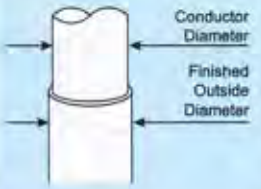
6. Magnet Wire Testing Method

6-1. Dimension

Measurements for the overall, conductor diameter and film thickness are indicated. The following types are available based on the film thickness.

Type 0: Thickest film
Type 1: Thick film
Type 2: Thin film
Type 3: Thinnest film

Summary of Test Method



Obtain the average diameter value by measuring at three different points that are almost at the same angle to the plane perpendicular to the conductor axis. The film thickness will be half of the difference between the overall and conductor diameter.

For details, please refer to item 5 of "Enamelled Wire Testing Method: JIS C 3003."

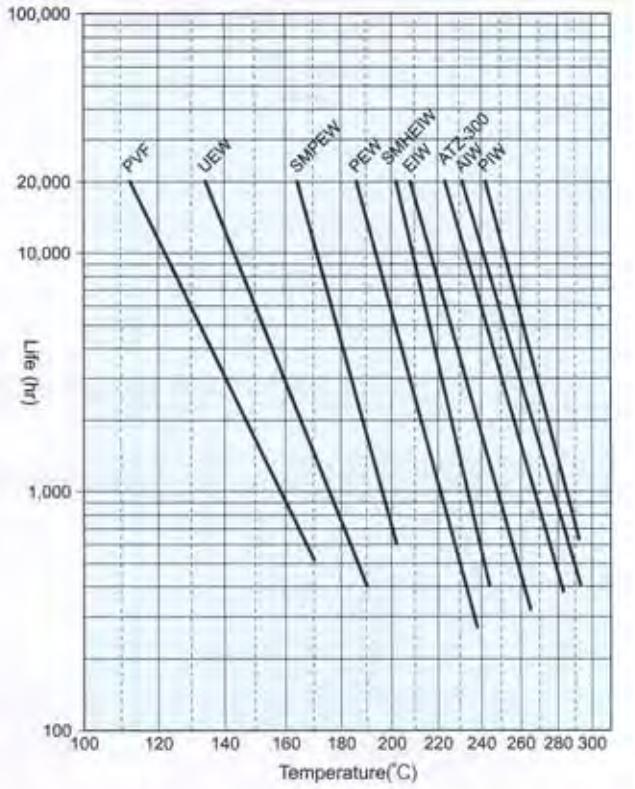
6-2. Thermal Characteristics

1)Heat Resistance Life

When selecting a winding wire for use with a device, first select the winding wire with a temperature index that meets the heat resistance of the device.
Temperature index can be calculated from the thermal life.
The testing method for heat resistance life is ASTM D2307. The heat resistance class and temperature index often used are classified in the following table.

Heat Resistance	Temperature
Y	90°C
A	105°C
E	120°C
B	130°C
F	155°C
H	180°C
200	200°C
220	220°C
250	250°C

Heat Resistance Life of Various Winding Wires



2)Heat Shock Resistance

Heat shock resistance is used to check if crack occurs when heated under a condition where the film is being stressed by stretching or bending.
Normally, winding wire with a high heat resistance does not crack even under a high heating temperature.
Please note that the insulation may crack due to heat during the operation of an electrical device if it was wound on small mandrel or elongated greatly.

Stretch the test specimen to the specified elongation rate or wind the wire by 10 turns of the specified diameter ratio to tighten it, followed by checking if there is any film crack after heating it under the specified temperature and time.

For details, please refer to item 20 of "Enamelled Wire Testing Method: JIS C 3003."

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3)Resistance to cut through

Resistance to cut through is used to check the temperature at which the film softens.
The winding wire wrapped around the electrical equipment experiences increased voltage depending on tension and molding during wire winding process. Heating under such conditions softens the film, and may lead to short circuit.
For electrical equipment with high allowable maximum temperatures, products with softening-resistance of high temperatures are used.
For electrical equipment with resin molding, products with softening-resistance of high temperature are necessary depending on the mold-parameters.

Stack two test specimens perpendicularly (forming a right angle) on a flat plate, put specified weight on its intersection, and raise the temperature in oven at 2°C per minute.
Run 100V of voltage between both lines and measure the temperature when the film-softens and electrical conduction occurs.

For details, please refer to item 11 of "Enamelled Wire Testing Method: JIS C 3003."

6-3. Electrical Characteristics

1)Pinhole

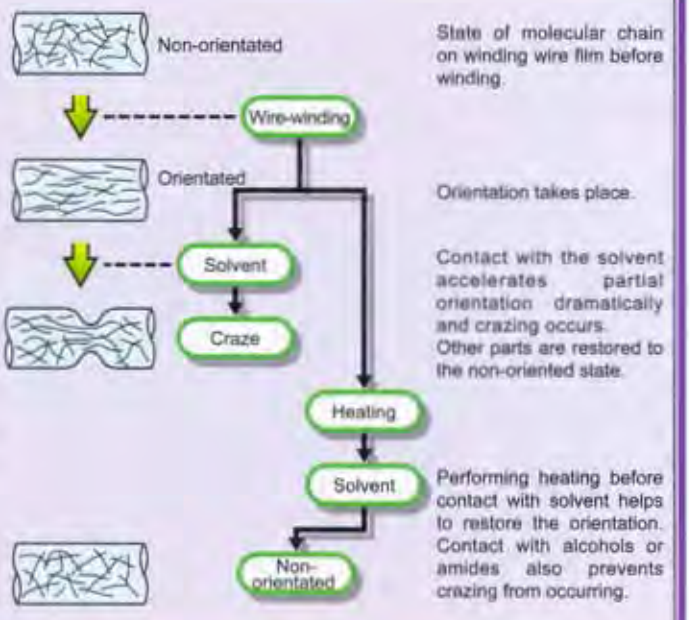
Pinhole is a method to check electrical defects such as tiny holes in the film.
The winding wire is insulated using the thin film.
Depending on the film type, pinhole may occur due to crazing when the pinhole test is performed after wire winding.

Check the number of pinholes that occur on wire when adding 12V of direct voltage for one minute. The liquid is positive pole and the test specimen is a negative pole. After soaking the wire with specified length (around 5m) into saline solution.

For details, please refer to item 6 of "Enamelled Wire Testing Method: JIS C 3003."

※Crazing Phenomenon

Winding wire on electrical equipment will result in elongation of the wire due to bending or tension, and hence stress on the film.
This stress results in molecular chain orientation of the entire film.
When the wire comes into contact with water or solvent in this state, orientational concentration and relaxation due to local yielding occurs, which results in crazing. Performing the pinhole test when crazing occurs causes the crazed parts to become pinholes, hence losing their insulation properties.
Normally, heating PVF and UEW series at 125°C and EIW series at 150°C for ten minutes or more (differs according to the size and form of equipment) helps to remove stress from the film and prevent crazing.



2)Dielectric Breakdown Voltage

Dielectric breakdown voltage is used to check the insulation performance of films, thus it differs according to the film thickness of the winding wire. Normally, two-piece method is used, but metal cylinder method is used in the case of small wires.
Dielectric breakdown voltage shows a high value as the film becomes thicker. It is necessary to examine the film thickness based on the line voltage and inter-phase voltage of electrical equipment.

In the two-piece method, twist a 12cm-length test specimen according to the specified number of twists, apply an alternating voltage between the lines and increase the voltage at 500V per second to find the voltage when breakdown occurs.

For details, please refer to item 10 of "Enamelled Wire Testing Method: JIS C 3003."

6-4. Mechanical Characteristics

1)Flexibility

Flexibility test is used for determining whether film crack occurs when the winding wire is bent, also is evaluated based on elongation or winding. Normally, crack does not occur in self-diameter coiling.

For 0.35mm and below, stretch the test specimen up to the specified value and check for cracks using a 15x magnifying glass.
For 0.37 mm and above, wind tightly 10 turns of the specified winding diameter, followed by checking visually for cracks.

For details, please refer to item 7 of "Enamelled Wire Testing Method: JIS C 3003."

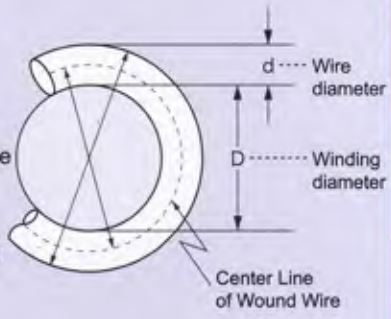
※Film elongation rate during wire winding

When the external film is stretched during wire winding, the values are as follow:

Winding diameter	Elongation of external film
Single diameter	50%
Double diameter	33%
Triple diameter	25%

Assuming that the center point is hardly stretched when wire is wound, the external film elongation of the wound wire is shown using the formula below:

$$\text{External film elongation (\%)} = \left[\frac{\pi(D+2d)}{\pi(D+d)} - 1\right] \times 100 = \left[\frac{d}{D+d}\right] \times 100$$



In other words, during double-diameter winding, D=2d.

$$\frac{d}{2d+d} \times 100 = \frac{1}{3} \times 100 \fallingdotseq 33\%$$

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2)Adhesion

Adhesiveness is used for investigating whether the adhesion between the film and conductor is maintained. When adhesion is poor, the film may peel off due to stress during wire winding.

When the test specimen is stretched at a tension speed of around 4m/s until it breaks, check whether film crack is found using a 15x magnifying glass.

For details, please refer to item 8 of "Enamelled Wire Testing Method: JIS C 3003."

3)Abrasion Resistance

Abrasion resistance is used to investigate the amount of force needed to apply on the film in order to break it.
This is an index of the film's strength against stress during wire winding.

Place the piano wire with a diameter of 0.23mm perpendicularly to the test specimen, and add load on the piano wire.
While moving the piano wire in the direction of the test specimen's length at a speed of 400mm/min, add the load at the same time, determine the weight when the film peels off and when the conductor comes into contact with the piano wire.

For details, please refer to item 9 of "Enamelled Wire Testing Method: JIS C 3003."

4)Coefficient of Static Friction

Coefficient of static friction indicates the smoothness of film surface.
The static friction coefficient (slip properties) of winding wires largely affects the wire winding properties on electrical equipment.
With the requirement in equipment miniaturization and efficiency, it will become more important to wind a larger amount of wire into a smaller space to enhance the space factor.

Stretch two wires across the mirror plate, place the slider where two wires are stretched across these wires such that wire perpendicularly intersect each other. Tilt the mirror plate gradually until the slider slides off and find the tan θ value of the inclination when this occurs.

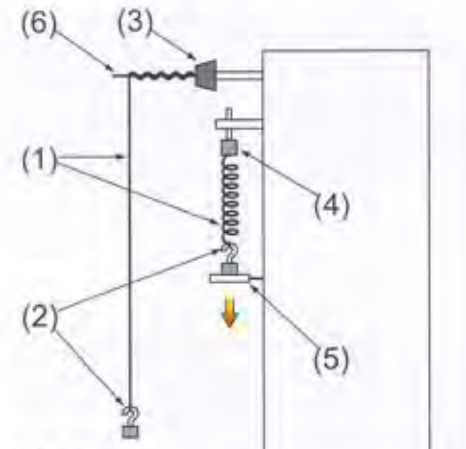
5)Softness

The winding wire softness largely affects the wire winding properties in electrical equipment. The softness index of winding wire applies elongation, spring elongation and springback.

(1) Elongation
Elongation indicates the increase in length in percentage against the original length.
Stretch the linear test specimen with gauge length of 200-250mm using a stretch test machine or pull test machine at the speed of 5±1mm/s until the conductor breaks. Calculate in percentage the increased length until breakage with respect to the original length.

For details, please refer item 18 of "Enamelled Wire Testing Method: JIS C 3003."

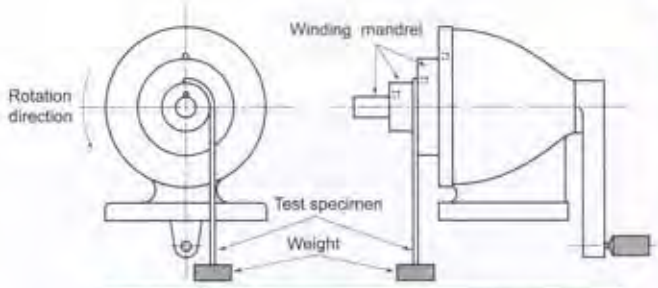
6. Magnet Wire Testing Method



(1) Test Specimen
(2) Weight
(3) Horizontal axis check
(4) Vertical axis check
(5) Supporting base
(6) Winding mandrel

(2) Spring Elongation
Take a test specimen with a length of around 1.2m, hang a 700g weight per cross sectional area of the conductor (mm^2) with a center length of 1m. While making a coil on a winding mandrel with a diameter that is 10 times the conductor diameter. Measure the coil's length L1 (mm).
Fix one end of the coil, attach a 700g weight per cross section area of the conductor (mm^2), and place it on the support base without stretching the coil.
Lower the support base at a speed of 50mm/s. After the weight is separated from the base, leave it intact for one minute. Remove the weight from the test coil, followed by measuring the coil length L2 (mm) after leaving it intact for one minute.
Calculate the spring elongation value using:
$\triangle L = L2 - L1$

For details please refer to item 19 of "Enamelled Wire Testing Method: JIS C 3003."



(3) Springback
Wind a test specimen with a length of about 1m to the winding mandrel on springback tester, with prescribed diameter at a rotation speed of 5-10 times/min. Press down one end of the coil after winding, release the other end slowly and read amplitude of the return from scale of springback tester.

For details please refer to item 19 of "Enamelled Wire Testing Method: JIS C 3003."

Conductor Diameter (mm)	Winding Mandrel Diameter (mm)	Weight Mass (g)
0.25~0.37	19	57
0.40~0.45	48	57
0.50~0.75	48	115
0.80~1.6	82	455

6-5. Chemical Characteristics

1)Solvent Resistance

Solvent resistance is used for investigating whether film swelling occurs when the wire is soaked in xylene. If the film is attacked by an organic solvent containing impregnating varnish during varnish treatment after winding, insulation performance may deteriorate.

After soaking the test specimen for 30 minutes in xylene at 60°C, take out the specimen and check whether there is any bubble, swelling on the film, and whether there is peeling using the squeeze method or pencil method.

For details please refer to item 13 of "Enamelled Wire Testing Method: JIS C 3003."

2)Chemical Resistance

Chemical resistance is used for investigating whether the film is attacked by alkali or acid. Insulation performance may deteriorate due to damage caused by the alkali or acid in the electrical equipment's operating environment.

Soak the test specimen for 24 hours at room temperature in chemicals (caustic soda, sulfuric acid) with the prescribed concentration. Check whether there is any bubbles or swelling of the film, and whether there is peeling using the squeeze method or pencil method.

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3)Solderability

Solderability is used for investigating whether soldering is possible under the prescribed temperature and time without peeling of film.

Dip 40mm of test specimen into solder bath, which is maintained at prescribed temperature, and leave it for the prescribed period of time. Upon taking the specimen out, check whether solder is attached uniformly to the dipped portion, excluding the top 10mm.

For details please refer item 14 of "Enamelled Wire Testing Method: JIS C 3003."

4)Refrigerant Resistance

Winding wires used in refrigerating machines must maintain insulation performance against refrigerant and refrigerating oil, and must not allow leakage of extracts from electrical wires into the refrigerant.

Put the test specimen in an airtight pressure container together with the refrigerant and refrigeration oil. After heating under the specified temperature and time, take it out and check the characteristics of the wire.

For details please refer to item 16 of "Enamelled Wire Testing Method: JIS C 3003."

5)Resistance to humidity

Resistance to humidity is used for investigating whether insulation performance of the film deteriorates due to hydrolysis.
When electrical equipment is used under high temperature and humidity, hydrolysis occurs, which deteriorates insulation performance. Care is required as PEW is susceptible to hydrolysis.
Changes in insulation performance due to hydrolysis of the main winding wires are shown in the right graph.

Put the test specimen and the specified quantity of water into the airtight pressure container. Perform heating under the specified temperature and time (e.g. 150°C for 24 hours) and measure the dielectric breakdown voltage or insulation resistance.

The test specimen and 0.2Vol% of water are placed in an airtight container, and the dielectric breakdown voltage after heating at 150°C is measured.

Changes in Insulation Performance due to Hydrolysis