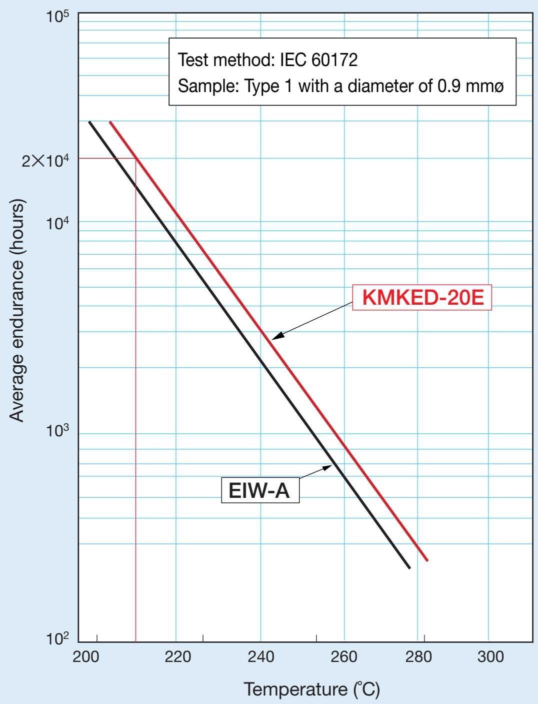
Structure



High-strength self-lubricating polyamide-imide (KOMAKI)

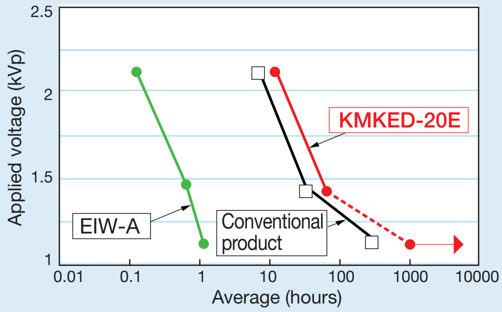
Partial discharge resistant polyester-imide by nano composite technology

Thermal endurance

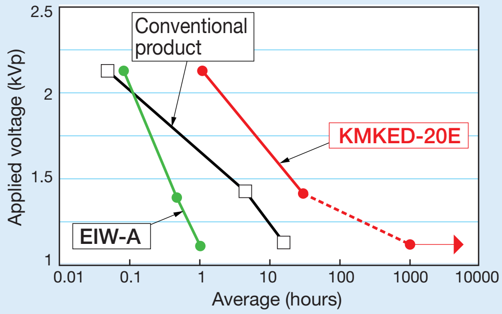


Voltage endurance (10 kHz sine wave)

No elongation



After 20% elongation



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-resistance 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)	Unidirectional type (N)	13.7	11.3	12.6
	Reciprocating type (number of times)	351	150	180
Static friction 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
Varnish adhesive strength (N) (Epoxy-based)		173	120	125
Temperature index (℃)		200	200	200

Pick up

Hitachi's high heat-resistance enamelled wires

IMWAD

We work to meet the needs of the times

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

Thermal index

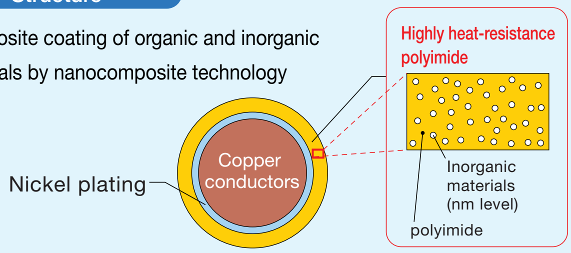
- 280℃

Application

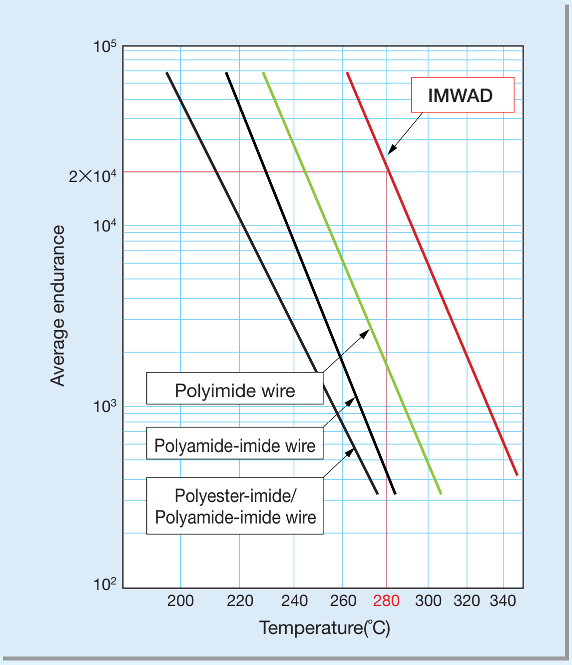
- Motors for electrical equipment
- Motors for special pumps
- Induction heating coils
- Motors and electric equipment used under high temperatures

Structure

- Composite coating of organic and inorganic materials by nanocomposite technology

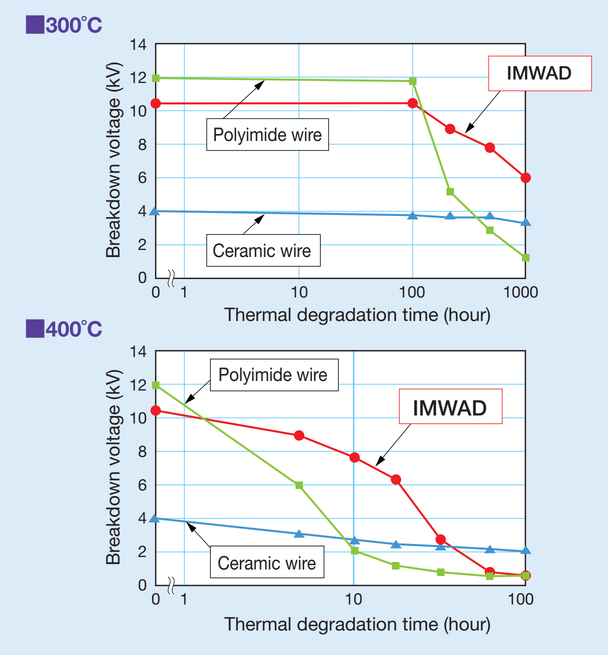


Thermal endurance



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

Thermal degradation property



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-resistance 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 (N)	Unidirectional type (N)	9.9	9.4	9.5
Breakdown voltage (kV)		10.5	3.9	12.0

Value in parentheses: thickness of ceramic layer

Pick up

Hitachi's high reliability rectangular enamelled wires

AIW rectangular wires

We work to meet the needs of the times

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

Advantages

- Excellent flexibility
- Uniform coating including at the corners provides good insulation property.
- Much higher space factor compared to round enamelled wires.

  [Theoretical maximum space factor]

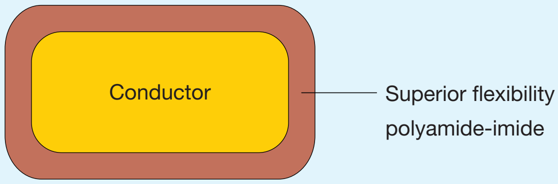
  Round enamelled wire: About 78%

  Rectangular enamelled wire: About 91%

Thermal index

220℃

Structure

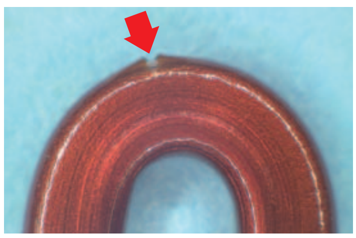


Application

- 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 with a bending diameter equal to the conductor width in 180 degree
Adherence (mm)	4.6	9.8	Length of wire portion in which film flakes off the conductor after breaking in tensile test
Breakdown voltage (V)	9,000	5,400	Metallic foil method
Cut through (℃)	430	430	

Enamelled wires: Type, symbol, standard and feature

Series name	Type	Symbol	Standard	Coating type	Size range (mm)	Temperature index (℃)	Advantages	Operational precautions	Applications
Formal series	Formal wire	PVF	JIS C 3202-2 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	JIS C 3202-4 SP70-90101	—	Shown in Table 22 (on page 33)				
Polyurethane enamelled wire series (Polyurethane wires)	Polyurethane enamelled wire	UEW	JIS C 3202-6 SP70-90030	Class 1 Class 2	} 0.6~1.0	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 electric meters 4.Micromotors 5.Magnet coils
Polyester enamelled wire series (polyester wires)	Polyester enamelled wire	PEW	JIS C 3202-5 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/P wire (Polyester/nylon wire)	PEW-P	SP70-90014	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-resistance 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 (℃)	Advantages	Operational precautions	Applications
Image series (polyimide wires)	Image wire	IMW	SP70-90080	Class 0 Class 1 Class 2	}0.1～3.2 0.1～1.0	240	●Most excellent heat resistance among enamelled wires. ●Excellent overload characteristic. ●Good resistance to chemical solvents.	●Coating is somewhat mechanically weak.	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-resistance 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-resistance double coated wire (Self-lubricating Polyester-imide / polyamide-imide wire)	KMK-20E	SP70-90062	Class 0 Class 1 Class 2	}0.32～2.0 0.32～1.0	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 0.32～1.0	220	●Excellent surface slip characteristics and mechanical strength; suited for high space-factor motors. ●Similar advantages to AMW.	Same with above	1.High space-factor motors 2.Freon motors 3.Motors for electrical equipment 4.Motors for electric tools
	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
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 only 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			

* Insulation layer temperature index

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

Enamelled wire performance comparison

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 electric properties. However, more careful examination must be made of the following properties as compared with other wires.

$$\text{Space factor}\ (\%) = \frac{d^2}{D^2} \times 100$$

(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.

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

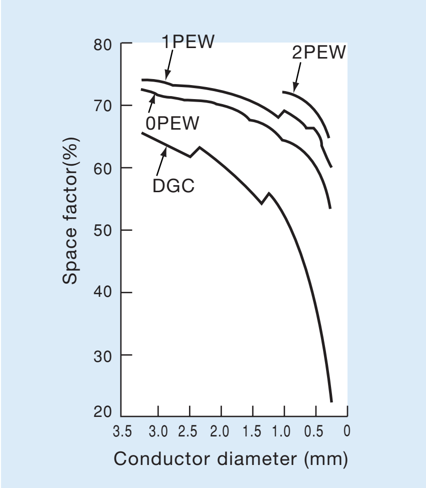


Figure 1: Comparison of magnet wire space factor

Table 1: Comparison of general enamelled wire performance

Test items			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	Unidirectional type (N)	13.90	9.78	11.63	11.90	13.46	14.50	15.90	14.95	15.46	16.80	11.22	
	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
		1d	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	1/5	0/5	
		2d	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
		result	×1、OK	×3、OK	×3、OK	×2、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	×1、OK	
Electric 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°C×C for 30 minutes
	Sulfuric acid(S.G1.2)		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	Immersion at normal temperature for 24 hours Determination using a nail.
	Sodium hydroxide(10%)		◎	◎	○	○	◎	◎	◎	◎	◎	◎	○	
	Transformer oil		◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	Determination { ◎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°C30min	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. However, pin holes are generally developed 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) before contact with water or solvents causes pin holes to disappear. Table 2 shows wet (water) crazing and solvent (dispersing agent) crazing.
It is advised to heat-treat crazing-prone enamelled wires at a temperature above the glass transition temperature after winding.

2 Flexibility

A winding test is a test for judging coating flexibility and is generally applied to round wires with a diameter of 0.37 mm or more.

●Figure 2: Winding test

3 Elongation

A stretching test, as in the case with winding test, is a test for judging coating flexibility. Wires demonstrate very similar tendencies.
For round wires with a diameter of 0.35 mm and under and rectangular wires in general, coating flexibility is generally judged using a stretching test.

4 Breakdown voltage

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

5 Abrasion

An abrasion test judges the mechanical strength of the coating. A unidirectional 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 wear resistance; special care must be taken during winding process. In recent years, it has become necessary to improve the workability of winding wires. Self-lubricating enamelled wires, of which the upper layer is baking-finished with a thin layer of lubricant with a good slip property, are excellent in wear resistance. Thus, coatings resist being damaged during the winding process. Accordingly, self-lubricating enamelled wires are often used. See pages 16 and 17 for self-lubricating enamelled wires.

●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. In selecting varnish, consideration must be given to these solvents.
All wires are nearly equal in oil resistance over a short period of time.

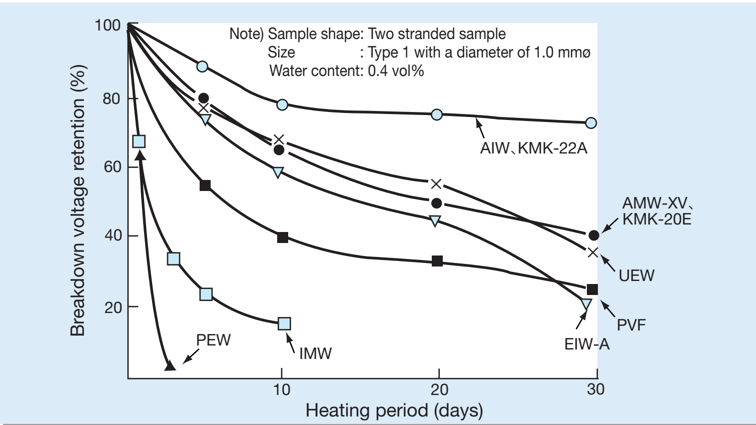
7 Hydrolyzability

An enamelled wire film is an organic polymer material with which wires are baking-finished. Some types are prone to hydrolytic degradation. A closed hydrothermal degradation test is an accelerating test for evaluating hydrolytic degradation of enamelled wires. In this method, an enamelled wire and water are put together in a sealed container and heated at 100°C 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 wires after closed 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.

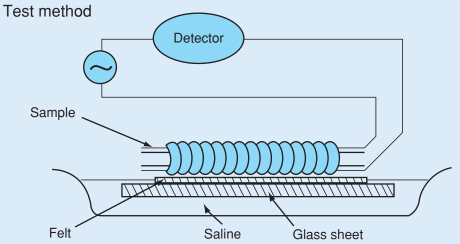
● Figure 3: Characteristic example of breakdown voltage after closed hydrothermal degradation (120°C)



● Table 4: Example of charge water resistance (Type 1 having 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°CX10min.

Note) Test method



● Table 3: Solvent resistance of enamelled wires

	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 °C	Methanol	◎	◎	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Ethanol	◎	◎	◎	○	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Butanol	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Naphtha	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Kerosene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Terpene	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Gasoline	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Benzole	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎	◎
	Cresol	×	×	○	△	○	△	○	△	○	△	N.T	N.T	N.T	N.T
65 °C	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 wires with no varnishing applied in accordance with IEC60172. Based on the combination, coil-varnished enamelled wires will not necessarily have a better life span than untreated enamelled wires.

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 wires are wound around motors or transformers. 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 wires, indicating that in general enamelled wires, with higher resistant temperature, show better performance.

Figure 4: Example heat life characteristics of enamelled wires

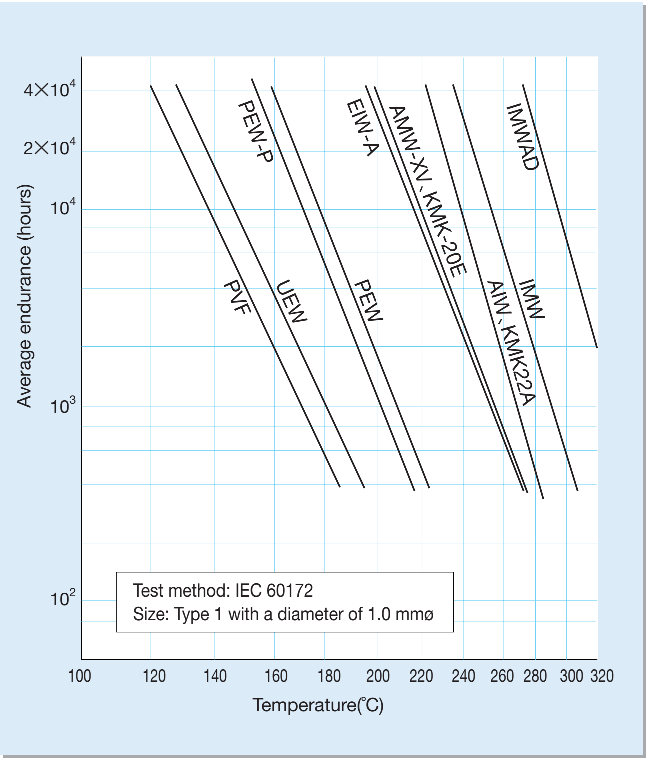
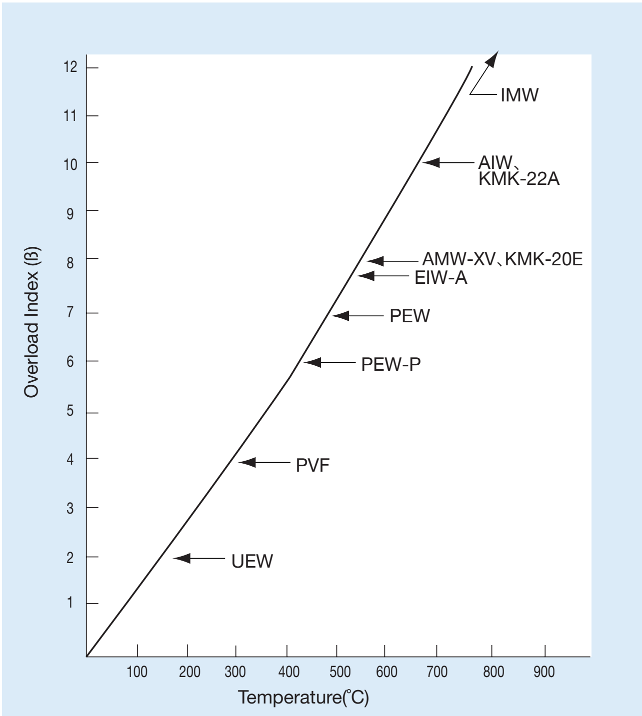


Figure 5: Allowable overload characteristic example of enamelled wires (NEMA method)



Note) Test equipment: Overload test machine made by Toshiba

12 Solderability

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

13 Resistance to refrigerants

The recent improvement of life environment has resulted in increase in demand for refrigerators, window coolers, and air conditioners.

Various types of Freon are used as refrigerants in these devices. These types of refrigerant easily erode enamelled wires; special care must be taken in application.

Table 5 shows the resistance of enamelled wires 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: Characteristic 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: Hitachi method (Freon/Refrigerator oil =1/1, processing time =7d, Blister: Measured after heating at 130℃ for 10 minutes,
Pencil hardness: Measured immediately after removal, Breakdown voltage: Measured after heating at 130℃ for one hour)

14 Resistance to varnish

Recently, electric 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 wires, treatment varnishes, and tapes can deliver substantial performance intended under the usage conditions. New heat-resistance enamelled wires particularly tend 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 wires are wound around coils while being elongated, twisted, bent, or abraded. After preliminary drying at a given temperature, the wires are 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 electric work, the conditions of use for enamelled wires are becoming harsher than ever with respect to processes and materials. Greater importance is being placed on the evaluation of compatibility between enamelled wires and treatment varnishes - 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 electric 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 wires. Therefore, enamelled wires are becoming more susceptible to greater damage than ever during Swinding.
On the other hand, as coil-wound end products are required to have high reliability, the need for enamelled wires that can endure under harsh winding conditions has been growing.
Self-lubricating enamelled wires can meet such needs, as they have excellent lubricating properties and wear resistance.
As Figure 6 shows, self-lubricating enamelled wires come 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 wires

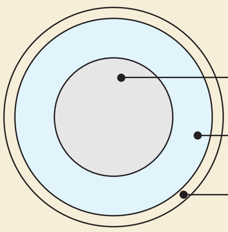


Table 6: Application example of self-lubricating enamelled wires

Insulating layer	Self-lubricating material	Symbol	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

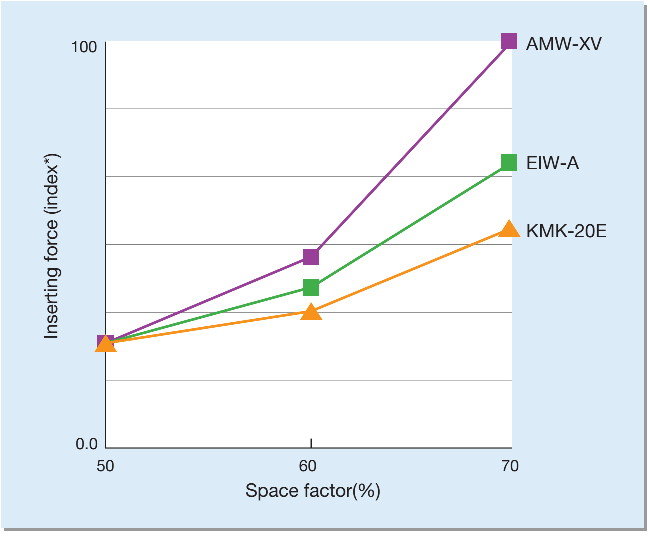
Table 7: Example of static friction coefficient of self-lubricating enamelled wires

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

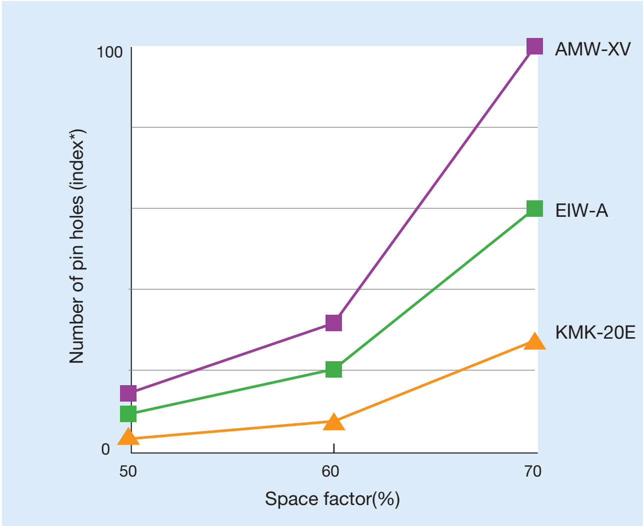
Figure 7 shows examples of coil inserting force of polyamide-imide self-lubricating enamelled wires. KMK-20E has a smaller inserting force than that of EIW-A and is thus superior. As Figure 8 shows, there are fewer pin holes after coil insertion.
Therefore, KMK-20E is suitable for improving reliability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

●Figure 7: Examples of coil inserting force



●Figure 8: Examples of the number of pin holes after coil insertion

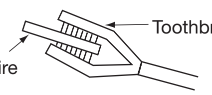
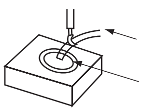


*Index when 70% of the AMW-XV space factor is 100.

16 Methods for removing film on enamelled wire

Table 8 shows methods for removing films on enamelled wires.

●Table 8: Methods for removing films on enamelled wires (example)

Method	Type	Specification	Applicable product type
Use of chemicals	Solcoat 1200	Several minutes at normal temperature	PEW、PVF
	Depent KC	Several minutes at normal temperature	PEW、PVF
	Solcoat ML	At high temperatures of 100−C or more for 8 to 12 minutes	AMW-XV AIW、IMW KMK-20E KMK-22A
	Depent CS	Fused alkali at 400−C for 3 to 15 seconds	All product types
Use of appliances	ABISOFIX		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 700C. 	All product types

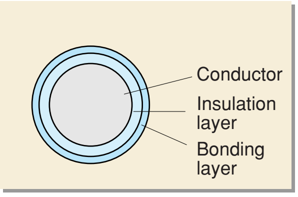
17 Self-bonding enamelled wires

Self-bonding enamelled wires are enamelled wires 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.

Self-bonding enamelled wires are provided with insulation properties at the insulation layer and coil fusion functionality at the fusion layer.

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

Figure 9: Example Bonding wire structure



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

(1) Characteristic example of heat seal

For electrical equipment or microwave ovens, wires are heat sealed in a thermostatic chamber or similar device after coil winding. After coil winding, the wires used for the deflecting yokes for displays of televisions or PCs are energized, heat sealed by Joule heat, and taken out from formers as air-core coils.

Figure 10 on page 19 shows the heat sealing properties of these wires.

(2) Adhesive strength characteristics at high temperatures

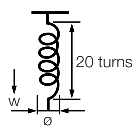
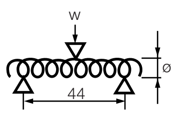
Figure 11 on page 19 shows the adhesive strength of fusing enamelled wires in a high temperature environment.

Table 9: Self-bonding enamelled wire fusion methods

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 Microwave ovens
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 Microwave ovens

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

Table 10: Self-bonding enamelled wire adhesive strength test method

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: Example of heat-seal characteristics of self-bonding wire

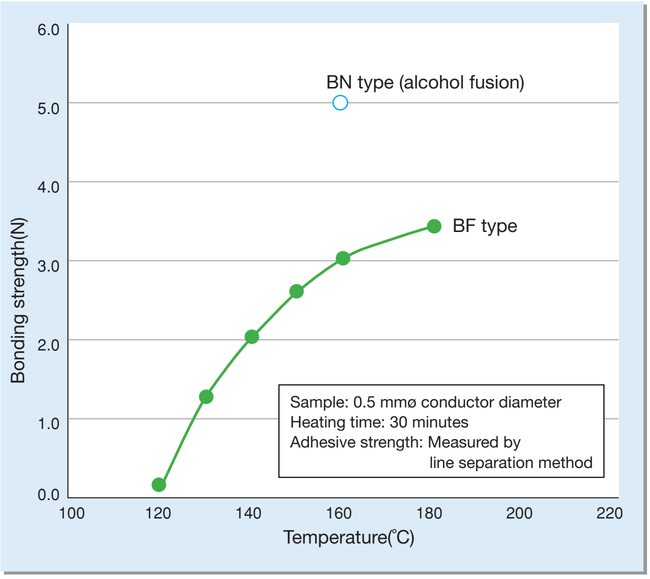
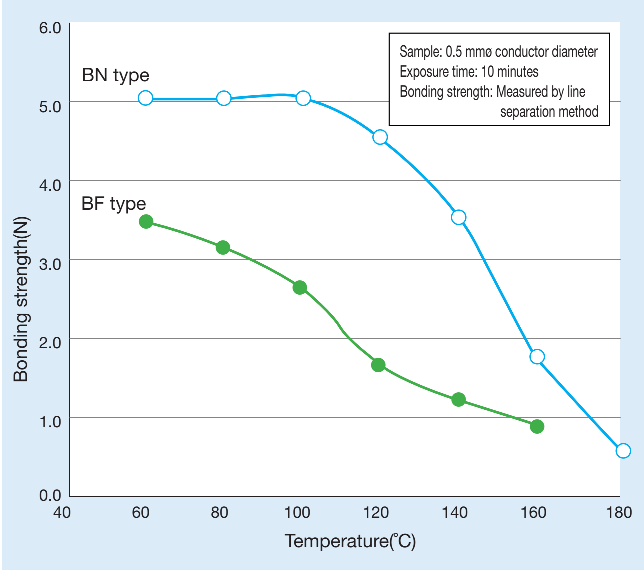


Figure 11: Example of adhesive strength characteristics of self-bonding wires at high temperatures



Covered conductor wires: 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 conductors)	TRWm (a×b) tKC	SP70-90790	(element wire size) Thickness: 1.2 to 3.0 Width: 4.0 to 10 (Number of element wires) 5 to 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-coavered wire	DMPC	SP70-90784	—	155	●Good heat resistance	●Coating is more susceptible to damage than fiberglass covered wires	1.Small rotating machines 2.Small to medium generators
Nomex paper covered wire	nNPC 2XC	SP70-90742 SP70-90748	—	200	●Good heat resistance ●Good space factor	●Coating is more susceptible to damage than fiberglass covered wires ●Inferior to SIC in flexibility	1.Dry-type transformer 2.Vehicle motors 3.Heat-resistance equipment
Kapton tape covered wire	nIC	SP70-90780	—	240	●Good heat resistance ●Good space factor ●Excellent dielectric strength	●Coating is more susceptible to damage than fiberglass covered wires	1.Vehicle motors 2.Heat-resistance equipment

[Content of standards]
JIS : Japanese Industrial Standards
JCS: Japanese Cable Makers' Association Standard
SP : Hitachi Cable 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 fiber covered wires

Magnet wires other than enamelled wires are required to have the properties listed in the preceding paragraph.

Tables 11 and 12 show the general properties of spiral shielded wires.

●Table 11: Characteristic examples of spiral shielded wires (round wires 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<
1AIW-Teleglass (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: Characteristic examples of spiral shielded wires (rectangular wires 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	× 740	△ 710	○ 730	◎ 730
Class H glassfiber covered wire (H-DGC)	0.196×0.143	830	840	830	× 720	△ 690	○ 690	◎ 690
Nomex (2mil butt lapping, double winding) (2XC)	0.116×0.102	1,020	1,010	1,000	× —	× —	× —	○ —
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
Kapton 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

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

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

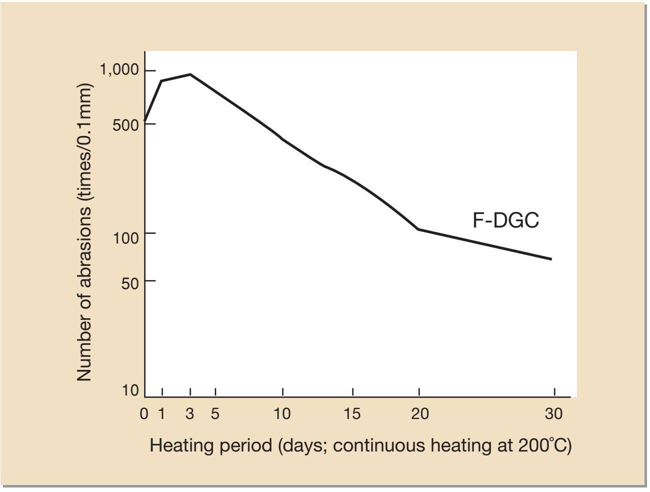
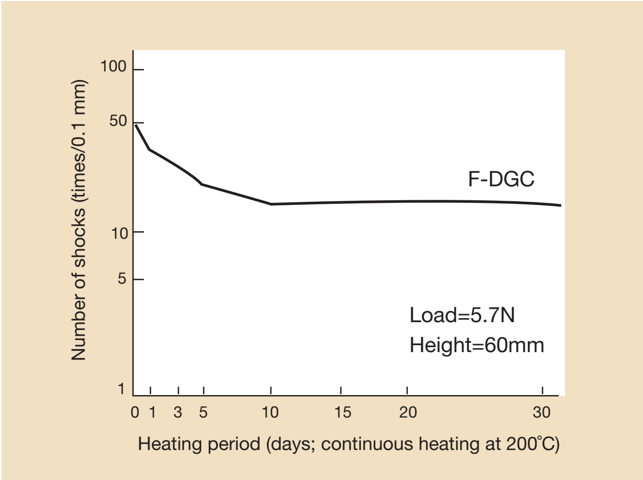


Figure 13: Changes in shock resistance under continuous heating at 200℃



2 Glass-fiber covered wire

Paper-covered wires 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 Kapton-tape-covered wires

Kapton tape-covered wires are manufactured by heating and heat-sealing wires taped with American company Du Pont's heat-resistance polyimide resin films (product name KAPTON) F type (with a thickness of 1.5 mil, 1 mil of which is the Kapton tape while the remaining 0.5 mil is PTFE*). Kapton tape-covered wires have a higher space factor than that of fiberglass covered wires and fully satisfy class-H heat resistance requirements. When Kapton tape-covered wires are used as substitutes for these fiberglass covered wires, electric equipment can be expected to be reduced in size and weight. Kapton-tape-covered wires have electrical characteristics and coating flexibility far superior to those of fiberglass covered wires. Kapton tape-covered wires are primarily used for electric motors in vehicles, large direct current machines, and dry-transformers. However, these wires are more costly than other winding wires. It is recommended, therefore, to use them when, there are problems in terms of space factor in particular. These wires are inferior to fiberglass covered wires in corona resistance. When using these wires in high-pressure equipment, special consideration must be given to insulation design.
Table 12 on page 21 shows the property comparison with fiberglass covered wires.

* polytetrafluoroethylene

4 Nomex Paper-covered wires

Nomex tape-covered wires are manufactured by taping heat-resistance polyamide paper around wires. These wires are inferior to Kapton tape-covered wires in terms of space factor but are superior to fiberglass covered wires. These wires fully satisfy Class H heat resistance requirements and enable the miniaturization of electric equipment. These wires are almost equal to fiberglass covered wires in electrical characteristics and coating flexibility. There is no difference with Kapton tape-covered wires in other characteristics. Table 12 on page 21 shows the properties of each type.

5 Mica tape-covered wires

Mica tape-covered wires are 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). These wires are superior to fiberglass covered wires in terms of space factor and are excellent in delivery and price; they are mainly used in small-sized rotating machines as substitutes for fiberglass covered wires.
These wires are inferior to fiberglass covered wires in high-pressure corona resistance. When using these wires 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 fiberglass covered wires.

6 Transposed wire (Continuous transposed conductors)

For winding wires 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.
These dislocation wires are wires 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 wires of high voltage and large capacity transformers, these wires are expected to reduce the man-hours needed for coil winding and to improve the characteristics and reliability of transformers.
Figure 14 shows the cross section structure of a dislocation wire, Figure 15 the appearance thereof, and Table 13 the standard specifications thereof.

Table 13: Standard specifications of dislocation wires

Item		Standard specifications
Element wire conductor dimensions	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 mass		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 to 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 (1.8×6) 0.75KC — 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

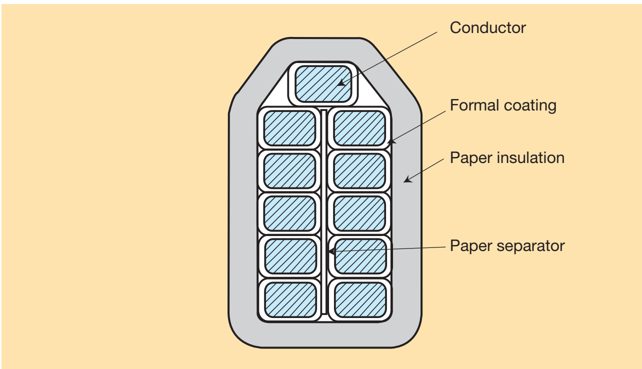
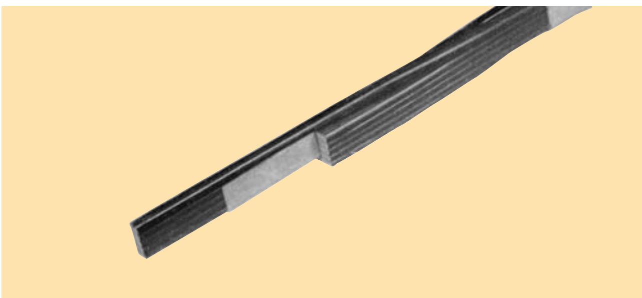


Figure 15: Appearance of Transposed wire



Combination wires: Type, symbol, standard, and feature

Type	Symbol	Standard	Cutting Type	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 Cable standard specifications
[Size range] Standard manufacturable size

Permissible current of magnet wires

Magnet wires are generally used as coils. 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)

Operational precautions for coil winding

General precautions

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

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

Dimensions that passed inspection at the time of wire manufacture are put to use; there may be no need to inspect the dimensions again. In case of misuse for reasons related to storage, management, or other such processes, be sure to measure the outside diameter, width and thickness immediately before use, checking 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.

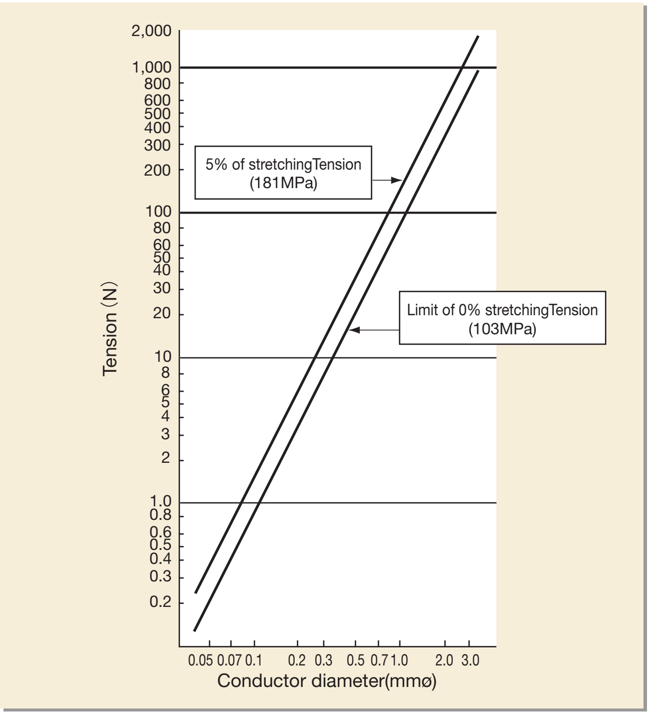
Precautions for enamelled wires

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

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 wires, except for thin wires, 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 wires to become corroded and disconnected; due care must be exercised. When peeling films, 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

Since general notes for handling wires have been described already, the below paragraphs described some considerations for forming coils. Most of the coil forming operation is performed manually. Therefore, consideration

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 for damage.

Precautions about brake

When winding a coil by a coil winding machine, appropriate tension must be given to a 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 wire stretching.
Special care must be taken with narrow wires.

Automatic machine winding

There is a recent trend toward direct coil winding to electric equipment by using an automatic coil winding machine. In general, there are a number of factors that make wires subject to harsh bending and stretching. Careful consideration must be given in advance to check coils with wires wound by a machine for damage or decreased dimensions.

Repairing at corners

In some cases, coating wires are bent with a few millimeters of bend radius by using the coil of a rotating machine. It is inevitable that films are damaged at the corners to some extent; detailed maintenance is required as described earlier. It is desirable for repair materials to be identical to those of coating. In cases of inevitable situation, materials with similar mechanical, electric 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.
This requires of each worker to pay close attention and to be ingenious in arranging and placing coils or even to use appropriate tools as necessary. Coils shall be stored away from dust particles (particularly metal powder) and moisture.
There is a recent trend toward omitting preliminary drying. However, due to the presence of strain, sweat, or moisture from enamel coatings in winding wires, preliminary drying shall be performed sufficiently to improve insulation properties.

For aluminum conductor magnet wires

1 Precautions about brakes

Since aluminum conductors have a low tensile strength, the brake strength for these conductors should be about 30% or less than that of copper wires. A higher brake strength increases stretching, thereby deteriorating the properties.

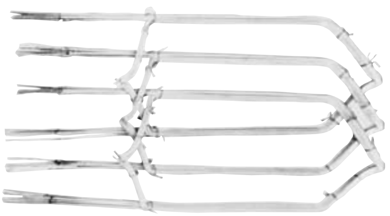
2 Precaution in automatic machine winding

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

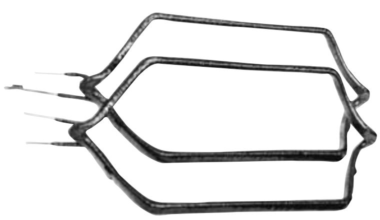
3 Precaution in molding process

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 glassfiber covered wire



After molding



After insulation treatment

Storage of wires

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

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

(2) Avoid high-humidity environments.

(3) Avoid special environments (gasses).

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

(5) Never store wires in a dusty area.

Storage period

If magnet wires are stored properly in accordance with paragraph 1, there will be no deterioration in properties even after 10 years or more have passed.
However, if wires are not stored properly, for the wires for which more than three years have passed since delivery, be sure to examine the characteristics and check for problems before use.
If you have any question, please contact us.

Dimensional table of magnet wires

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

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

Conductor		Minimum film thickness (mm)	Overall diameter		Estimated mass(kg/km)		Conductor resistance 20℃ (Ω/km)			
							Copper		Aluminum	
Diameter (mm)	Tolerance (mm)		Nominal (mm)	Maximum (mm)	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 wires (Class 0)

Conductor		Minimum film thickness (mm)	Overall diameter		Estimated mass(kg/km)		Conductor resistance 20˚C (Ω/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 wires (Class 2 and 3)

Conductor		Class 2				Class 3				Conductor resistance 20℃ (Ω/km)	
Diameter (mm)	Tolerance (mm)	Minimum film thickness (mm)	Overall diameter		Estimated mass (kg/km)	Minimum film thickness (mm)	Overall diameter		Estimated mass (kg/km)		
			Nominal(mm)	Maximum(mm)			Nominal(mm)	Maximum(mm)		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 wires (Highbon wire) [In the case of finish Class 0, insulation layer Class 1]

Conductor		Insulation layer (Class 1)				Highbon 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 wires (Highbon wire) [in the case of finish Class 1, insulation layer Class 2]

Conductor		Insulation layer (Class 2)				Highbon 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 wires (Highbon wire) [in the case of finish Class 2, insulation layer Class 3]

Conductor		Insulation layer (Class 3)				Highbon 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 chamfering radiuses of rectangular copper wires

Dimensional tolerances (JIS C 3104)

Thickness or width	Tolerance(mm)
0.50 to <1.2.	±0.035
1.2 to <2.6.	±0.05
2.6 to <5.0	±0.07
5.0 to <10.0	±0.10
10.0 to <20.0	±0.15
20.0 to <32.0	±0.25

Chamfering radiuses (JIS C 3104)

Thickness(mm)	Chamfering radius (approximate)(mm)
0.50 to <0.80	1/2 of thickness
0.80 to <1.2	0.4
1.2 to <2.6	0.6
2.6 to <4.0	0.8
4.0 to <6.0	1.2
6.0 to <10.0	1.6

●Table 21: Maximum conductor resistances of rectangular copper wires

Unit Ω/km(20℃)

Conductor thickness mm \ Conductor width 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 wires
(maximum finish thicknesses, minimum film thicknesses in width and thickness directions of enamel rectangular copper wires)

Unit mm

Conductor thicknesses and tolerances \ Conductor widths and tolerances		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 thicknesses 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 thicknesses in thickness direction (one side)		0.03																				0.035							

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

Conductor		Single glassfiber covered wire (SGC)				Double glassfiber covered wire (DGC)				Maximum conductor resistance 20˚C(Ω/km)	
Diameter (mm)	Tolerance (mm)	Minimum insulation thicknesses (mm)	Maximum overall diameters (mm)	Estimated masses(kg/km)		Minimum insulation thicknesses (mm)	Maximum overall diameters (mm)	Estimated mass(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 wires (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			

Packing

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

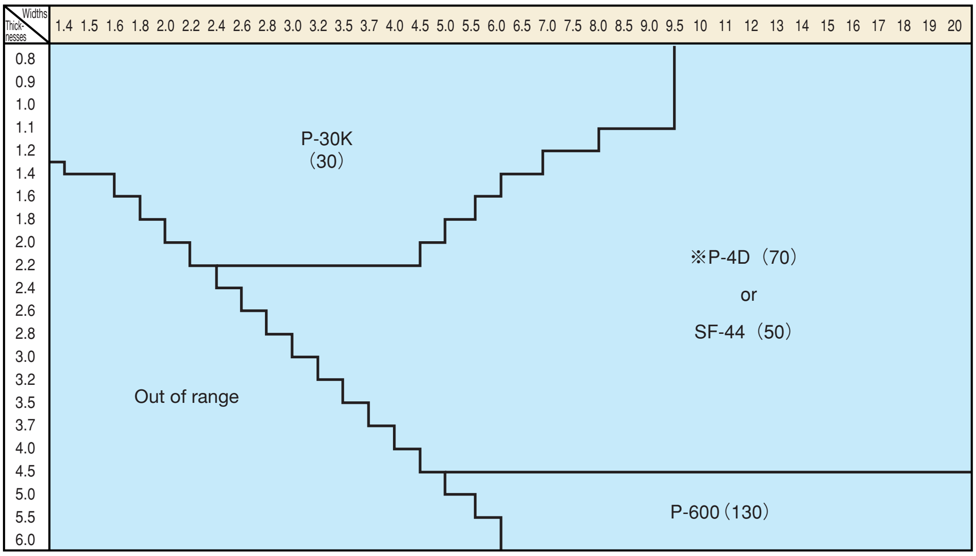
● Table 25: Standard bobbin or pack and standard winding mass (round wire)

Conductor diameters (mm)	Enamelled wires: Bobbin	Enamelled wires: Pack	Covered conductor wires
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 winding mass (unit: kg)
2. The tolerance of standard winding mass is ±30%.
3. Standard winding masses are values when conductors are made of copper. For aluminum conductors, the values shall be 1/3.3.

● Table 26: Standard assembled forms and standard winding masses (rectangular wires)

1.All rectangular wires except for paper-covered wires



Note) 1. Value in parentheses: Standard winding mass (unit: kg)
2. For sections marked with an asterisk (*), P-4D shall be Hitachi 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 winding mass shall be ±30%.
4. Standard winding masses are values when conductors are made of copper. For aluminum conductors, the values shall be 1/3.3.

2. Paper-covered rectangular wires

Conductor thickness (mm)	Drum No.	Standard winding mass (kg)
<5.0	P-4D	70
5.0 and over	P-600	130

Note) 1. Standard winding mass tolerance shall be ±30%.
2. For paper-covered wires, the standard winding mass differs slightly depending on the number of paper.
3. Standard winding masses are values when conductors are made of copper. For aluminum conductors, the values shall be 1/3.3.

Table 27: Dimensional table of winding frames for standard wires

Unit mm

	Types	Flange diameter D		Barrel diameter d		Inside width W	Flange thickness a	Bore diameter h
Plastic bobbin	P-30K(For rectangular wires) 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

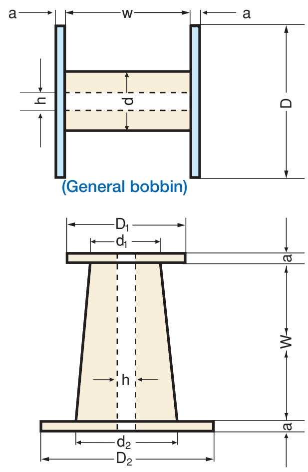
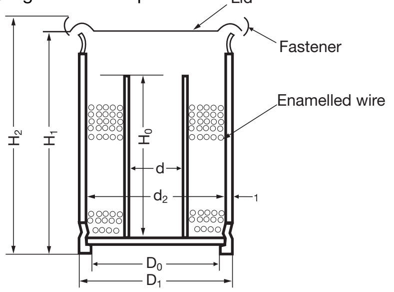


Table 28: Standard pale pack dimensions

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

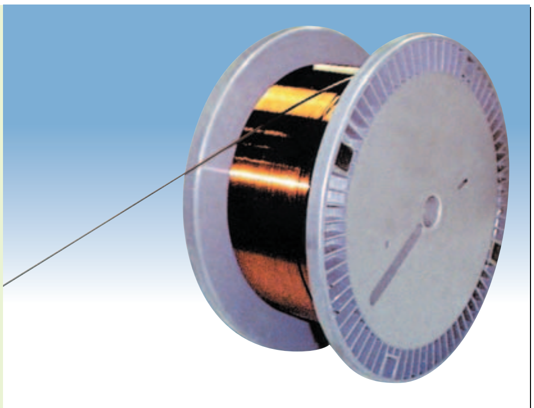


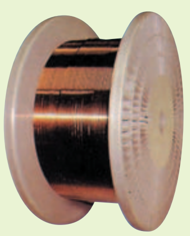
We provide you with usability.

Hitachi regular winding enamelled wire

- Correction work is not required without small bending
- No need to correct small bending; wires will not be hard.

Hitachi regular winding enamelled wires contribute to improvement in the efficiency of coil winding work for extra wide enamelled wires (having a diameter of 2.0 to 3.2 mmø) that are difficult to process.





Regular winding products

General winding products

Hitachi regular winding enamelled wire stock

Product type	Size (mm)	Assembled form	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 (JIS C 3202-5)
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 (JCS No. 334)

*Standard winding mass: 35kg

UL recognized product

File No.:E68042

Material Designation	Coating Type		ANSI Type	Temperature Index (℃)
	Basecoat	Topcoat		
PVF ˉ	Polyvinyl formal	—	MW15, MW18	105
UEW +	Polyurethane	—	—	130
UEW-BU	Polyurethane	—	MW75C	130
UEW-P +	Polyurethane	Polyamide	MW28C	130
PEW ˉ	Polyester	—	—	155
PEW-P	Polyester	Polyamide	MW24C	155
PEW-PU	Polyester	Polyamide	MW24C	155
NY-PEW	Polyester	Polyamide	MW24C	155
AMW-X	Polyester-Imide	—	MW30C	180
AMW-XV AMW-RE AMW-XVE KMK-20E RFW-VEU	Polyester-Imide	Polyamide-Imide	MW-35C, MW-73C	200
EIW-AU	Polyester-Imide	Polyamide-Imide	MW35C, MW73C	200
KMKED-20E	Modified Polyester-imide	Polyamide-Imide	MW35C	200
AIW, KMK-22A	Polyamide-Imide	—	—	220
IMW	Aromatic polyimide	—	MW16C	240
HBH-AIW	Polyamide-Imide	Phenoxy	—	220
HBH-AI-AMW-H	Polyester-Imide	Polyamide-Imide-Phenoxy	—	200

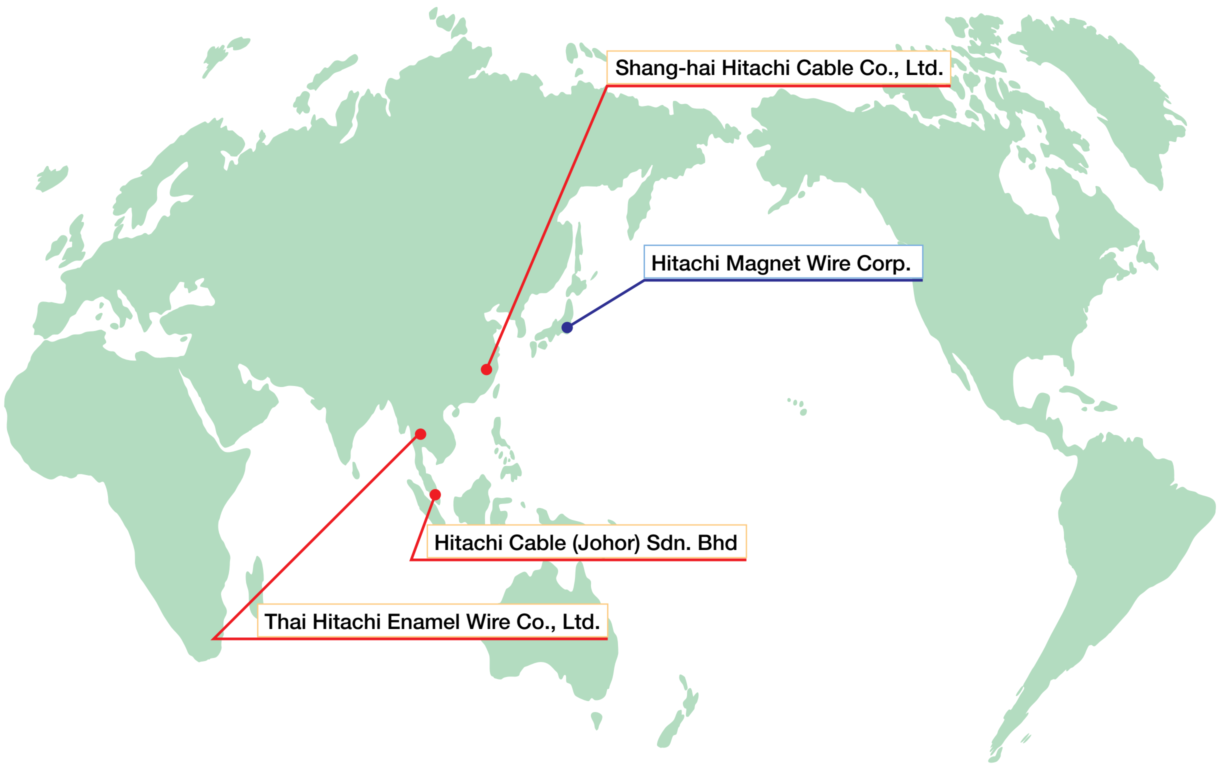
ˉ Note: Magnet wire may employ a rectangular shape.
+ Note: Magnet wires may be twisted together.

Conclusion

As already described, there is a very wide variety of wires for winding used in electric equipment. The development in synthetic chemistry and process technology is expected to further activate the advancement and improvement of magnet wires. We persevere in research and development and are always making efforts in manufacturing better magnet wires to meet the demands of users. Needless to say, the performance of equipment largely depends on the performance of magnet wires used therein. It is of great importance, therefore, to become thoroughly aware of the advantages and disadvantages of these wires and to make appropriate selection and application by making full use of their characteristics.
We hope that this catalogue serves as a guide for users and contributes to the development of electric equipment and the improvement of working efficiency.

●Various special-purpose magnet wires are available. Please contact our nearest sales center.
Catalogues and technical data are prepared.

Hitachi Magnet Wire's Global Network



■Manufacturing Centers

Hitachi Magnet Wire Corp.
4-10-1, Kawajiri-cho, Hitachi City, Ibaraki Prefecture 319-1411, Japan
Product: All kinds of magnet wires Tel:+81-294-42-5453

Hitachi Cable (Johor) Sdn. Bhd
PLO 40, Kawasan Perindustrian Senai, 81400 Senai, Johor, Malaysia
Product: Round enamelled wire(0.03~1.6mm) Tel:+60-7-599-4350

Thai Hitachi Enamel Wire Co., Ltd.
171, Moo 12, Tambol Bangwua Amphur, Bangpakong Chachoengsao 24180, Thailand
Product: Round enamelled wire(0.05~4.0mm) Tel:+66-38-53-2071

Shang-hai Hitachi Cable Co., Ltd.
318 Mei Neng Da Road, Songjiang Industrial Zone, Shanghai, China
Product: Round enamelled wire(0.1~2.6mm) Tel:+86-21-5774-2000

■Business Centers

Hitachi Cable,Ltd.
http://www.hitachi-cable.co.jp/en/

Akihabara UDX, 14-1 Sotokanda 4-chome, Chiyoda-ku, Tokyo 101-8971, Japan Tel:+81-3-5256-5454

Hitachi Cable America, Inc.

Head Office
10 Bank Street, Suite 590, White Plains NY 10606-1943, U.S.A
Tel:+1-914-933-0990

San Jose Office
2665 North First Street, Suite 200 San Jose, CA 95134, U.S.A.
Tel:+1-408-324-1880

Hitachi Cable Europe Ltd.

Head Office
4th Floor, 50/51 High Holborn London WC1V 6ER, U.K.
Tel:+44-20-7831-0422

Milan Liaison Office
Foro Bonaparte 68, 20121, Milan, Italy
Tel+39-02-8699-8496

Hitachi Cable Asia Ltd.

Head Office
Rm 1202 12/F, Empire Centre,
68 Mody Road, Tsimshatsui,
Kowloon, Hong Kong, China
Tel:+852-2721-2077

Philippine Branch
Lima Technology Center,
Lipa City, Batangas,
"SEZ"Philippines 4217
Tel:+63-43-981-0131

Taipei Office
Room 2403, 24/F.
333 Keelung Road, Section1,
Taipei 110, Taiwan, China
Tel:+886-2-2345-9189

Hitachi Cable Asia Pacific (HCAP) Pte. Ltd.

61, Alexandra Terrace, #05-05 Harbourlink,
Singapore 119936, Singapore
Tel:+65-6265-6711

Hitachi Cable (China) Trading Co.,Ltd.

Room 1401 Maxdo Center, No.8 Xingyi Road,
Hong Qiao Development Zone Shanghai 200336, China
Tel:+86-21-6278-7752

CAT.NO.ME001

Printed in Japan '10-9 (ICC)