

TECHNICAL NOTE

Aluminum Foil for Aluminum Electrolytic Capacitor



Catalog No.F-161 (FEB. 2026)

1. Specification

1.1 Capacitance Specification for Anode Foil

Items	Specification
Effective Width of Foil	① U199–50. 2Vfs over ▪ U191–45. 6Vfs over ▪ LM120GF3 All Voltage 475mm (500mm wide roll less 12.5mm at each edge) ② All Other Foils Formed Foil: 480mm (500mm wide roll less 10mm at each edge) Etched Foil:
Average Capacitance (X)	As per Specification
Tolerance of Average Capacitance (X)	As per Specification
Calculation of AverageCapacitance (X)	A1, A2, A3 : Measured capacitance values at outer side of a foil B1, B2, B3 : Measured capacitance values at core side of a foil $\bar{X} = (A \text{ max} + A \text{ min} + B \text{ max} + B \text{ min}) \div 4$
Dispersion Range	13% or less
Calculation of Dispersion Range	A1, A2, A3 : Measured capacitance values at outer side of a foil B1, B2, B3 : Measured capacitance values at core side of a foil $\text{Dispersion Rate} = \frac{A \text{ max or } B \text{ max} - A \text{ min or } B \text{ min}}{\text{Average Capacitance}} \times 100 \text{ (\%)}$

☆The above specifications are subject to change without notice

1.2 Specification for Cathode Foil Capacitance

Items	Specification
Effective Width of Foil	480mm (500mm wide roll less 10mm at each edge)
Capacitance	As per Section 3. Specification
Determination of Capacitance	The minimum value of either outer side capacitance A or core side capacitance B
Hydration Process Time	60 minutes
Change of Capacitance after Hydration Process	$\Delta C_{60} \geq -10\%$

* ΔC_{60} (change of capacitance after Hydration Process) is applied to C518, C519, C439 and C531.
It is not applied to other cathode etched foil and cathode formed foil.

1.3 Nominal Formation Voltage Range

Foil Category	Nominal Formation Voltage Range
Formed Foil, Extreme Low Voltage	$3.0 \leq V_{fs} \leq 6.6$
Formed Foil, Low Voltage	$8.0 \leq V_{fs} \leq 170$
Formed Foil, Middle to High Voltage	$208 \leq V_{fs} \leq 628$
Formed Foil, Cathode	$0.9 \leq V_{fs} \leq 3.0$

1.4 Specification for Residual Chloride Content

Items	Specification	
Residual Chloride Content	Etched Foil for Anode, Low Voltage	2.0mg/m ² or less
	Formed Foil for Anode, Low Voltage, Cathode Formed Foil	0.8mg/m ² or less
	Etched Foil for Anode, Middle to High Voltage Formed Foil for Anode, Middle to High Voltage Cathode Etched Foil	1.0mg/m ² or less

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1.5 Specification for Visual Appearance

Items	Specification
Visual Appearance	For Etched and Formed Foil, the appearance of one roll may be slightly different from another. They may look different because of variances in raw foil, production process, etc. The following minor defects shall not be reasons for rejection as long as they are proven not to be harmful electrically and/or mechanically to the capacitor: 1) Small Speckles 2) Wrinkles and Marks or Visible Corrections of Them 3) Visible Aluminum Hydroxide on Foil Surface 4) Small Pin-holes 5) Small Scratch 6) Variations of Surface Color If you have any question about your shipment of foil, please contact us based upon “5-4 Rejections and Claims” .

1.6 Specification for Rise Time and Dielectric Withstanding Voltage

1.6.1 Formed Foil for Anode, Extreme Low Voltage

Items	Specification
Nominal Formation Voltage Range	$3.0 \leq V_{fs} \leq 6.6$
Name of Test Methode	Film Dielectric Withstanding Test (Vt)
Code of Dielectric Withstanding Voltage	Vt
Dielectric Withstanding Voltage (Vt)	$V_{fs} \leq V_t$
Rise Time (Tr)	$T_r \leq (V_{fs} \times 0.5 + 100)$ second
Hydration Resistance Test Time	60 minutes
Rise Time after Hydration Process (Tr60)	$T_{r60} \leq 150$ seconds

1.6.2 Formed Foil for Anode, Low Voltage

Items	Specification
Nominal Formation Voltage Range	$8.0 \leq V_{fs} \leq 170$
Name of Test Methode	Film Dielectric Withstanding Test (Vt)
Code of Dielectric Withstanding Voltage	Vt
Dielectric Withstanding Voltage (Vt)	$V_{fs} \leq V_t$
Rise Time (Tr)	$T_r \leq (V_{fs} \times 0.5 + 100)$ second
Hydration Resistance Test Time	60 minutes
Rise Time	$T_{r60} \leq 150$ seconds

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1.6.3 Formed Foil for Anode, Middle to High Voltage

Items	Specification
Nominal Formation Voltage Range	$208 \leq V_{fs} \leq 628$
Name of Test Methode	Film Dielectric Withstanding Test (Vt)
Code of Dielectric Withstanding Voltage	Vt
Dielectric Withstanding Voltage (Vt)	$V_{fs} \leq V_t$
Rise Time (Tr)	$Tr \leq (V_{fs} \times 0.5 + 100)$ second
Hydration Resistance Test Time	60 minutes
Rise Time after Hydration Process (Tr60)	$Tr_{60} \leq 150$ seconds

1.6.4 Formed Foil for Cathode

Items	Specification
Nominal Formation Voltage Range	$0.9 \leq V_{fs} \leq 3.0$
Name of Test Methode	Film Dielectric Withstanding Test (Vt)
Code of Dielectric Withstanding Voltage	Vt
Dielectric Withstanding Voltage (Vt)	Each voltage is equivalent to the dielectric dielectric withstanding voltage in the catalog.

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2. Nominal Length

2.1 Nominal Length for Etched and Formed Foil

(Unit:m)

Item	Small	Medium	Large
Standard Outside Diameter Gauge (μm)	200mm	280mm	390mm
22 (20~22)	1, 250	2, 500	5, 000
25 (21~25)	1, 100	2, 200	4, 400
30 (26~30)	900	1, 800	3, 600
35 (31~35)	800	1, 600	3, 200
40 (36~40)	700	1, 400	2, 800
45 (41~45)	650	1, 300	2, 600
50 (46~50)	500	1, 000	2, 000
55 (51~55)	500	1, 000	2, 000
60 (56~60)	450	900	1, 800
65 (61~65)	430	860	1, 720
70 (66~70)	400	800	1, 600
75 (71~75)	350	700	1, 400
80 (76~80)	350	700	1, 400
85 (81~85)	300	600	1, 200
90 (86~90)	300	600	1, 200
95 (91~95)	300	600	1, 200
100 (96~100)	250	500	1, 000
105 (101~105)	250	500	1, 000
110 (106~110)	250	500	1, 000
115 (111~115)	250	480	950
120 (116~120)	230	450	890
125 (121~125)	220	430	860
135 (131~135)	210	400	790

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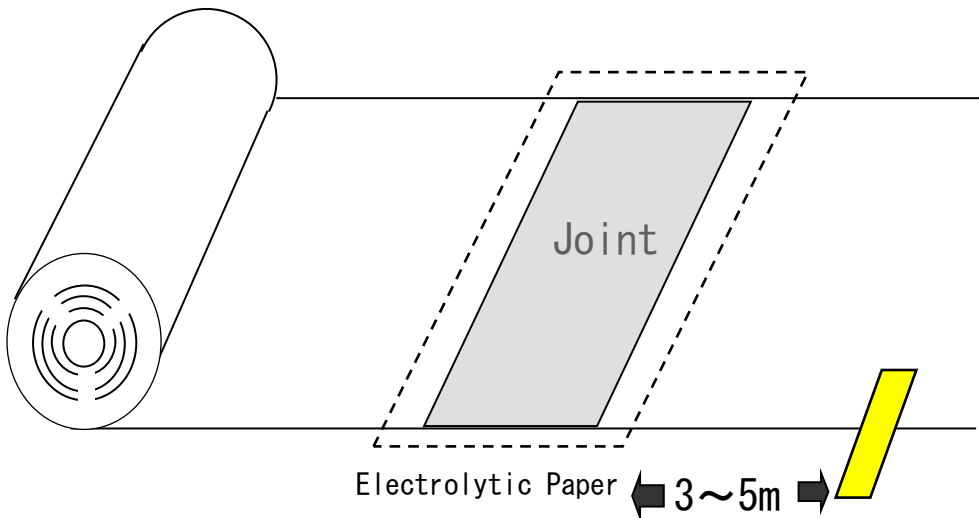
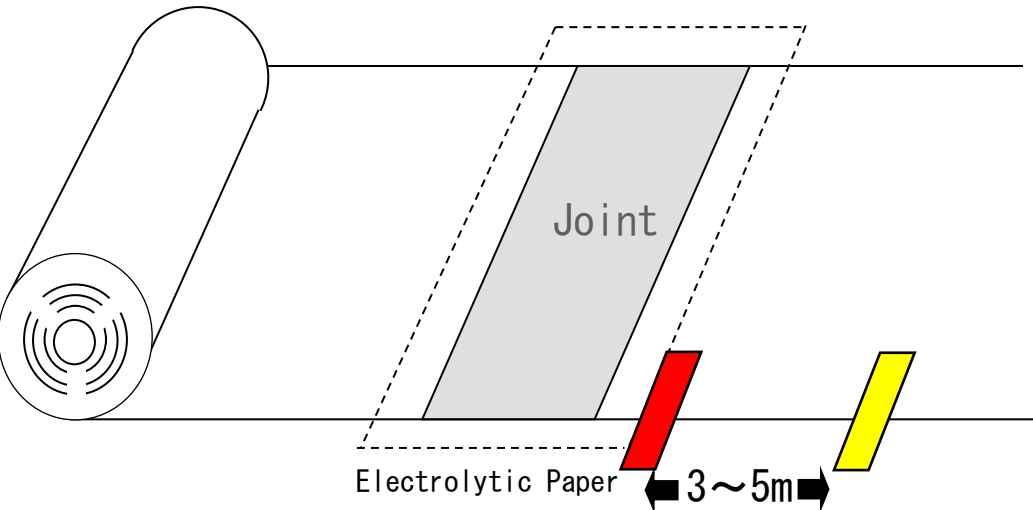
3. Joint Specification

3.1 Number of Joints and Joint Intervals for Etched and Formed Foil

Size of Roll	Small Size Roll	Medium Size Roll	Large Size Roll
Container Type	Corrugated Cardboard Box		
Number of Joints	One or None	Two or Less	
Joint Intervals	Interval from joint to the end of foil is 50m or more.	Interval from joint to the end of foil is 50m or more. Interval between joints is 50m or more.	

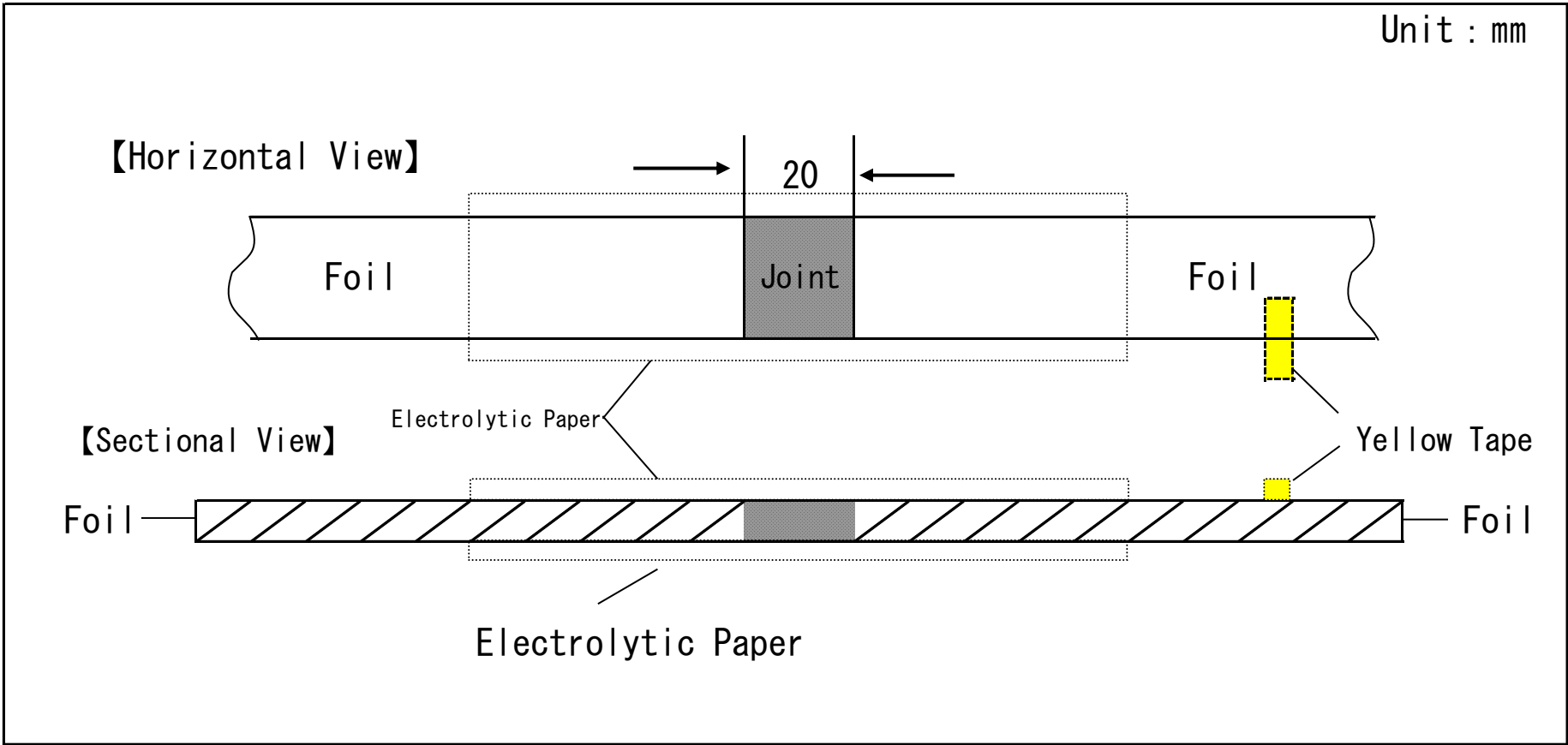
3.2 Marking of Joints for Etched and Formed Foil

For efficiency during the formation and slitting processes at the customer’s site, colored tape is used within rolls to indicate joint locations. Yellow tape is affixed 3-5m before a joint, and red tape is affixed immediately before the joint on the following foil types: etched foil for medium/high-voltage anodes, etched foil for cathodes, formed foil for low-voltage anodes, formed foil for medium/high-voltage anodes, and formed foil for cathodes. Electrolytic paper is applied at the joint.

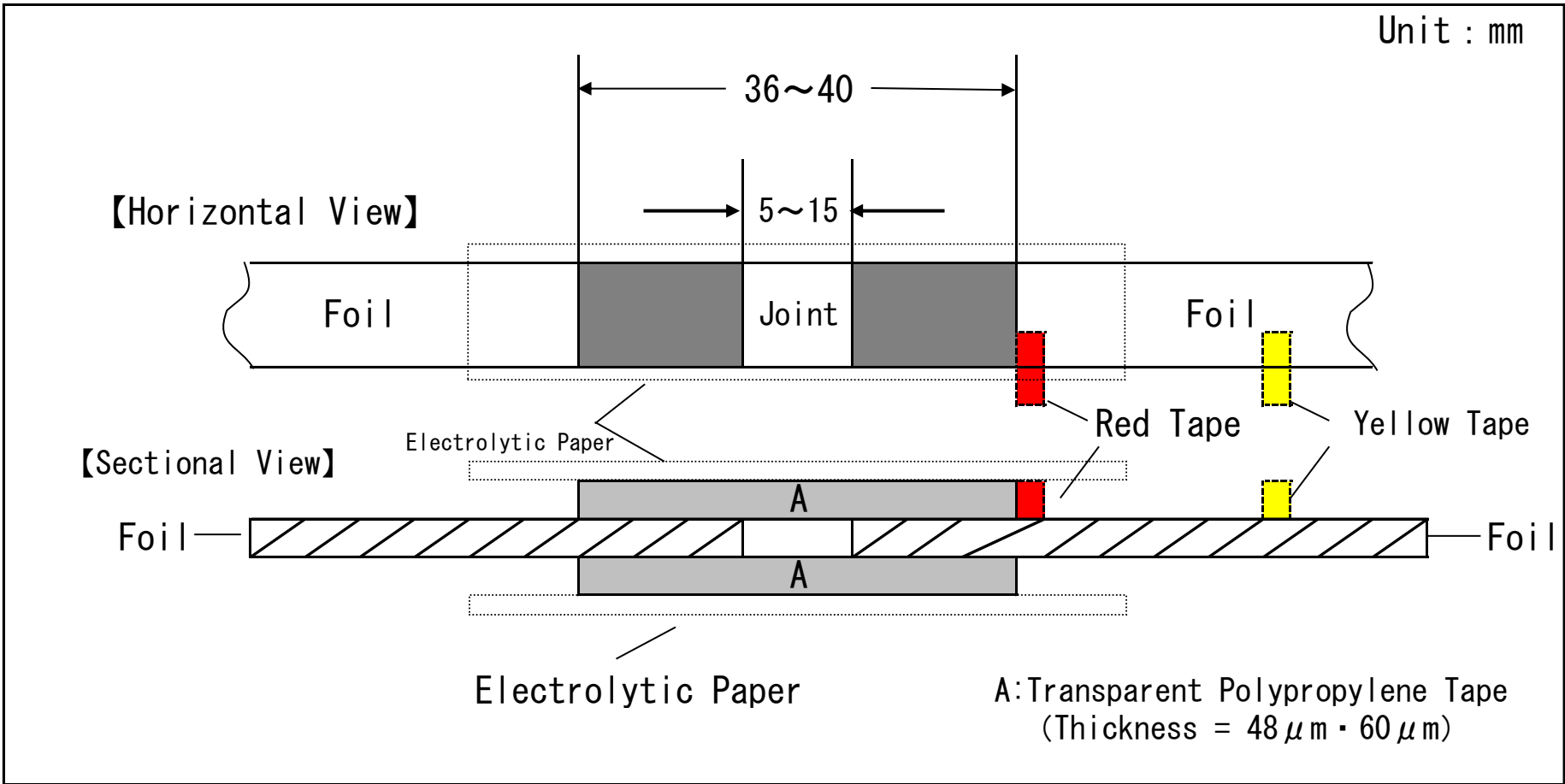
Item	Joint Markings
Etched Foil for Anode, Low Voltage	 Electrolytic Paper 3~5m Yellow Tape
Etched Foil for Anode, Middle to High Voltage Cathode Etched Foil Formed Foil for Anode, Low Voltage Formed Foil for Anode, Middle to High Voltage Cathode Formed Foil	 Electrolytic Paper 3~5m Red Tape Yellow Tape

3.3 Joint Methods for Etched and Formed Foil

3.3.1 Low Voltage Etched Foil (Cold Weld)



3.3.2 Middle to High Voltage Etched Foil, Formed Foil,
Low Voltage Formed Foil, Cathode Etched Foil, Formed Foil



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4. Packing Information

Care should be taken when transporting and storing the electrode foil to avoid damaging the product
Product packaging is designed to facilitate handling after unpacking.
Packaging standards have been designed with this in mind.

4.1 Standard Packing Specification

Items	Formed Foil / Etched Foil		
Size of Roll	Small Size Roll	Medium Size Roll	Large Size Roll
Container Type	Carton		
Foil Winding Width	500 $\begin{smallmatrix} +5 \\ -0 \end{smallmatrix}$ mm		
Core Size	Length : 600 ± 1 mm I. D. : 75 $\begin{smallmatrix} +2 \\ -1 \end{smallmatrix}$ mm		
Core Materials	Painted Steel		
Dimensions of Container	(J2) 470 D × 610W × 540 H, (R1) 433 D × 615W × 539 H (mm)		
Weight of One Roll (Without Container)	Approx. 25kg	Approx. 50 kg	Approx. 100 kg

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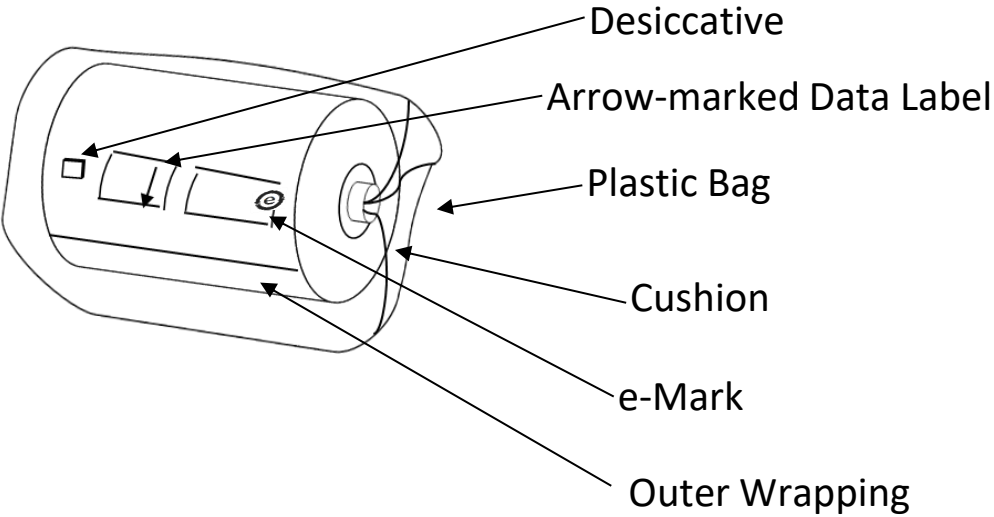
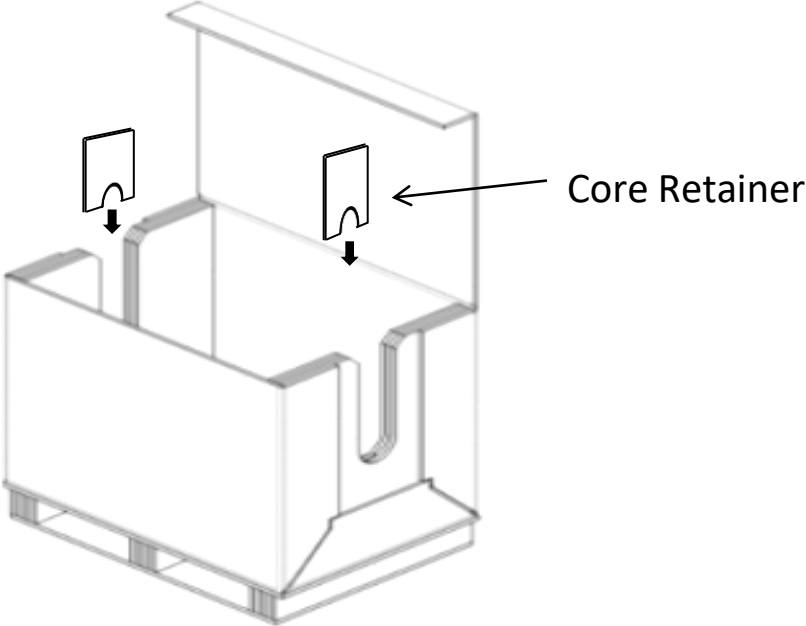
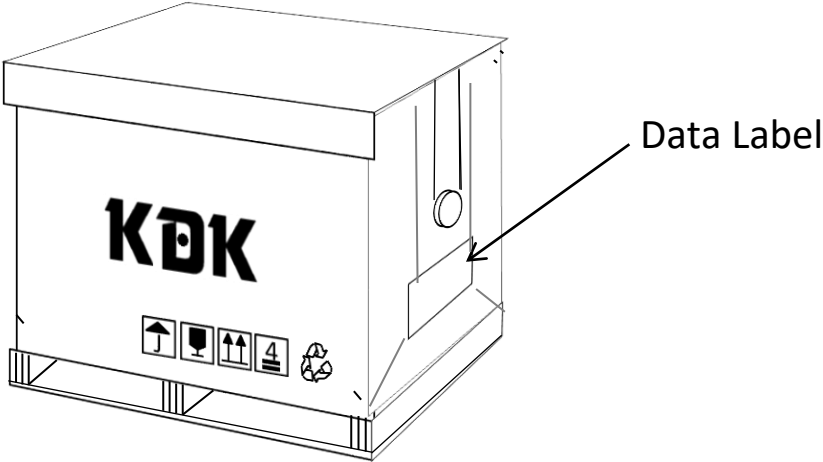
4.2 Packing Methods

4.2.1 Etched, Formed Foil (J2)

Size of Roll	Packing Method
Small Medium Large Size Roll	Box Carton(J2) : 470D × 610W × 540HUnit: mm Box Carton Lib Arrow mark Data Label Desiccative Cushion Plastic Bag e-Mark Outer Wrapping Paper Core Retainer Box Carton Box Carton Pedestal Band Data Label

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4. 2. 2 Etched, Formed Foil (R1)

Size of Roll	Packing Method
Small Medium Large Size Roll	Box Carton (R1) : 433D × 615W × 539HUnit: mm   

☆The above specifications are subject to change without notice.

4.3 Inspection Certificate (Data Sheet and Label)

An Inspection Certificate (Data Sheet and Label) which shows the following information is accompanied to each product delivered.

1	Foil Part No.		
2	Gauge	μm	
3	Purity of Raw Aluminum Foil	%	
4	Roll Width	mm	
5	Effective Width	mm	
6	Foil No.		
7	Date of Production		
8	Date of Inspection		
9	Foil Length	m	
10	Foil Area	m ²	
11	Joints	Times	
12	Weight	kg	
13	Tensile Strength	N/cm	
14	Bending Strength	Bends	
15	Residual Chloride Content	mg/m ²	(Etched and Formed Foil)
16	Capacitance at Each Measurement Point and Average Capacitance	$\mu\text{F}/\text{cm}^2$	(Etched and Formed Foil)
17	Capacitance Dispersion Rate	%	(Etched and Formed Foil)
18	Nominal Formation Voltage	Vfs	(Formed foil)
19	Vt values at Each Measurement Point and Average Vt Values		(Formed Foil)

※1 “2 Gauge” , “3 Purity of Raw Aluminum Foil” , and “4 Roll Width” are listed the standard value.

※2 “13 Tensile Strength” : All middle and high voltage formed foil don't have the standard value.

※3 “14 Bending Strength” : All F-tech foil don't have the standard value.

※4 “15 Residual Chloride Content” : All formed foil are listed the standard value.

5. Quality Assurance

5.1 Quality Assurance System Flow Chart

In the next Page.

5.2 Quality Assurance

5.2.1 Quality Assurance of Foil

During KDK' s etching and formation processes, major processing conditions like electric current, voltage and temperature are automatically controlled and simultaneously recorded by KDK' s continuous recording system. The quality assurance of KDK foil is achieved by maintaining the production conditions in accordance with the specified processing conditions.

5.2.2 Performance Tests for Large Size Roll

KDK' s basic production policy is to produce large size rolls of aluminum foil for all etched and formed foils. Foil test samples for Etched Foil are taken from the outer side and the core side of every large roll of raw aluminum foil and used for all performance tests. Foil test samples for Formed Foil are taken from the outer side and core side of ever large roll and used for all performance test. The test results from the large rolls are the ones presented to our customers.

5.2.3 Performance Tests for Small and Medium Size Rolls

Large size rolls are divided into small or medium size rolls after the performance tests. The test results of large rolls are printed on the Inspection Certificate that is attached to small and medium size rolls.

5.3 Factory Keep Samples

Besides our quality assurance system, KDK has a Factory Keep Sample system. The factory keeps samples of all foils ordered and delivered for twelve months. This makes it possible to trace quality problems, if any, by using these Keep Samples for reference and examination.

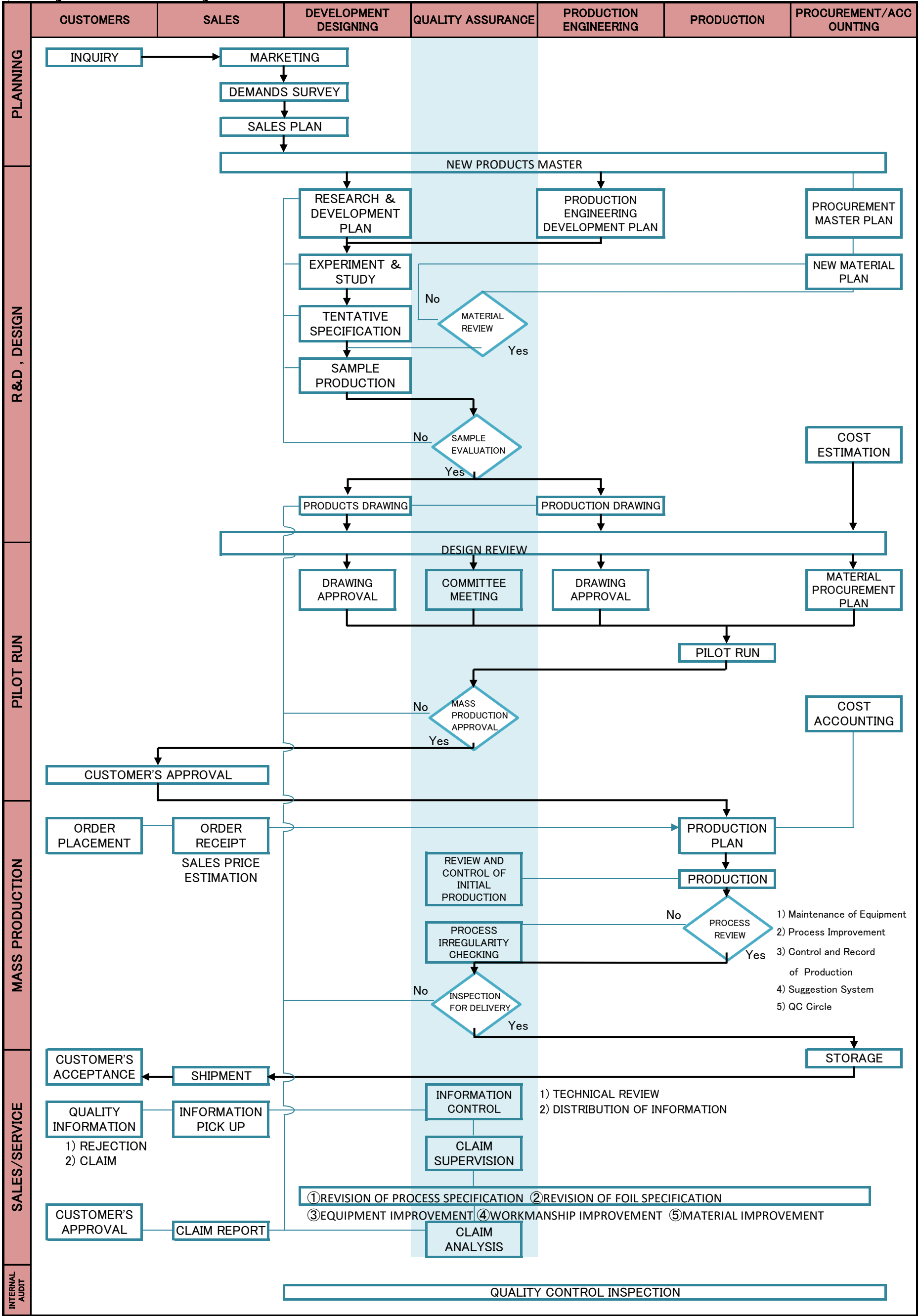
5.4 Rejections and Claims

If you have a problem with our foil, please send us the following information and materials that are essential to handling the case properly and promptly.

1. Customer' s Foil Receiving Date
2. Customer' s Acceptance Test Date
3. Foil Part Number, such as U915
4. Foil Number, such as "xxxxxx – xxxx" which appears on our Inspection Certificate (Data Sheet)
5. Rejected Quantity
6. Customer' s Purchase Order Number
7. Foil Sample for Analysis (submit minimum size of product wide by 300 mm long, one piece)
8. Reason(s) for Rejection and/or Claim, and briefly describe how the defect was found.

KDK will analyze the rejection and/or claim based on the information above, check our production records and Keep Sample, if necessary, and advise the customer of our findings.

Quality Assurance System Flow Chart



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6. Request for Quality Control

6.1 Acceptance Test

Upon receiving our foil, users generally perform their own acceptance test. Depending on foil type, please make sure the acceptance test is conducted at the following designated time:

- | | |
|----------------------------|-------------------|
| 1) Formed Foil for Anode | : Before Slitting |
| 2) Etched Foil for Anode | : Before Forming |
| 3) Etched Foil for Cathode | : Before Slitting |
| 4) Formed Foil for Cathode | : Before Slitting |

If you have any problems with our foil, please contact us after referring to the instructions specified under 6-4 Rejections and Claims on our web site.

6.2 Handling Aluminum Foil – <Do not handle foils with bare hands>

Never handle aluminum foil with your bare hands because the chloride in fingerprints and perspiration has a strong corrosive effect on aluminum. To prevent chloride contamination of aluminum foil during the manufacturing process of aluminum electrolytic capacitors, remember to wear clean, sterile gloves when handling the foil.

6.3 Storage at User's Site

When foils are stored at user's site, please remember the following points:

- 1) Keep Storage area free of chloride contamination.
- 2) Maintain normal temperature (5 to 30° C) and low humidity (less than 85%) in the storage area.
- 3) Never put water on any type of foil. Water on foil can create a gas over a period of time, and because foil is stored in closed containers, the build-up generated gas may cause an explosion.
- 4) Store foil in sealed containers until just before usage.
- 5) Do not subject foil to mechanical stress because it can cause problems during the manufacturing process.

6.4 Shelf Life

Your foil is guaranteed for the first six months after KDK shipment. After six months, the foil should be tested before processing.

7. Test Method

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7-1 Selecting Test Specimens for Electrical Characteristics Measurements 1 of 1

1. Scope of Test

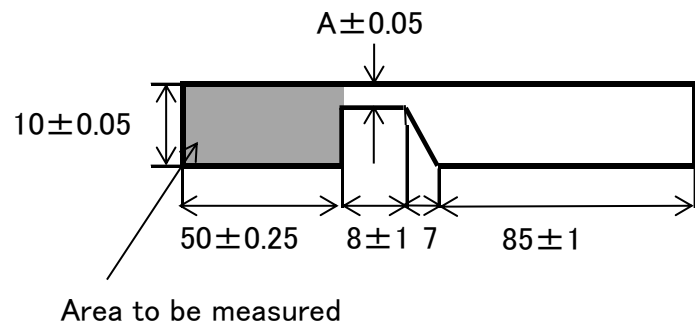
Etched Foil and Formed Foil

2. Size of Test Specimen

Projected Area (area to be measured) : 5 cm^2 Unit: mm

A = 5 : Etched Foil for Anode, Middle to High Voltage

A = 3 : All Other Foils



Note: No Burrs

Figure 1

3. Test Specimen Locations

Definition of selecting position for test specimens

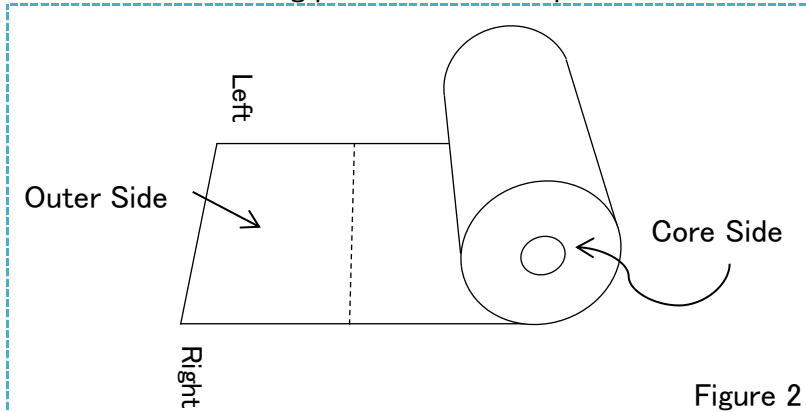


Figure 2

3-1. Etched and Formed Foil for Anode

Test specimens should be taken from the locations ①~⑥.

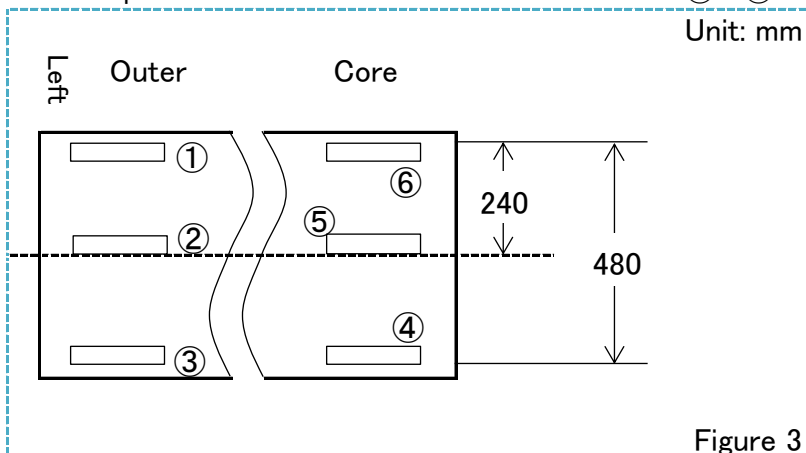
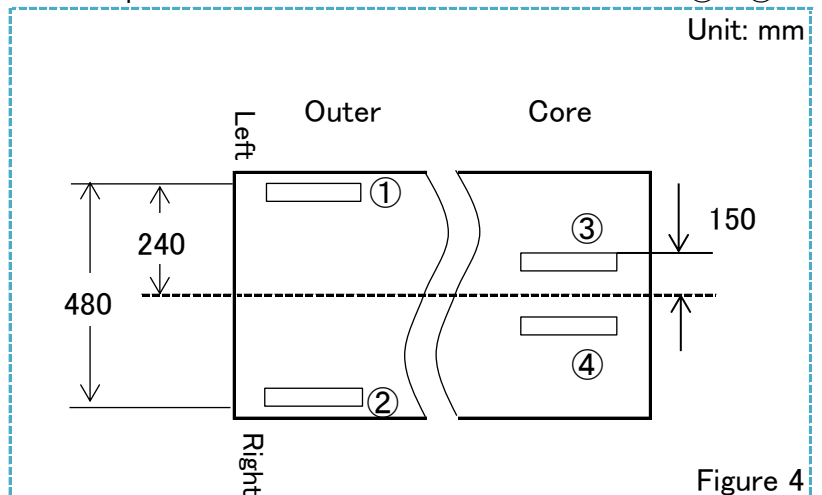


Figure 3

3-2. Etched Foil for Cathode

Test specimens should be taken from the locations ①~④.

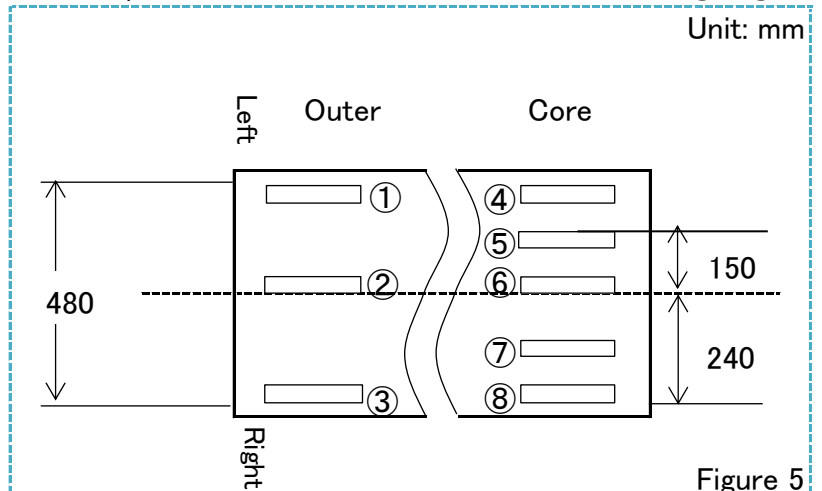


Note:

When measuring capacitance, the specimens from the locations ① and ② as well as ③ and ④ will be used for the test.

3-3. Formed Foil for Cathode

Test specimens should be taken from the locations ①~⑧.



Note:

When measuring capacitance, the specimens from the locations ① and ③ as well as ⑤ and ⑦ will be used for the test.

When measuring V_t , the specimens from the locations ①, ②, ③, ④, ⑥, ⑧ will be used for the test.

7-2 Selecting Test Specimens for Mechanical Strength Measurements 1 of 1

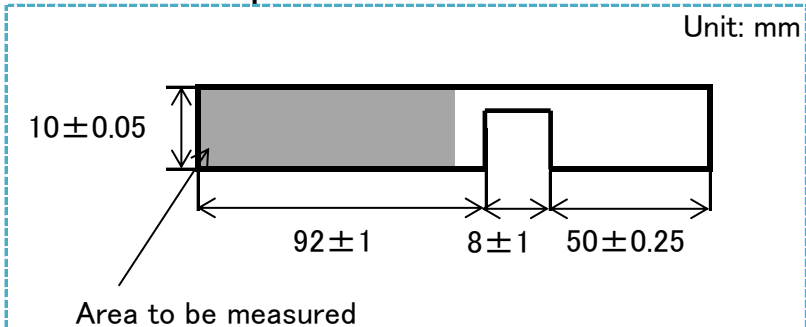
1. Scope of Test

Etched Foil and Formed Foil

2. Mechanical Strength

- 1) Tensile Strength
- 2) Bending Strength

3. Size of Test Specimen



Note: No Burrs

Figure 6

4. Test Specimen Locations

Definition of selecting position for test specimens

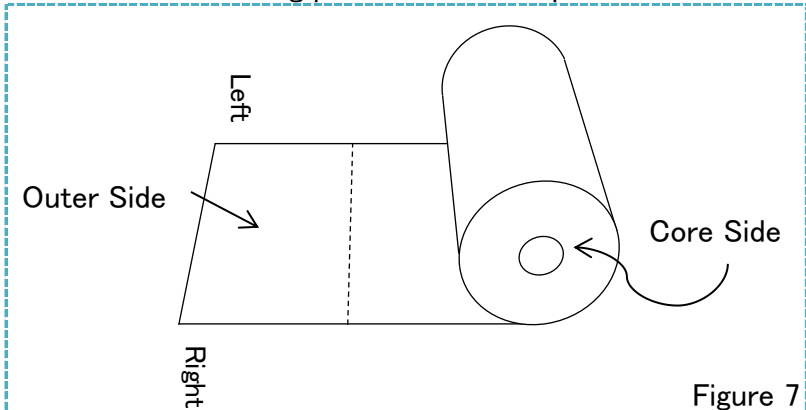


Figure 7

4-1. Etched and Formed Foil for Low Voltage

Test specimens should be taken from the locations ①~②

- ① for Tensile Strength Test
- ② for Bending Strength Test

Unit: mm

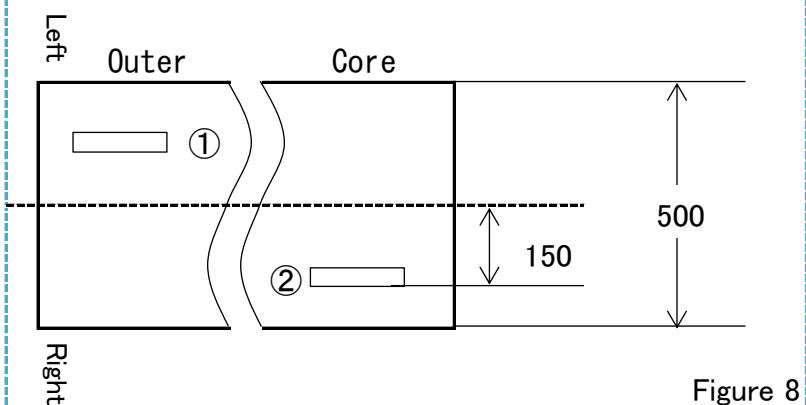


Figure 8

4-2. Etched Foil for Middle to High Voltage

Test specimens should be taken from the locations ①~⑤

- ① for Tensile Strength Test
- ②, ③, ④ and ⑤ for Bending Strength Test

Unit: mm

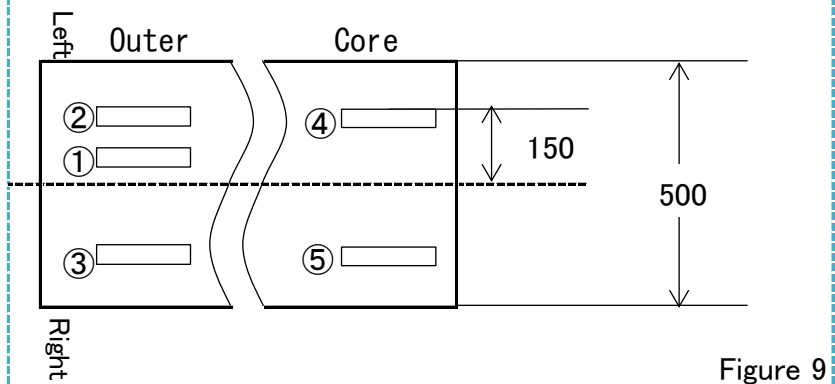


Figure 9

4-3. Formed Foil for Middle to High Voltage

Test specimens should be taken from the locations ①~④

- ①~④ for Bending Strength Test

Unit: mm

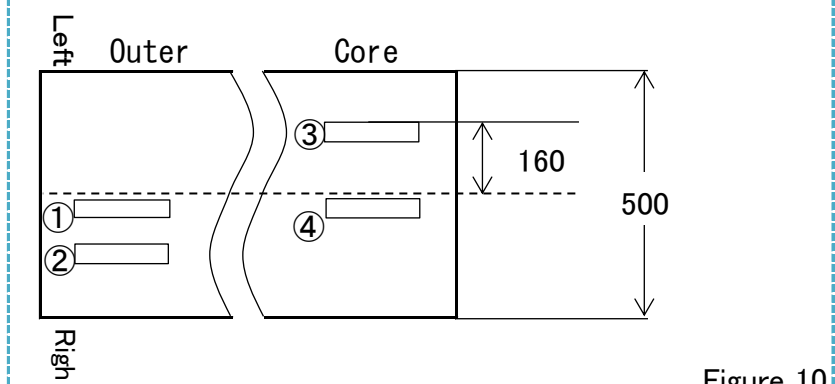


Figure 10

4-4. Etched Foil for Cathode

Test specimens should be taken from the locations ①~④

- ① and ④ for Tensile Strength Test
- ② and ③ for Bending Strength Test

Unit: mm

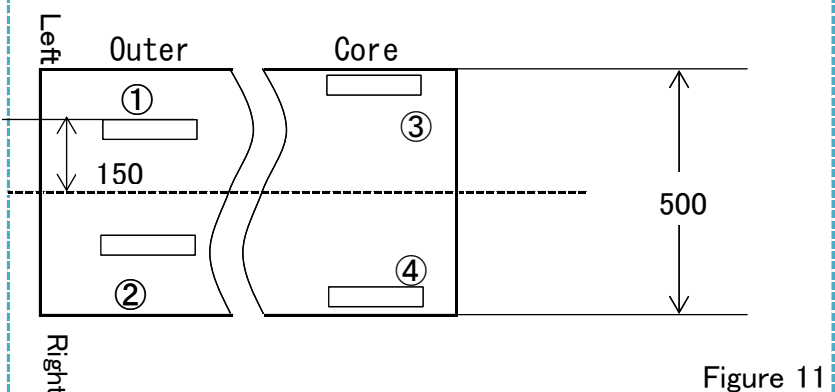


Figure 11

4-5. Formed Foil for Cathode Foil

Test specimens should be taken from the locations ①~②

- ① for Tensile Strength Test
- ② for Bending Strength Test

Unit: mm

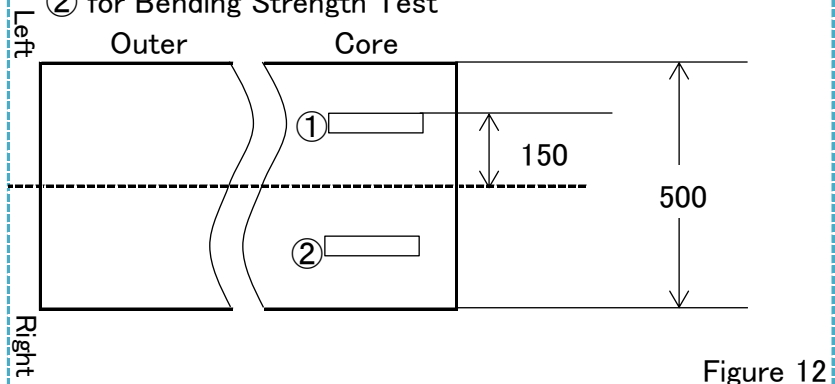


Figure 12

7-3 Test Method – Formed Foil for Anode, Extreme Low Voltage 1 of 2

1. Scope of Test

$$3.0 \leq V_{fs} \leq 6.6$$

2. Definitions of Technical Codes

- 1) V_{fs} : Nominal Formation Voltage
- 2) V_t : Dielectric Withstanding Voltage
- 3) V_r : 90% of V_{fs}
- 4) T_r : Rise Time
- 5) T_{r60} : Rise Time after Hydration Process (60 min.)

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Film Dielectric Withstanding Test (V_t , T_r)
 - ② Capacitance Measurement (Cap)
 - ③ Hydration Resistance Test (T_{r60})

4. Test Equipment

(Film Dielectric Withstanding, Hydration Resistance)

- 1) DC Constant-Current Power Supply

Ripple Content	: 2% or less for 50,60Hz 1% or less for 100,120Hz
DC Voltage Stability	: $\pm 3\%$
- 2) DC Voltmeter

Internal Resistance	: $1M\Omega$ or higher
Accuracy	: $\pm 0.5\%$
- 3) DC Ammeter

Internal Resistance shall be sufficiently small compared to Load Resistance	
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- 4) Measurement Vessel

Material	: SUS304 or equivalent with corrosion resistance
Volume	: 500mL or more
Depth	: 100mm or more
- 5) Counter Electrode

Measurement Vessel	: SUS304 or equivalent with corrosion resistance
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- 6) Referential Electrode

Material	: Platinum Plate
Purity	: 99.99% or more
Dimensions	: 10mm × 20mm × 0.1mm
- 7) Volt Recorder

Internal Resistance	: $1M\Omega$ or higher
Accuracy	: $\pm 0.5\%$
- 8) Vessel for Hydration Process

Material	: SUS304 or equivalent with corrosion resistance
Volume	: 600mL or more
Temperature Control	: Capable of maintaining deionized water at 95°C or higher

5. Test Equipment for Capacitance Measurement

- 1) Capacitance Measurement Device

Capacitance Meter in accordance with JIS C 5101-1,4,7	
Measurement Frequency	: $120\text{Hz} \pm 5\%$
Measurement Voltage	: $0.5V_{rms}$ or less
- 2) Measurement Vessel

Material	: Glass or Acrylic
Volume	: 200mL or more
- 3) Counter Electrode : Test Specimens

6. Test Specimen

Test Specimen : In accordance with 8-1 *Selecting Test Specimens for Electrical Characteristics Measurements.*

7. Film Dielectric Withstanding Test (V_t , T_r)

- 1) Test Solution

Ammonium Adipate	: $150\text{g} \pm 15\text{g}$
Deionized Water	: $1,000\text{mL} \pm 50\text{mL}$
Specific Resistance	: $6.5(+2.0 -1.5) \Omega \text{cm} / 70 \pm 2^\circ\text{C}$
pH	: $6.7(+0.5 -1.5) / 50 \pm 2^\circ\text{C}$
- 2) Test Conditions

Measurement Temperature	: $85 \pm 2^\circ\text{C}$
Current Density	: $0.5 \pm 0.05\text{mA} / 1 \text{ Test Specimen } 5\text{cm}^2$

3) Measurement Circuit

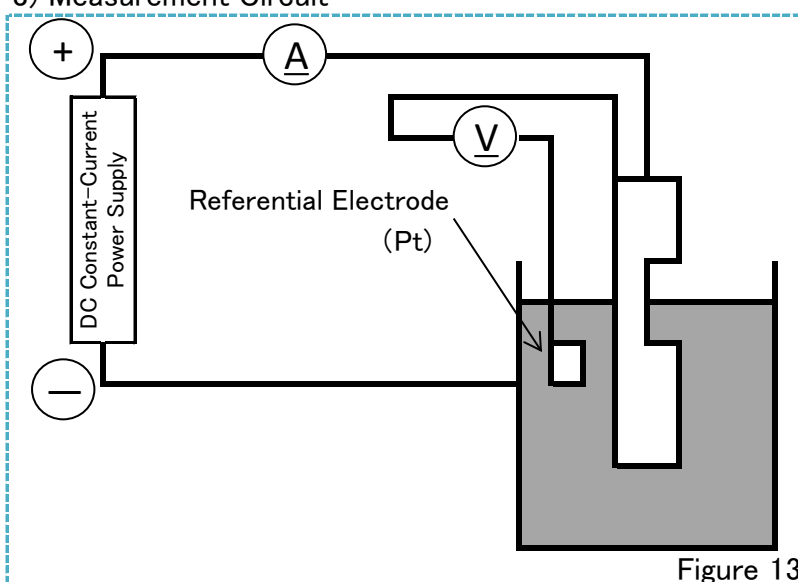


Figure 13

4) Measurement Method

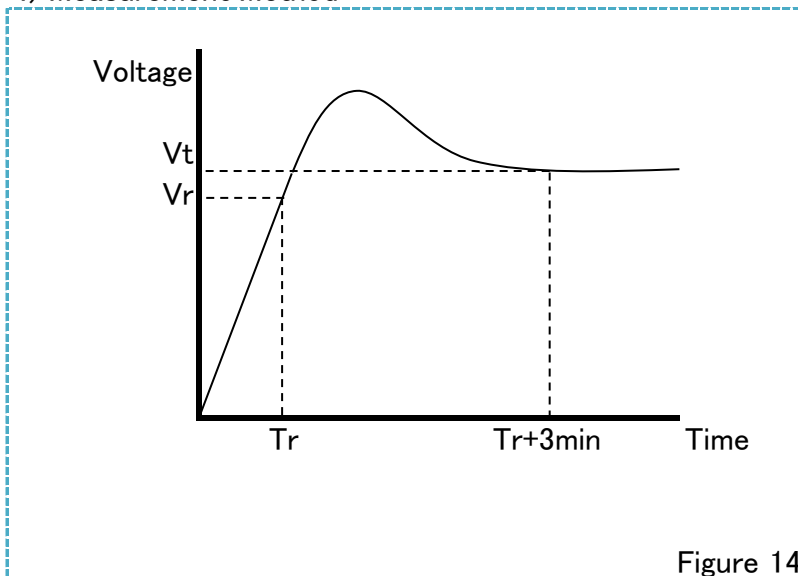


Figure 14

- ① The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6-8mm below the surface.
- ② The increase in voltage shall be measured after applying constant DC current.
- ③ Rise Time (T_r) is measured when the voltage reaches 90% of Nominal Formation Voltage (V_{fs}).
- ④ Dielectric Withstanding Voltage (V_t) shall be the voltage measured 3 minutes after T_r .

7-3 Test Method – Formed Foil for Anode, Extreme Low Voltage 2 of 2

8. Capacitance Measurement (Cap)

1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5) Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

2) Test Conditions

Measurement Temperature : 30±2°C

3) Measurement Circuit

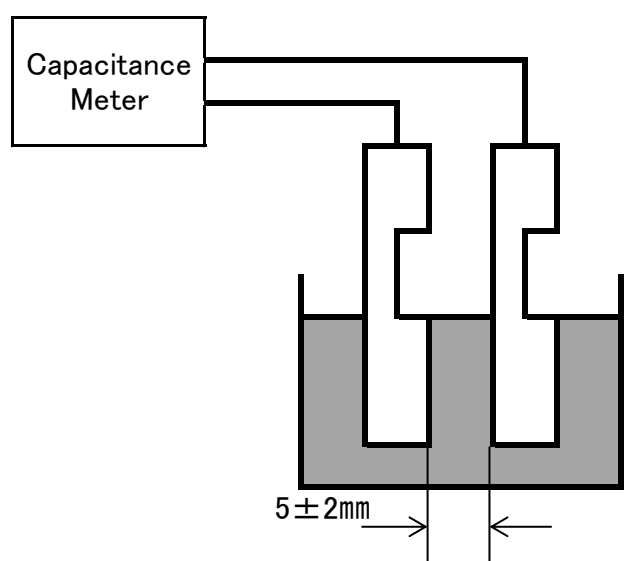


Figure 15

The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{C_m \times 2}{5}$$

Where : C_m = Measured Value (μF)

: C = Capacitance (μF/cm²) per 1cm²

9. Hydration Resistance Test (Tr60)

1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5) Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

2) Test Conditions

Measurement Temperature : 85±2°C

Current Density : 0.5±0.05mA/1 Test Specimen 5cm²

3) Hydration Process

Test Specimen : Use the same specimen already measured by the Vt test process for dielectric withstanding voltage.

Hydration Process Time : 60±1min

Hydration Temperature : 95°C or higher

Number of Specimen : Approx. 6 pieces / 500 mL as a guideline.

Deionized Water Change : Change deionized water for every hydration process.

4) Measurement Circuit

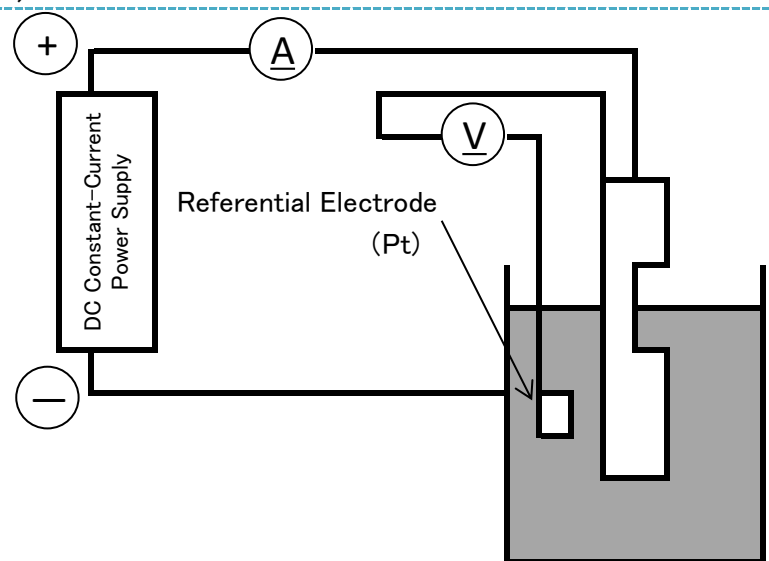


Figure 16

5) Measurement Method

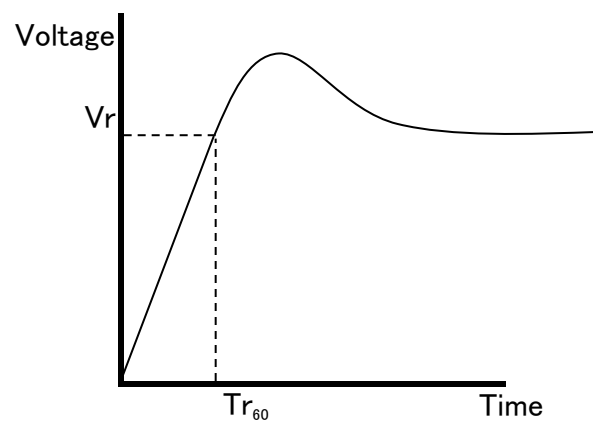


Figure 17

- ①The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is below the place that measured by the Vt test process.
- ②The increase in voltage shall be measured after applying constant DC current.
- ③Rise Time (Tr60) is measured when the voltage reaches 90% of Nominal Formation Voltage (Vfs).

7-4 Test Method – Formed Foil for Anode, Low Voltage 1 of 2

1. Scope of Test

$$8.0 \leq V_{fs} \leq 170$$

2. Definitions of Technical Codes

- 1) V_{fs} : Nominal Formation Voltage
- 2) V_t : Dielectric Withstanding Voltage
- 3) V_r : 90% of V_{fs}
- 4) T_r : Rise Time
- 5) T_{r60} : Rise Time after Hydration Process (60 min.)

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Film Dielectric Withstanding Test (V_t , T_r)
 - ② Capacitance Measurement (Cap)
 - ③ Hydration Resistance Test (T_{r60})

4. Test Equipment

(Film Dielectric Withstanding, Hydration Resistance)

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
 - Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Measurement Vessel
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 500mL or more
 - Depth : 100mm or more
- 5) Counter Electrode
 - Measurement Vessel : SUS304 or equivalent with corrosion resistance
- 6) Volt Recorder
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 7) Vessel for Hydration Process
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 600mL or more
 - Temperature Control : Capable of maintaining deionized water at 95°C or higher

5. Test Equipment for Capacitance Measurement

- 1) Capacitance Measurement Device
 - Capacitance Meter in accordance with JIS C 5101-1,4.7
 - Measurement Frequency : $120\text{Hz} \pm 5\%$
 - Measurement Voltage : $0.5V_{rms}$ or less
 - DC Bias Voltage : 1.5V
- 2) Measurement Vessel
 - Material : Glass or acrylic
 - Volume : 200mL or more
- 3) Counter Electrode
 - Material : Platinum Plate of $40,000\mu\text{F}$ or higher

6. Test Specimen

Test Specimen : In accordance with 8-1 *Selecting Test Specimens for Electrical Characteristics Measurements*.

7. Film Dielectric Withstanding Test (V_t , T_r)

- 1) Test Solution
 - Ammonium Adipate : $150\text{g} \pm 15\text{g}$
 - Deionized Water : $1,000\text{mL} \pm 50\text{mL}$
 - Specific Resistance : $6.5(+2.0 - 1.5)\Omega\text{cm}/70 \pm 2^\circ\text{C}$
 - pH : $6.7(+0.5 - 1.5)/50 \pm 2^\circ\text{C}$
- 2) Test Conditions
 - Measurement Temperature : $85 \pm 2^\circ\text{C}$
 - Current Density : $1.0 \pm 0.1\text{mA}/1\text{ Test Specimen } 5\text{cm}^2$

3) Measurement Circuit

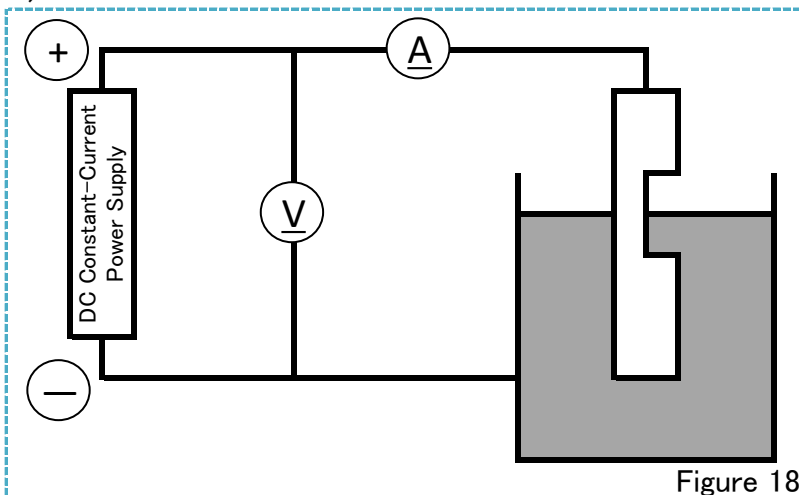


Figure 18

4) Measurement Method

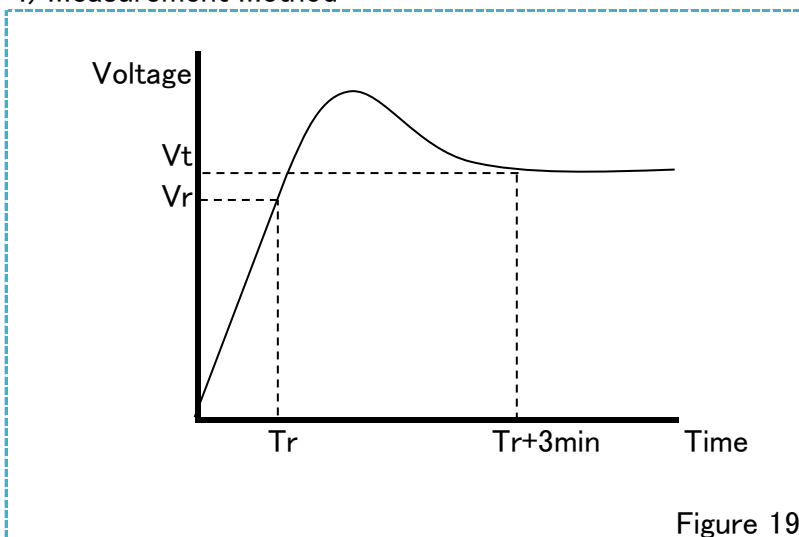


Figure 19

- ① The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6-8mm below the surface.
- ② The increase in voltage shall be measured after applying constant DC current.
- ③ Rise Time (T_r) is measured when the voltage reaches 90% of Nominal Formation Voltage (V_{fs}).
- ④ Dielectric Withstanding Voltage (V_t) shall be the voltage measured 3 minutes after T_r .

7-4 Test Method – Formed Foil for Anode, Low Voltage 2 of 2

8. Capacitance Measurement (Cap)

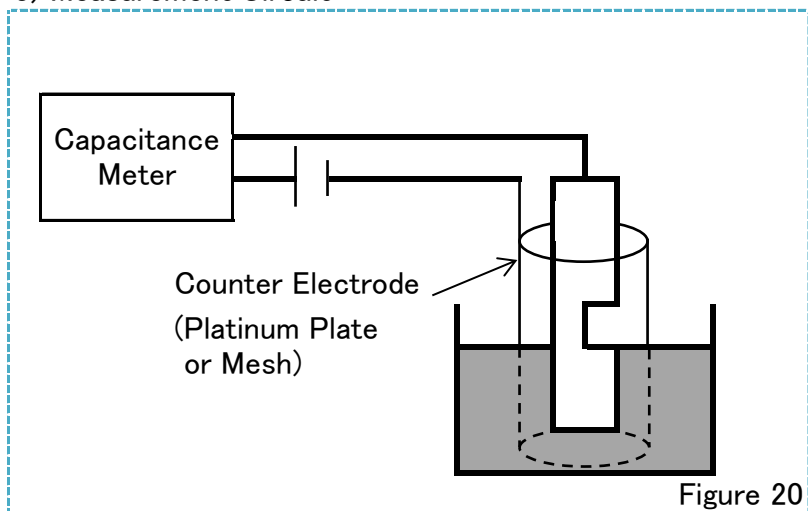
1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5) Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

2) Test Conditions

Measurement Temperature : 30±2°C

3) Measurement Circuit



The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{C_m}{5}$$

Where : C_m = Measured Value (μF)
: C = Capacitance ($\mu F/cm^2$) per 1cm²

9. Hydration Resistance Test (Tr60)

1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5) Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

2) Test Conditions

Measurement Temperature : 85±2°C
Current Density : 1.0±0.1mA/1 Test Specimen 5cm²

3) Hydration Process

Test Specimen : Use the same specimen already measured by the Vt test process for dielectric withstanding voltage.

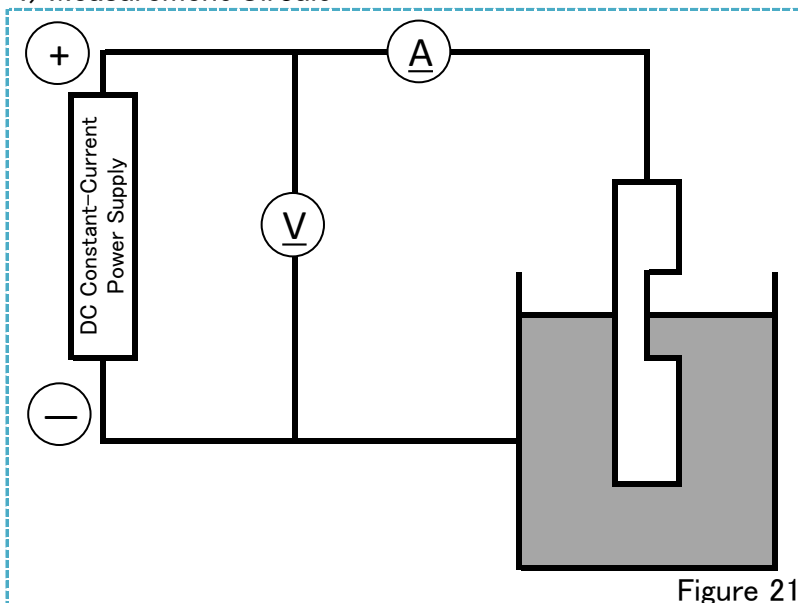
Hydration Process Time : 60±1min

Hydration Temperature : 95°C or higher

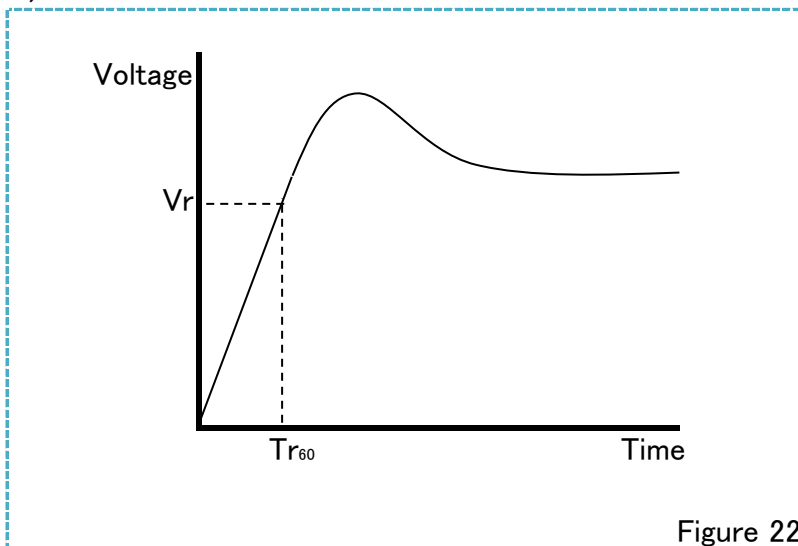
Number of Specimen : Approx. 6 pieces / 500 mL as a guideline.

Deionized Water Change : Change deionized water for every hydration process.

4) Measurement Circuit



5) Measurement Method



- ①The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is below the place that measured by the Vt test process.
- ②The increase in voltage shall be measured after applying constant DC current.
- ③Rise Time (Tr_{60}) is measured when the voltage reaches 90% of Nominal Formation Voltage (Vfs).

7-5 Capacitance Test Method – Etched Foil for Anode, Low Voltage 1 of 3

1. Scope of Test

Etched Foil for Anode, Low Voltage

2. Definitions of Technical Codes

- 1) Vfs : Nominal Formation Voltage
- 2) Vfe : Voltage across Terminals
- 3) Vt : Dielectric Withstanding Voltage

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Specified Formation
 - ② Film Dielectric Withstanding Test (Vt)
 - ③ Capacitance Measurement (Cap)

4. Test Equipment for Formation

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
 - Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Formation Vessel
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : Approx. 1L or more
 - Temperature Control : Capable of maintaining the solution temperature at $85\pm 2^\circ\text{C}$ or at $88\pm 2^\circ\text{C}$.
- 5) Counter Electrode
 - Formation Vessel : SUS304 or equivalent with corrosion resistance
- 6) Heat Treatment Device
 - Temperature Control: Capable of maintaining $500\pm 25^\circ\text{C}$

5. Test Equipment for Film Dielectric Withstanding

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
 - Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Measurement Vessel
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 500mL or more
 - Depth : 100mm or more
- 5) Counter Electrode
 - Measurement Vessel : SUS304 or equivalent with corrosion resistance
- 6) Volt Recorder
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$

6. Test Equipment for Capacitance Measurement

- 1) Capacitance Measurement Device
 - Capacitance Meter in accordance with JIS C 5101-1,4.7
 - Measurement Frequency : $120\text{Hz}\pm 5\%$
 - Measurement Voltage : $0.5V_{\text{rms}}$ or less
- 2) Measurement Vessel
 - Material : Glass or Acrylic
 - Volume : 200mL or more
- 3) Counter Electrode
 - Material : Platinum plate/mesh for capacitance of $40,000\ \mu\text{F}$ or higher

7. Test Specimen

Test Specimen : In accordance with 8-1 *Selecting Test Specimens for Electrical Characteristics Measurements.*

8. Formation

- 1) Solution A: Ammonium Adipate
 - Ammonium Adipate : $150\text{g}\pm 15\text{g}$
 - Deionized Water : $1,000\text{mL}\pm 50\text{mL}$
 - Specific Resistance : $6.5(+2.0 -1.5)\Omega\text{m}/70\pm 2^\circ\text{C}$
 - pH : $6.7(+0.5 -1.5)/50\pm 2^\circ\text{C}$
- 2) Solution P: Ammonium Dihydrogen Phosphate
 - Ammonium Dihydrogen Phosphate : $1.4\text{g}\pm 0.1\text{g}$
 - Deionized Water : $1,000\text{mL}\pm 50\text{mL}$
 - Specific Resistance : $390\pm 15\Omega\text{cm}/70\pm 2^\circ\text{C}$
 - pH : $4.8\pm 0.5/50\pm 2^\circ\text{C}$

3) Formation Circuit

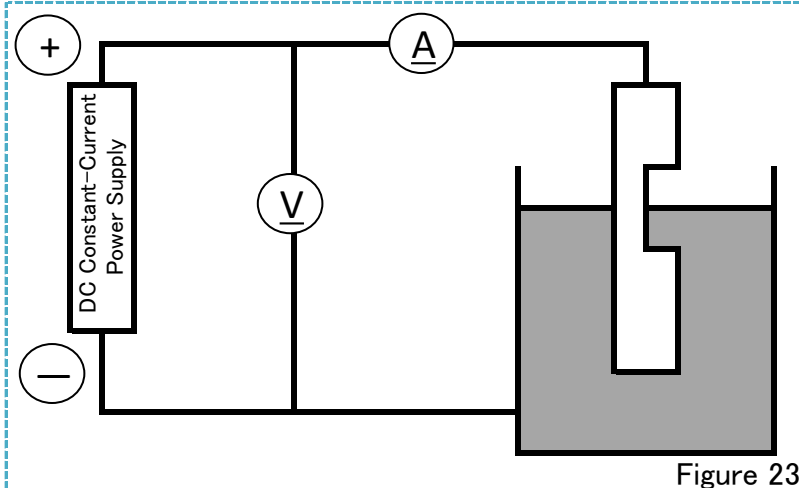


Figure 23

The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 8-40mm below the surface.

7-5 Capacitance Test Method – Etched Foil for Anode, Low Voltage 2 of 3

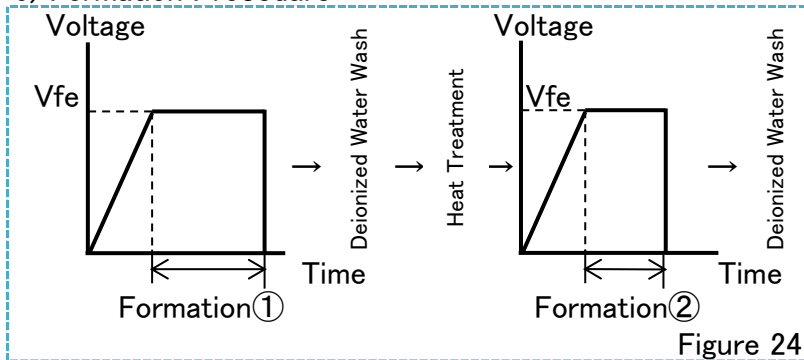
4) Formation Conditions for 20.5Vfs and 65.5Vfs

Process	Items	Unit	Conditions
Formation ①	Vfe	V	Varies by Foil
	Current Density	mA/cm ² (immersion area)	50
	Temperature	°C	85±2
	Time	min	10±1
	Formation Electrolyte	—	Solution A
Deionized Water Wash	—	°C	Room Temperature
Heat Treatment	Temperature	°C	500±25
	Time	min.	2±0.2
Formation ②	Vfe	V	Varies by Foil
	Current Density	mA/cm ² (immersion area)	50~60
	Temperature	°C	85±2
	Time	min	2±0.2
	Formation Electrolyte	—	Solution A
Deionized Water Wash	—	°C	Room Temperature
Formation Procedure			Figure 24

5) Formation Conditions for 132Vfs

Process	Items	Unit	Conditions
Formation ①	Vfe	V	Varies by Foil
	Current Density	mA/cm ² (Immersion Area)	50
	Temperature	°C	85±2
	Time	min	10±2
	Formation Electrolyte	—	Solution A
Deionized Water Wash	—	°C	Room Temperature
Heat Treatment	Temperature	°C	500±25
	Time	min.	2±0.2
Formation ②	Vfe	V	Varies by Foil
	Current Density	mA/cm ² (Immersion Area)	50~60
	Temperature	°C	88±2
	Time	min	2±0.2
	Formation Electrolyte	—	Solution P
Deionized Water Wash	—	°C	Room Temperature
Formation Procedure			Figure 24

6) Formation Procedure



9. Film Dielectric Withstanding Test (Vt)

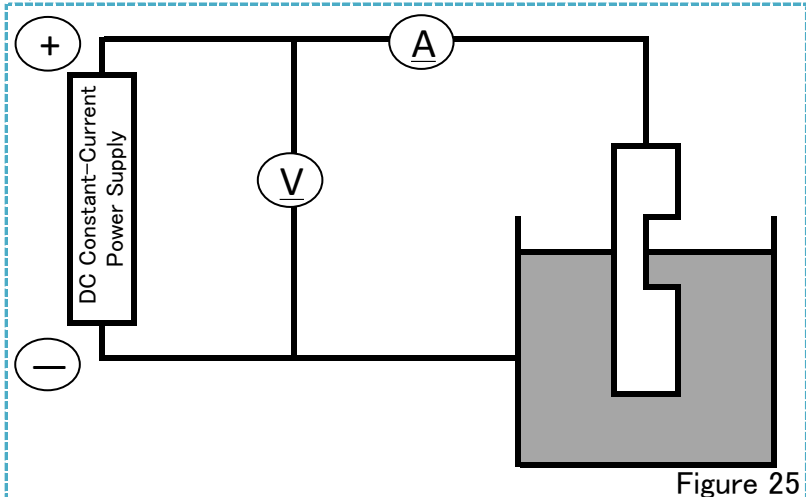
1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5)Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

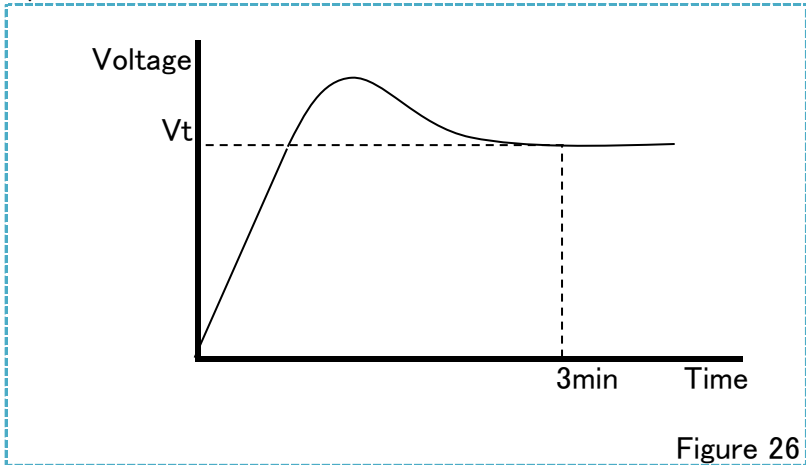
2) Test Conditions

Measurement Temperature	: 85±2°C
Current Density	: 2.0±0.1mA/ 1Test Specimen 5cm ²

3) Measurement Circuit



4) Measurement Method



- ①The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6-8mm below the surface.
- ②The increase in voltage shall be measured after applying constant DC current.
- ③Dielectric Withstanding Voltage (Vt) shall be defined as the voltage measured 3 minutes after applying DC current.

10. Capacitance Measurement (Cap)

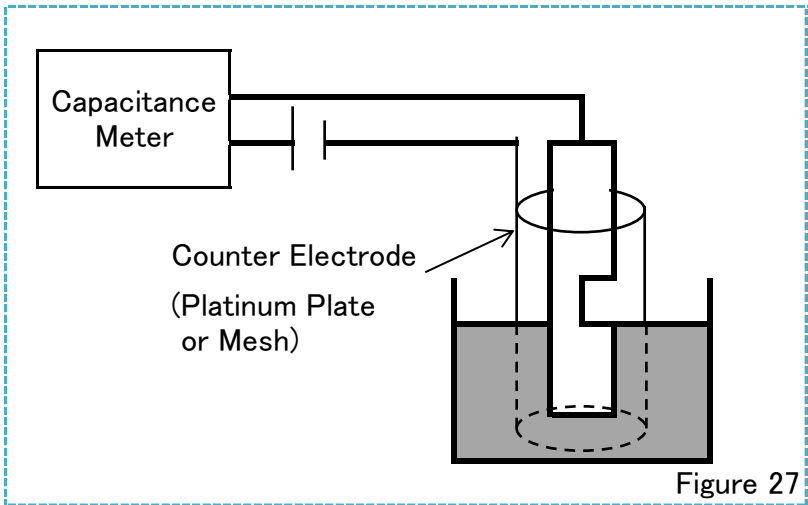
1) Test Solution

Ammonium Adipate	: 150g±15g
Deionized Water	: 1,000mL±50mL
Specific Resistance	: 6.5(+2.0 -1.5)Ω cm/70±2°C
pH	: 6.7(+0.5 -1.5) /50±2°C

2) Test Conditions

Measurement Temperature	: 30±2°C
-------------------------	----------

3) Measurement Circuit



The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{V_{tm} \times C_m}{\text{Specified } V_t \times 5}$$

- Where : Specified V_t = Varies by Foil
: V_{tm} = Measured Value (V)
: C_m = Measured Value (μF)
: C = Capacitance ($\mu F/cm^2$) per 1cm²

7-6 Test Method – Formed Foil for Anode, Middle to High Voltage 1 of 2

1. Scope of Test

$208 \leq V_{fs} \leq 628$

2. Definitions of Technical Codes

- 1) V_{fs} : Nominal Formation Voltage
- 2) V_t : Dielectric Withstanding Voltage
- 3) V_r : 90% of V_{fs}
- 4) T_r : Rise Time
- 5) T_{r60} : Rise Time after Hydration Process (60 min.)

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Film Dielectric Withstanding Test (V_t , T_r)
 - ② Capacitance Measurement (Cap)
 - ③ Hydration Resistance Test (T_{r60})

4. Test Equipment for V_t Measurement

(Film Dielectric withstanding, Hydration Resistance)

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
 - Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Measurement Vessel
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 500mL or more
 - Depth : 100mm or more
- 5) Counter Electrode
 - Measurement Vessel : SUS304 or equivalent with corrosion resistance
- 6) Volt Recorder
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 7) Vessel for Hydration Process
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 600 ± 60 mL
 - Temperature Control : Capable of maintaining deionized water at 95°C or higher

5. Test Equipment for Capacitance Measurement

- 1) Capacitance Measurement Device
 - Capacitance Meter in accordance with JIS C 5101-1,4,7
 - Measurement Frequency : $120\text{Hz} \pm 5\%$
 - Measurement Voltage : $0.5V_{rms}$ or less
 - DC Bias Voltage : 1.5V
 - Accuracy : $\pm 2.0\%$
- 2) Measurement Vessel
 - Material : Glass or Acrylic
 - Volume : 200mL or more
- 3) Counter Electrode
 - Material : Platinum Plate/Mesh for Capacitance of $40,000 \mu\text{F}$ or higher

6. Test Specimen

Test Specimen : In accordance with *8-1 Selecting Test Specimens for Electrical Characteristics Measurements*.

7. Film Dielectric Withstanding Test (V_t , T_r)

1) Test Solution

V_{fs}	$\sim 628V_{fs}$
Boric Acid	$70g \pm 7g/L$
Deionized Water	$1,000 \pm 50\text{mL}$
Specific Resistance	$7.5 \pm 0.3k\Omega / 70 \pm 2^\circ\text{C}$
pH	$3.2(+1.0 -0.5) / 50 \pm 2^\circ\text{C}$

2) Test Conditions

Measurement Temperature : $85 \pm 2^\circ\text{C}$

Current Density : $2.0 \pm 0.2\text{mA} / 1 \text{ Test Specimen } 5\text{cm}^2$

3) Measurement Circuit

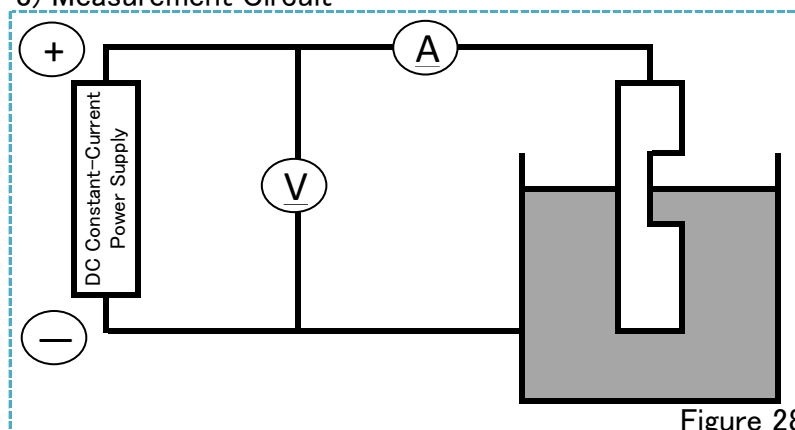


Figure 28

4) Measurement Method

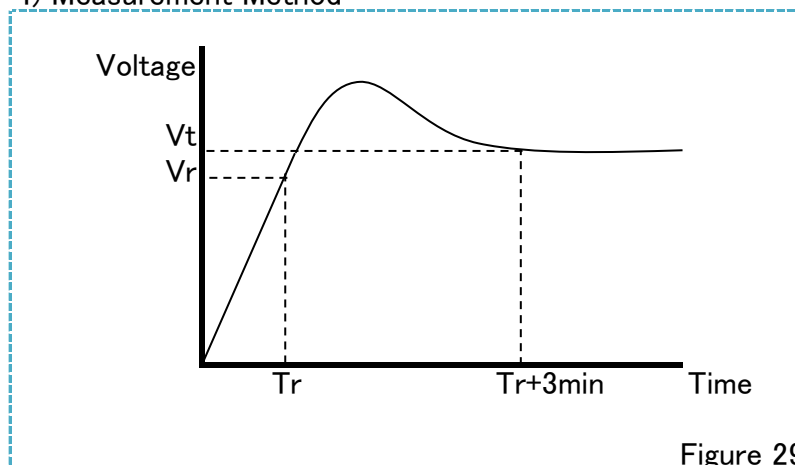


Figure 29

- ① The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6–8mm below the surface.
- ② The increase in voltage shall be measured after applying constant DC current.
- ③ Rise Time (T_r) is measured when the voltage reaches 90% of Nominal Formation Voltage (V_{fs}).
- ④ Dielectric Withstanding Voltage (V_t) shall be the voltage measured 3 minutes after T_r .

7-6 Test Method – Formed Foil for Anode, Middle to High Voltage 2 of 2

8. Capacitance Measurement (Cap)

1) Test Solution

Ammonium Pentaborate	: 80g ±8g
Deionized Water	: 1,000 ±50mL
Specific Resistance	: 30(±5) Ω cm/70±2°C
pH (Reference Value)	: 7.4(+0.5 -1.0)/50±2°C

2) Test Conditions

Measurement Temperature : 30±2°C

3) Measurement Circuit

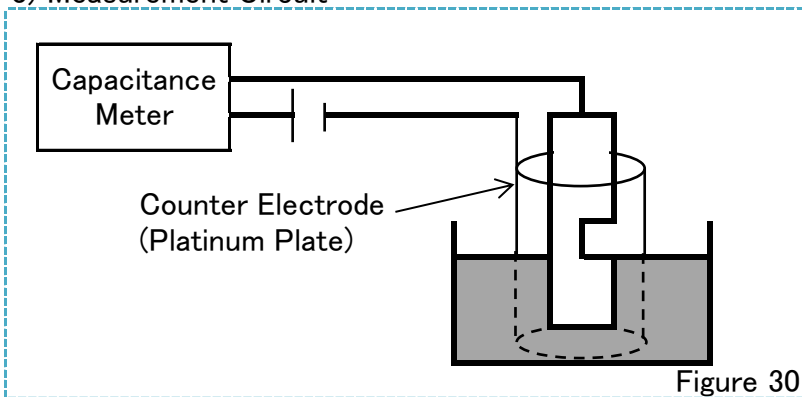


Figure 30

- ① The test specimen shall be thoroughly rinsed with water and dried after Vt (Vh) measurement.
- ② The specimen shall be immersed so that the upper end of the measured portion coincides with the surface of the test solution.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{C_m}{5}$$

Where : C_m = Measured Value (μF)
: C = Capacitance (μF/cm²) per 1cm²

9. Hydration Resistance Test (Tr60)

1) Test Solution

Vfs	~628Vfs
Boric Acid	70g ±7g/L
Deionized Water	1,000 ±50mL
Specific Resistance	7.5±0.3k Ω /70±2°C
pH	3.2(+1.0 -0.5)/50±2°C

2) Test Conditions

Measurement Temperature : 85±2°C
Current Density : 2.0±0.2mA/1 Test Specimen 5cm²

3) Hydration Process

Test Specimen : Use the same specimen already measured by the Vt test process for dielectric withstanding voltage.

Hydration Process Time : 60±1min

Hydration Temperature : 95°C or higher

Number of Specimen : Approx. 6 pieces / 500 mL as a guideline.

Deionized Water Change : Change deionized water for every hydration process.

4) Measurement Circuit

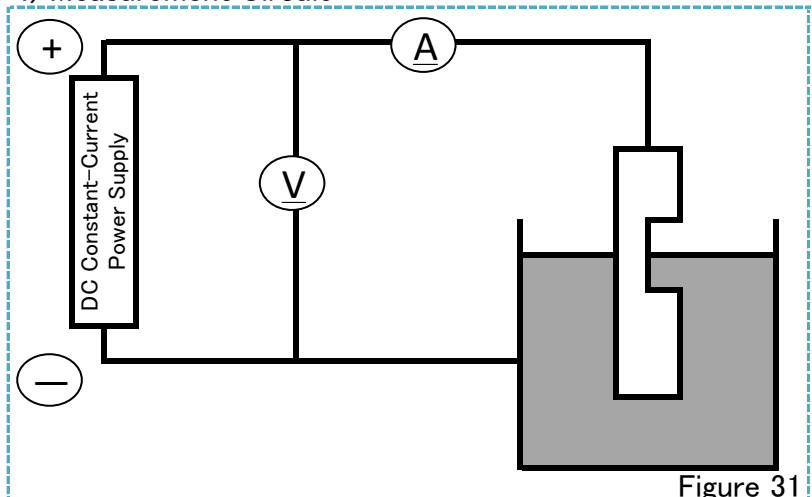


Figure 31

5) Measurement Method

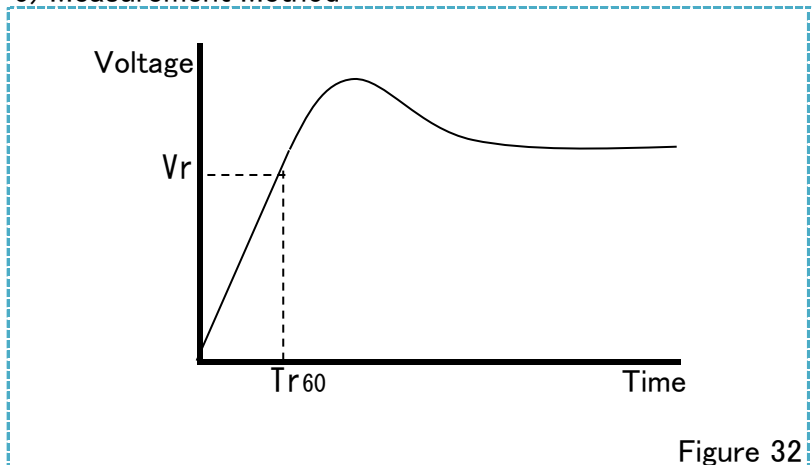


Figure 32

- ① The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is below the place that measured by the Vt test process.
- ② The increase in voltage shall be measured after applying constant DC current.
- ③ Rise Time (Tr60) is measured when the voltage reaches 90% of Nominal Formation Voltage (Vfs).

7-7 Capacitance Test Method – Etched Foil for Anode, Middle to High Voltage 1 of 4

1. Scope of Test

Etched Foil for Anode, Middle to High Voltage

2. Definitions of Technical Codes

- 1) Vfs : Nominal Formation Voltage
- 2) Vfe : Voltage across Terminals
- 3) Vt : Dielectric Withstanding Voltage

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Specified Formation
 - ② Film Dielectric Withstanding Test (Vt)
 - ③ Capacitance Measurement (Cap)

4. Test Equipment for Formation

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
 - Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Formation Vessel
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : Approx. 1L or more
 - Temperature Control : Capable of maintaining the solution temperature at 95°C or higher.
- 5) Counter Electrode
 - Formation Vessel : SUS304 or equivalent with corrosion resistance
- 6) Heat Treatment Device
 - Temperature Control: Capable of maintaining $500 \pm 25^\circ\text{C}$
- 7) Vessel for Depolarization
 - Material : SUS304 or equivalent with corrosion resistance
 - Volume : 600mL or more
 - Temperature Control : Capable of maintaining the temperature of deionized water at $90 \pm 2^\circ\text{C}$
- 8) Vessel for Boiling Treatment
 - Material : SUS304 or Glass
 - Volume : 600mL or more
 - Temperature Control : Capable of maintaining the temperature of deionized water at 98°C or more
- 9) Vessel for Chemical Treatment
 - Material : Glass
 - Volume : 600mL or more
 - Temperature Control : Capable of controlling and maintaining the solution temperature at $70 \pm 2^\circ\text{C}$

5. Test Equipment for Film Dielectric Withstanding

- 1) DC Constant-Current Power Supply
 - Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
 - DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
 - Internal Resistance : $1M\Omega$ or higher
 - Accuracy : $\pm 0.5\%$

3) DC Ammeter

Internal Resistance shall be sufficiently small compared to Load Resistance

4) Measurement Vessel

Material : SUS304 or equivalent with corrosion resistance
Volume : 500mL or more
Depth : 100mm or more

5) Counter Electrode

Measurement Vessel : SUS304 or equivalent with corrosion resistance

6) Volt Recorder

Internal Resistance : $1M\Omega$ or higher
Accuracy : $\pm 0.5\%$

6. Test Equipment for Capacitance Measurement

1) Capacitance Measurement Device

Capacitance Meter in accordance with JIS C 5101-1,4.7
Measurement Frequency : $120\text{Hz} \pm 5\%$
Measurement Voltage : 0.5Vrms or less
DC Bias Voltage : 1.5V

2) Measurement Vessel

Material : Glass or Acrylic
Volume : 200mL or more

3) Counter Electrode

Material : Platinum Plate/Mesh for Capacitance of $40,000 \mu\text{F}$ or higher

7. Test Specimen

Test Specimen : In accordance with 8-1 *Selecting Test Specimens for Electrical Characteristics Measurements.*

8. Formation

1) Solution BM

Boric Acid : $150\text{g} \pm 15\text{g}$
28% Aqueous Ammonia : 1.3 mL (Reference Value, Determined by Specific Resistance)
Deionized Water : $1,000 \pm 50\text{mL}$
Specific Resistance : $350\text{--}550 \Omega\text{cm}/80 \pm 2^\circ\text{C}$
Specific gravity : $1.018 + 0.005, -0.004 / 80 \pm 2^\circ\text{C}$

2) Solution BSH

Boric Acid : $90\text{g} \pm 5\text{g}$
28% Aqueous Ammonia : 0.25mL
Deionized Water : $1,000 \pm 50\text{mL}$
Specific Resistance : $1,600\text{--}1,800 \Omega\text{cm}/80^\circ\text{C} \pm 2^\circ\text{C}$
Specific Gravity : $1.003 + 0.002, -0.001 / 80 \pm 2^\circ\text{C}$

3) Chemical Treatment

Phosphoric Acid : $60\text{g} \pm 5\text{g}$
Deionized Water : $1,000 \pm 50\text{mL}$
Specific Resistance : $27\text{--}33 \Omega\text{cm}/56^\circ\text{C} \pm 1^\circ\text{C}$

4) Formation Circuit

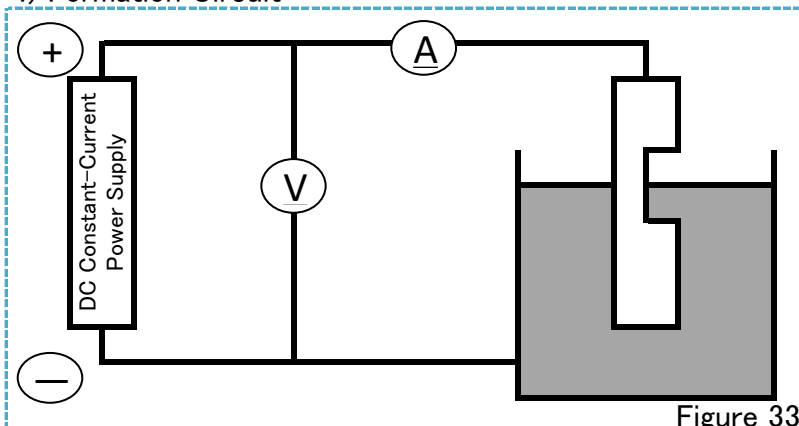


Figure 33

The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 8-15mm below the surface.

7-7 Capacitance Test Method – Etched Foil for Anode, Middle to High Voltage 2 of 4

5)Formation Conditions for 257Vfs

Process	Items	Unit	Conditions
Boiling Treatment	Temperature	°C	99±1
	Time	min	6±0.5
Formation ①	Vfe	V	Varies by Foil
	Current Density	mA/cm² (Immersion Area)	25
	Temperature	°C	≥95
	Time	min.	10±1
	Formation Electrolyte	—	Solution BM
Deionized Water Wash	—	°C	Room Temperature
Depolarization	Temperature	°C	90±2
	Time	min	1.5±0.15
Formation ②	Vfe	V	Varies by Foil
	Current Density	mA/cm² (Immersion Area)	25
	Temperature	°C	≥95
	Time	min	10±1
	Formation Electrolyte	—	Solution BM
Deionized Water Wash	—	°C	Room Temperature
Formation Procedure			Figure 34

6) Formation Conditions for 628Vfs

Process	Items	Unit	Conditions
Boiling Treatment	Temperature	°C	99±1
	Time	min	15±1
Formation ①	Vfe	V	Varies by Foil
	Current Density	mA/cm² (Immersion Area)	25
	Temperature	°C	≥90
	Time	min	20±2
	Formation Electrolyte	—	Solution BSH
Deionized Water Wash	—	°C	Room Temperature
Heat Treatment	Temperature	°C	500±25
	Time	min	5±0.2
Formation ②	Vfe	V	Varies by Foil
	Current Density	mA/cm² (Immersion Area)	25
	Temperature	°C	≥90
	Time	min	5±0.5
	Formation Electrolyte	—	Solution BSH
Deionized Water Wash	—	°C	Room Temperature
Chemical Treatment	Temperature	°C	70±2
	Time	min	2±0.2
	Solution	—	Chemical Solution
Deionized Water Wash	—	°C	Room Temperature
Formation ③	Vfe	V	Varies by Foil
	Current Density	mA/cm² (Immersion Area)	25
	Temperature	°C	≥90
	Time	min	5±0.5
	Formation Electrolyte	—	Solution BSH
Deionized Water Wash	—	°C	Room Temperature
Formation Procedure			Figure 35

7) Formation Procedure for 257Vfs

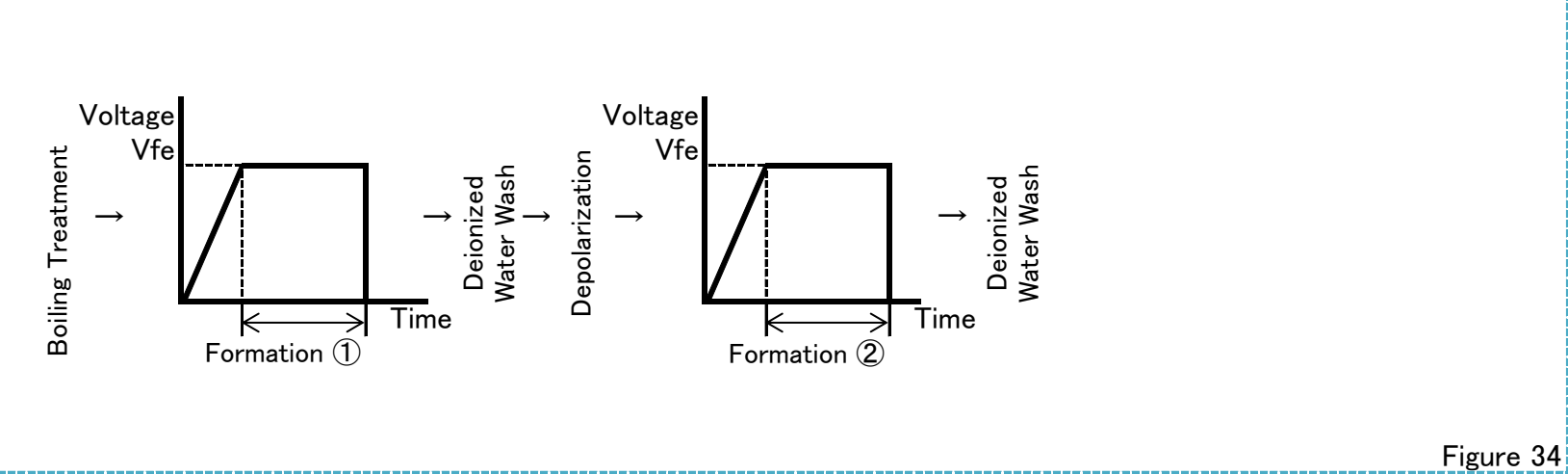


Figure 34

8) Formation Procedure for 628Vfs

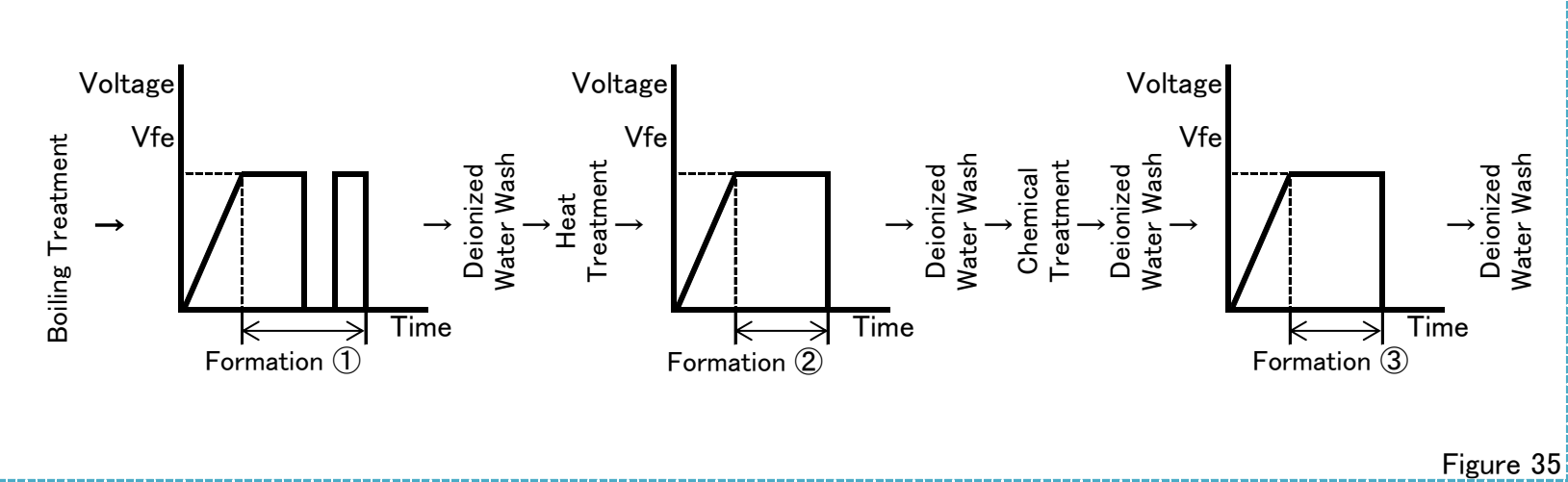


Figure 35

7-7 Capacitance Test Method – Etched Foil for Anode, Middle to High Voltage 4 of 4

9. Film Dielectric Withstanding Test (Vt)

1) Test Solution

Boric Acid	: 70g ± 7g
Deionized Water	: 1,000 ± 50mL
Specific Resistance	: 7.5(±0.3)k Ω cm/70 ± 2°C
pH	: 3.2(+1.0 -0.5)/50 ± 2°C

2) Test Conditions

Measurement Temperature	: 85 ± 2°C
Current Density	: 2.0 ± 0.2mA/1 Test Specimen 5cm ²

3) Measurement Circuit

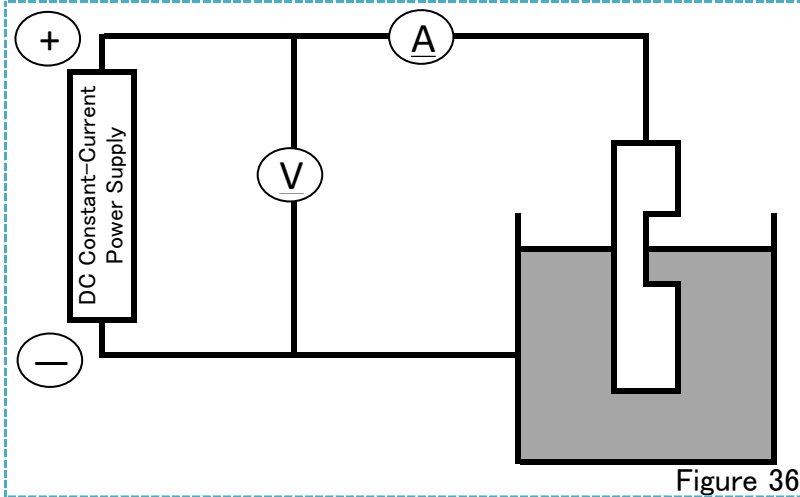


Figure 36

4) Measurement Method

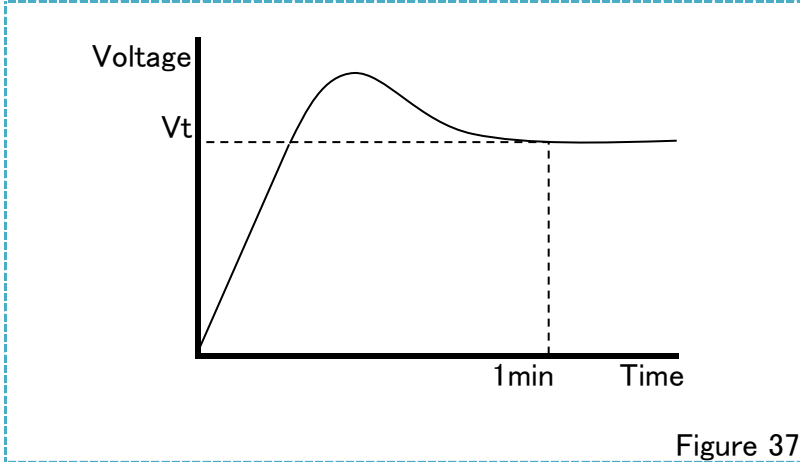


Figure 37

- ① The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6–8mm below the surface.
- ② The increase in voltage shall be measured after applying constant DC current.
- ③ Dielectric Withstanding Voltage (Vt) shall be defined as the voltage measured 1 minute after applying DC current.

10. Capacitance Measurement (Cap)

1) Electrolyte for Capacitance Measurement

Ammonium Pentaborate	: 80g ± 8g
Deionized Water	: 1,000 ± 50mL
Specific Resistance	: 30(±5) Ω cm/70 ± 2°C
pH	: 7.4(+0.5 -1.0)/50 ± 2°C

2) Condition for Capacitance Measurement

Measurement Temperature	: 30 ± 2°C
-------------------------	------------

3) Measurement Circuit

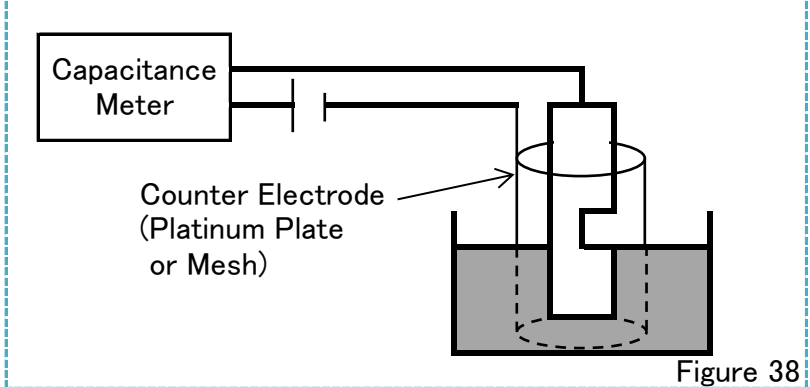


Figure 38

The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{V_{tm} \times C_m}{\text{Specified } V_t \times 5}$$

Where : Specified Vt = Varies by Foil
 : Vtm = Measured Value (V)
 : Cm = Measured Value (μF)
 : C = Capacitance (μF/cm²) per 1cm²

7-8 Test Method – Formed Foil for Cathode 1 of 2

1. Scope of Test

$0.9 \leq V_{fs} \leq 3.0$

2. Definitions of Technical Codes

- 1) V_{fs} : Nominal Formation Voltage
- 2) V_t : Dielectric Withstanding Voltage

3. Test Procedure

- 1) Procedure ①Capacitance Measurement (Cap)
②Film Dielectric Withstanding Test (V_t)

4. Test Equipment for Capacitance Measurement

- 1) Capacitance Measurement Device
Capacitance Meter in accordance with JIS C 5101-1,4.7
Measurement Frequency : $120\text{Hz} \pm 5\%$
Measurement Voltage : $0.5V_{rms}$ or less
- 2) Measurement Vessel
Material : Glass or Acrylic
Volume : 200mL or more
- 3) Counter Electrode
Test Specimens

5. Test Equipment for V_t Measurement

- 1) DC Power Supply
Ripple Content : 2% or less for 50,60Hz
1% or less for 100,120Hz
DC Voltage Stability : $\pm 3\%$
- 2) DC Voltmeter
Internal Resistance : $1\text{M}\Omega$ or higher
Accuracy : $\pm 0.5\%$
- 3) DC Ammeter
Internal Resistance shall be sufficiently small compared to Load Resistance
- 4) Measurement Vessel
Material : SUS304 or equivalent with corrosion resistance
Volume : 500mL or more
Depth : 100mm or more
- 5) Counter Electrode
Measurement Vessel : SUS304 or equivalent with corrosion resistance
- 6) Referential Electrode
Material : Platinum Plate
Purity : 99.99% or more
Dimensions : $10\text{mm} \times 20\text{mm} \times 0.1\text{mm}$
- 7) Volt Recorder
Internal Resistance : $1\text{M}\Omega$ or higher
Accuracy : $\pm 0.5\%$

6. Test Specimen

Test Specimen : In accordance with *8-1 Selecting Test Specimens for Electrical Characteristics Measurements*.

7. Capacitance Measurement (Cap)

1) Test Solution

Ammonium Adipate : $150\text{g} \pm 15\text{g}$
Deionized Water : $1,000\text{mL} \pm 50\text{mL}$
Specific Resistance : $6.5(+2.0 -1.5)\Omega \text{ cm}/70 \pm 2^\circ\text{C}$
pH : $6.7(+0.5 -1.5) / 50 \pm 2^\circ\text{C}$

2) Test Conditions

Measurement Temperature : $30 \pm 2^\circ\text{C}$

3) Measurement Circuit

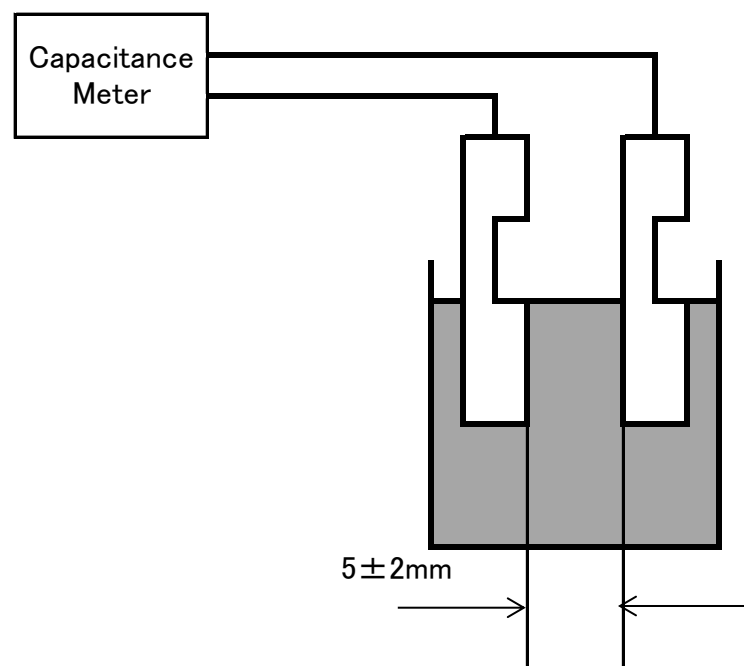


Figure 39

The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm^2 is calculated by the following formula

$$C = \frac{C_m \times 2}{5}$$

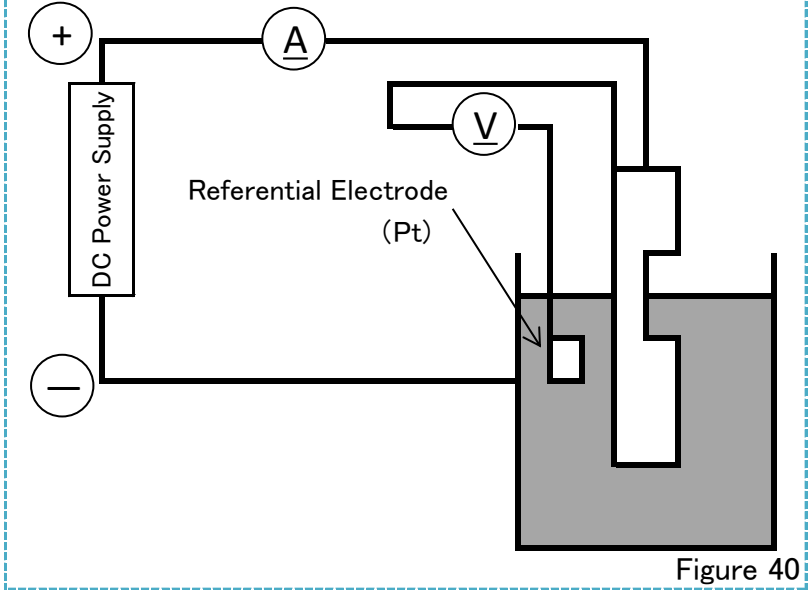
Where : C_m = Measured Value (μF)

: C = Capacitance ($\mu\text{F}/\text{cm}^2$) per 1cm^2

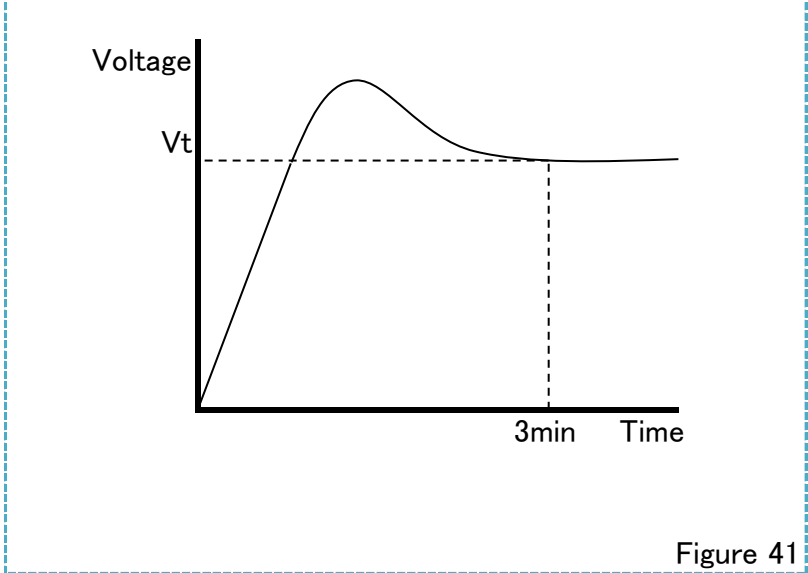
8. Film Dielectric Withstanding Test (Vt)

- 1) Test Solution
- Ammonium Adipate : 150g ±15g
- Deionized Water : 1,000mL ±50mL
- Specific Resistance : 6.5(+2.0 -1.5)Ω cm/70±2°C
- pH : 6.7(+0.5 -1.5) /50±2°C
- 2) Test Conditions
- Measurement Temperature : 85±2°C
- Current Density : 0.5±0.05mA/ 1 Test Specimen 5cm²

3) Measurement Circuit



4) Measurement Method



- ①The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is 6-8mm below the surface.
- ②The increase in voltage shall be measured after applying constant DC current.
- ③Dielectric Withstanding Voltage (Vt) shall be defined as the voltage measured 3 minutes after applying DC current.

7-9 Capacitance Test Method – Etched Foil for Cathode1 of 1

1. Scope of Test

Etched Foil for Cathode

2. Definitions of Technical Codes

- 1) C₀ : Initial Capacitance
- 2) C₆₀ : Capacitance after Hydration Process (60 min)
- 3) ΔC_{60} : $\{(C_{60} - C_0) \div C_0\} \times 100(\%)$

3. Test Procedure

- 1) The following tests and measurements shall be performed on the same test specimen.
- 2) Procedure
 - ① Capacitance Measurement (C₀)
 - ② Hydration Resistance Test (C₆₀)

4. Test Equipment for Capacitance Measurement

(Capacitance Measurement, Hydration Resistance)

- 1) Capacitance Measurement Device

Capacitance Meter in accordance with JIS C 5101-1,4.7

Measurement Frequency : 120Hz $\pm$ 5%

Measurement Voltage : 0.5Vrms or less
- 2) Measurement Vessel

Material : Glass or Acrylic

Volume : 200mL or more
- 3) Counter Electrode

Test Specimens
- 4) Vessel for Hydration Process

Material : SUS304 or equivalent with corrosion resistance

Volume : 600mL or more

Temperature Control : Capable of maintaining the temperature of deionized water at 95°C or higher.

5. Test Specimen

Test Specimen : In accordance with *8-1 Selecting Test Specimens for Electrical Characteristics Measurements*.

6. Capacitance Measurement (C₀ and C₆₀)

- 1) Test Solution

Ammonium Adipate : 150g $\pm$ 15g

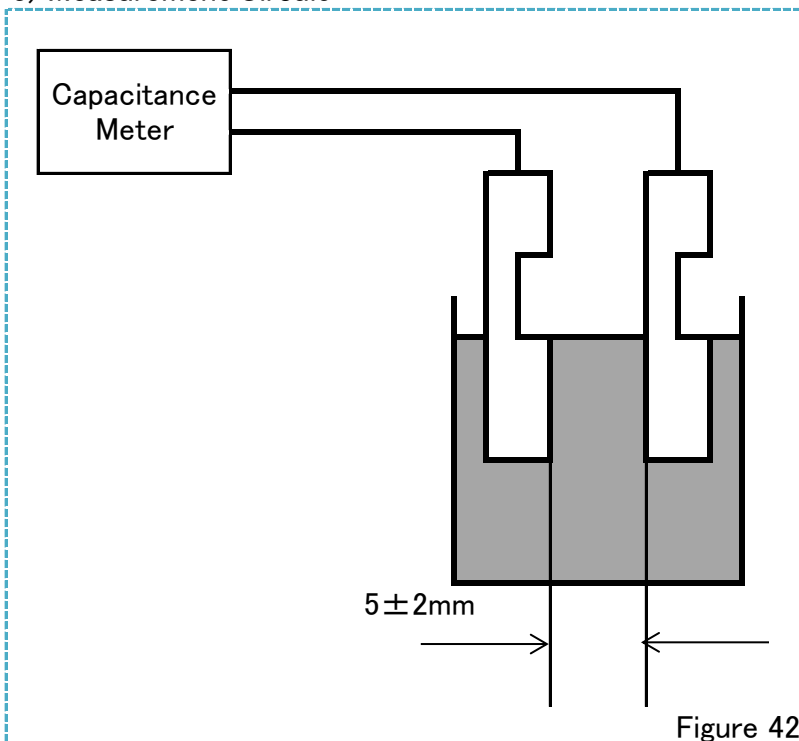
Deionized Water : 1,000mL $\pm$ 50mL

Specific Resistance : 6.5(+2.0 -1.5) Ω cm/70 $\pm$ 2°C

pH : 6.7(+0.5 -1.5) /50 $\pm$ 2°C
- 2) Test Conditions

Measurement Temperature : 30 $\pm$ 2°C

3) Measurement Circuit



The test specimen shall be immersed in the measuring electrolyte so that the top edge of the Projected Area (area to be measured) is level with the surface.

4) Measurement Calculation

Capacitance per 1cm² is calculated by the following formula

$$C = \frac{C_m \times 2}{5}$$

Where : C_m = Measured Value (μF)
 : C = Capacitance (μF/cm²) per 1cm²

7. Hydration Resistance Test (C₆₀)

1) Hydration Process

Test Specimen : Use the same specimen already measured by the Capacitance test process for initial capacitance(C₀).

Hydration Process Time : 60 $\pm$ 1min

Hydration Temperature : 95 °C or higher

Number of Specimen : Approx. 6 pieces / 500 mL as a guideline.

Deionized Water Change : Change deionized water for every hydration process.

2) Capacitance Measurement (C₆₀)

Measure the capacitance after hydration process (C₆₀) according to Article 6 above.

3) Measurement Calculation of ΔC_{60}

Use the following formula to calculate foil capacitance stability after the hydration process.

$$\Delta C_{60} : \{(C_{60} - C_0) \div C_0\} \times 100(\%)$$

Note:

Hydration resistance test shall be used for foil C518, C519, C439 and C531.

7-10 Test Method – Tensile Strength 1 of 1

1. Scope of Test

Etched Foils and Formed Foils

2. Test Equipment

Testing Device : Tensile Testing Machine
Conforming to JIS B 7721

3. Test Specimen

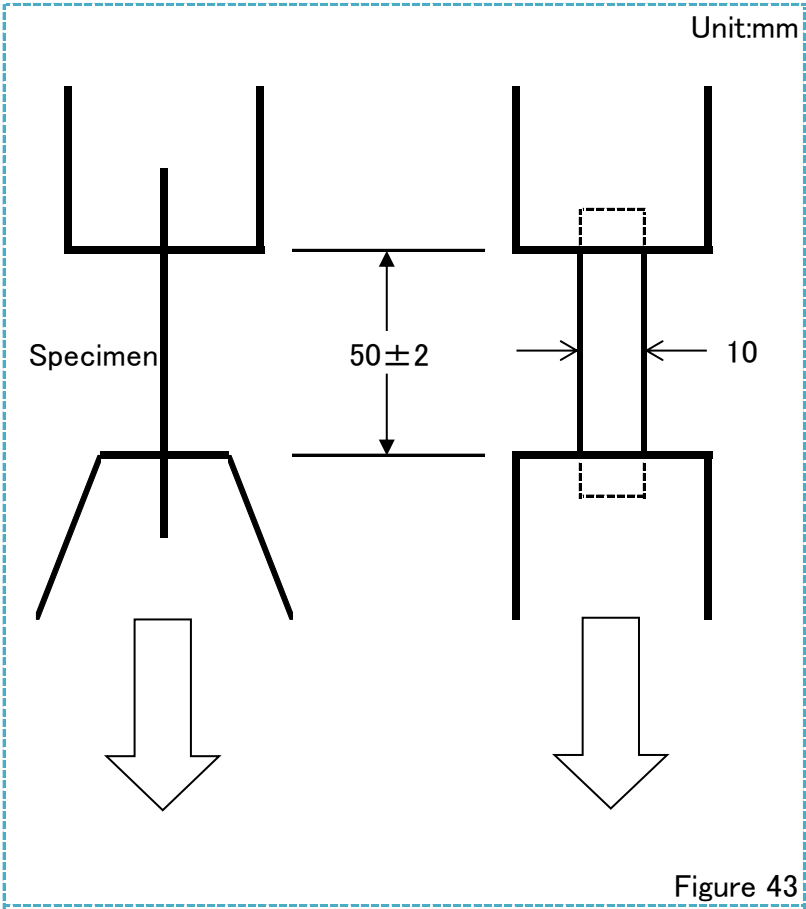
Test Specimen :
In accordance with 8-2 *Selecting Test Specimens for Mechanical Strength Measurements*.

4. Tensile Strength Test Method

- 1) Mounting of Test Specimen
Refer to Figure 43 for Mounting Test Specimen
- 2) Testing Speed
10±1mm/min
- 3) Tensile Strength
The tensile strength shall be determined by applying tension force on the test specimen until it breaks. If the specimen breaks near the cramping position, the test shall be repeated.
- 4) Unit of Measurement
Newton (N/cm)

5. Tensile Strength Measurement

The measured value (N/cm) shall be the Tensile Strength.



7-11 Test Method – Bending Strength 1 of 1

1. Scope of Test

Etched Foils and Formed Foils

2. Test Equipment

Testing Device : MIT-type Automatic Bending Endurance Testing Machine Conforming to JIS P 8115

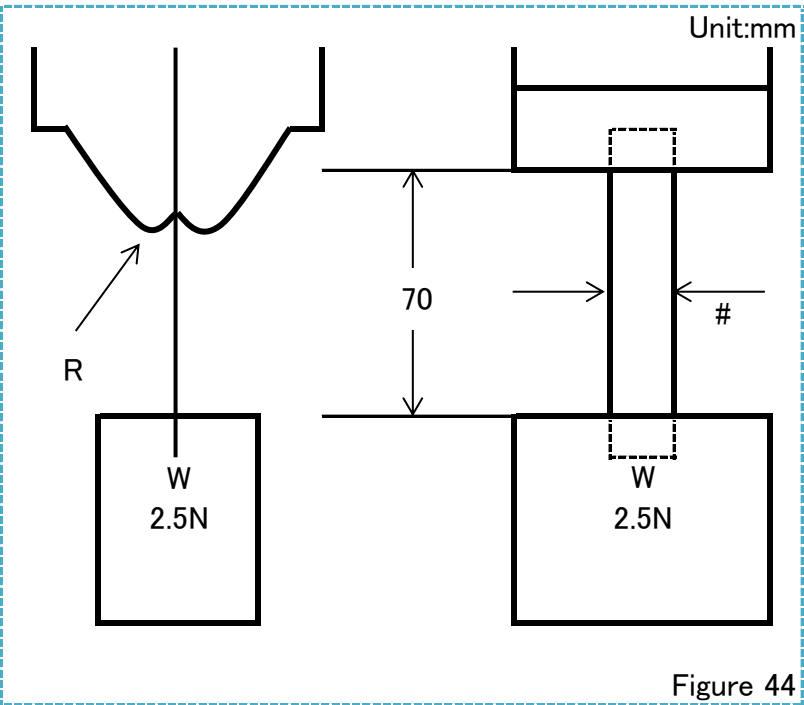
3. Test Specimen

Test Specimen :
In accordance with 8-2 *Selecting Test Specimens for Mechanical Strength Measurements.*

4. Bending Strength Test Method

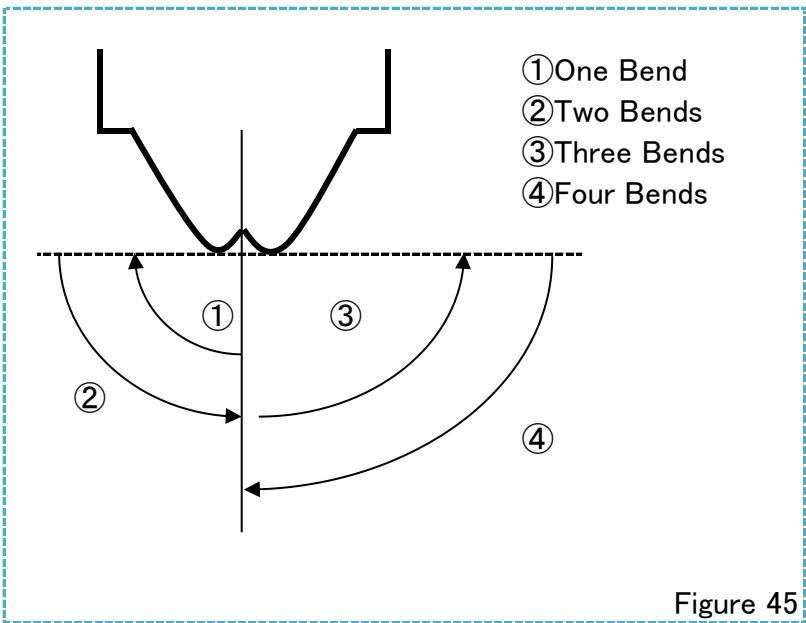
- 1) Mounting of Test Specimen
Refer to Figure 44 for Mounting Test Specimen.
- 2) Bending Angle
 $90 \pm 2^\circ$
- 3) Bending Speed
6 times/sec.
- 4) Load
 $2.5 \pm 0.05\text{N}$
- 5) Bending Strength
The bending strength shall be determined by the minimum number of bends before the test specimen breaks.
- 6) Unit of Measurement
Number of Bends
- 7) Radius of Mandrel
In accordance with values in table below:

Foil Category		R(mm)
Low Voltage	Etched Foil	0.5 ± 0.05
	Formed Foil	
Middle to High Voltage	Etched Foil	1.0 ± 0.1
	Formed Foil	3.5 ± 0.35
Cathode Foil	Etched Foil	0.5 ± 0.05
	Formed Foil	



5. Counting the Number of Bends

The clipping point of the automatic bending tester must be fixed, and the clipping point of the die (at the other end of the test piece) must be able to move 90° to the right and to the left, or a total of 180° . As shown in Figure 45, each 90° bend shall be counted; consequently, when the test piece moves within the 180° , 4 bends are counted.



6. Bending Strength Measurement

- 1) Etched and Formed Foil for Anode, Low Voltage, Etched and Formed for Cathode
The bending strength value shall be measured by using one test specimen taken from one location.
- 2) Etched and Formed Foil for Anode, Middle to High Voltage Formed Foil for Photo Flash
The bending strength value shall be determined by the minimum value measured at four points (two outer point and two core point).

7-12 Test Method – Residual Chloride Content for Anode Formed Foil 1 of 2

1. Scope of Test

All Formed Foils for Anode

2. Principle

The chloride ion on foil is extracted in a sodium hydroxide solution. The extract is heated with nitric acid and clarified by centrifugation. A silver nitrate solution is added to the clarified extract to form a suspension of colloidal silver chloride.

Residual chloride content of the sample solution is then compared with a standard solution by means of a turbidimetric test.

3. Reagents

1) 0.2% Sodium Hydroxide Aqueous Solution

The solution is made by dissolving 2g of sodium hydroxide (as specified in JIS K 8576 – High Grade Reagent) in 1L of deionized water. Store in a polyethylene container (or amber bottle).

2) 0.5 wt% (0.029 mol/L) Silver Nitrate Aqueous Solution

The solution is made by dissolving 2.5g of silver nitrate (as specified in JIS K 8550 – High Grade Reagent) in 500mL of deionized water. Store in an amber bottle.

3) 60% Nitric Acid Solution (16 mol/L)

Use 60% nitric acid (reagent grade) specified in JIS K 8541.

4) Chloride 1ppm Reference Solution

Chloride ion standard solution(1000mg/L), 1mL of this solution is diluted in deionized water, and the total amount is adjusted to 1L.

4. Test Specimen

All test specimens shall consist of a foil with a projected area of $125 \pm 5 \text{ cm}^2$, cut into small pieces of approximately 1–4 cm^2 .

5. Apparatus

- | | |
|---|---|
| 1) Centrifuge | : Capable of achieving $\geq 3000 \text{ rpm}$. |
| 2) Warm Water Bath | : Capable of controlling temperature at $80 \pm 10 \text{ }^\circ\text{C}$ and $30 \pm 2 \text{ }^\circ\text{C}$. |
| 3) Turbidity Meter with Fluorescent Light | : A dark box. |
| 4) Centrifuge Tube | : 50mL |
| 5) Temperature Measurement Device | : Conforming to JIS B 7414 or equivalent, with graduation up to $100 \text{ }^\circ\text{C}$ and accuracy of $\pm 1 \text{ }^\circ\text{C}$. |
| 6) Turbidity Test Tubes | : 50 mL, graduated, same type/shape |
| 7) Conical Flask | : 100mL |
| 8) Measuring Flask | : 100mL |
| 9) Measuring Pipette | : 5mL |
| 10) Cooling Vessel | : Capable of cooling to room temperature. |
| 11) Scissors | |
| 12) Dispenser | |

6. Test Procedure

6-1.Extraction Using Sodium Hydroxide

- 1) Place test pieces in a 100mL conical flask or beaker.
- 2) Pour 60mL of the Sodium Hydroxide Solution into the conical flask or beaker, stir once or twice and let it stand for approximately 5 minutes at room temperature.

6-2.Clarification of Extract

- 1) Rinse the test pieces two separate times in 10mL of deionized water. Pour this water and the extract obtained from step 6-1. 2) into the 100mL measuring flask and add 3mL of the 60% Nitric Acid Solution.
- 2) Heat the measuring flask with the solution obtained from step 6.2 1) in a warm water bath ($80 \pm 10^\circ\text{C}$) for about 20 minutes.
- 3) Cool solution to room temperature, fill the measuring flask with deionized water to the 100mL marked line and shake extract well before distribution.

6-3.Distribution of Extract

Transfer approximately 40 mL of the extract into a centrifuge tube and centrifuge at 3000 rpm (0, +20%) for about 15 ± 1 minutes. Then, transfer 20 mL of the supernatant into a turbidity test tube, which will be used as the test solution.

7-12 Test Method – Residual Chloride Content for Anode Formed Foil 2 of 2

6-4.Procedure for Turbidity Determination

- 1) Use the measuring pipette to transfer the Chloride 1ppm Reference Solution into four turbidity test tubes. Add deionized water to each tube to adjust total amount to 20mL and make the Reference Solution below.

Note: Addition of the standard solution is allowed if necessary.

0.4 mg/m ² standard solution	: Chloride 1ppm Reference Solution 1.0mL
0.6 mg/m ² standard solution	: Chloride 1ppm Reference Solution 1.5mL
0.8 mg/m ² standard solution	: Chloride 1ppm Reference Solution 2.0mL
1.0 mg/m ² standard solution	: Chloride 1ppm Reference Solution 2.5mL
1.2 mg/m ² standard solution	: Chloride 1ppm Reference Solution 3.0mL

- 2) Add approximately 1mL of the 60% Nitric Acid Solution to the Reference Solutions A, B, C and D as well as the Test Solutions developed in 6-3. 1) and 2). Shake well and place the test tubes in a warm water bath ($30\pm 2^{\circ}\text{C}$) for 5 minutes.
- 3) Add approximately 2 mL of silver nitrate solution to the test tubes, mix well, and store for 15 minutes.
- 4) Transfer the test tubes to a dark box and determine the chlorine concentration (mg/m²) of the test solutions by comparing their turbidity with that of the standard solution.

7. Residual Chloride Content Measurement

Evaluation in 0.1 mg/m² increments using the standard solution.

1.Scope of Test

- 1) All Etched Foils
- 2) All Formed Foils for Cathode

2.Principle

Burn the foil at high temperature and channel the chlorine gas generated into acetic acid solution.

The chloride ions dissolved in the acetic acid solution shall be quantified by coulometric titration using silver.

3.Test Apparatus

Automated titrator which is composed of AUTO-BOARD-CONTROLLER; test specimen on specimen-board is lead to electric furnace and combusted, and TITRATOR; produced Hydrogen Chloride is titrated with electrolytically-generated AG-ION and the endpoint detected with set-up final electric potential.

Applicable Unit : Chlorine Analysis Devices such as TOX-2100H

4.Reagents

- 1) 85% Acetic Acid Solution (Electrolyte Solution)

①Add 0.8g of gelatin (Grade 1, JIS K 6503) to about 150 mL of deionized water, heat and stir, then allow to cool.

②Accurately weigh 1.35g of sodium acetate anhydrous (special grade reagent, JIS K 8372) and add it to solution ①. Add 850 mL of acetic acid (special grade reagent, JIS K 8355), then add deionized water to make up to 1000 mL.

③Add 1mL of commercially available volumetric hydrochloric acid solution, 0.01 mol/L, in accordance with JIS K 8001, 5 (hydrochloric acid), to solution ②. (Shelf life: 6 months, store tightly sealed in a cool, dark place.)

- 2) 1mol/L Kalium Chloride Solution (inside-reference-extrode solution)

This solution is made by dissolving 7.46g (precise weighing) of Kalium Chloride (as specified in JIS K 8121 – high grade reagent) in 100mL of deionized water. 1 mol/L KCl solution for testing/research may also be used. Shelf life: 6 months, store sealed in a cool, dark place.

- 3) 1mol/L Potassium Nitrate Solution (outside-reference-electrode solution)

This solution is made by dissolving 10.1g (precise weighing) of Potassium Nitrate (as specified in JIS K8548 – high grade reagent) in 100mL of deionized water. 1 mol/L KNO₃ solution for testing/research may also be used. Shelf life: 6 months, store sealed in a cool, dark place.

- 4) Concentrated Sulfuric Acid (dewatering bath)

98% Sulfuric Acid (as specified in JIS K 8951 – high grade reagent) is used.

- 5) 0.01mol/L Hydrochloric Acid Solution (hydrochloric acid reference solution)

Use commercially available volumetric hydrochloric acid solution, 0.01 mol/L, in accordance with JIS K 8001, 5 (hydrochloric acid).

5.Test Specimen

Take foil with a projected area of 10 cm² and, without introducing Cl contamination, fold and roll it to fit the sample board using a bamboo skewer or a SUS Test Probe on electrolytic paper. If not measured immediately, wrap the sample in waxed paper or electrolytic paper for storage.

6.Apparatus

- 1) Electrolytic Paper
- 2) Waxed Paper
- 3) Specimen Crusher or Bamboo Skewer / SUS Test Probe
- 4) Quartz Board
- 5) Chlorine/Sulfur Analyzer: for Coulometric Titration of Combustion Gases
- 6) Scissors
- 7) 25 μL Micro-Syringe
- 8) Tweezers
- 9) Volumetric Flasks: 100 mL and 1000 mL

7. Measurement

1) Combustion Temperature

in Argon Stream : 850°C

in Oxygen Stream : 900°C

2) Test Titration

Setup the end-electric potential of titration and titer coefficient.

End Potential : 290–315mV

Titer Coefficient : Within the Range of 0.5–5.0

3) Coulometric Titration Yield (precision), Exam 1

Put 10 μ l of Hydrochloric Acid reference solution in electrolysis cell directly using microsyringe, then titrate.

Yield : Examine within 95–105%

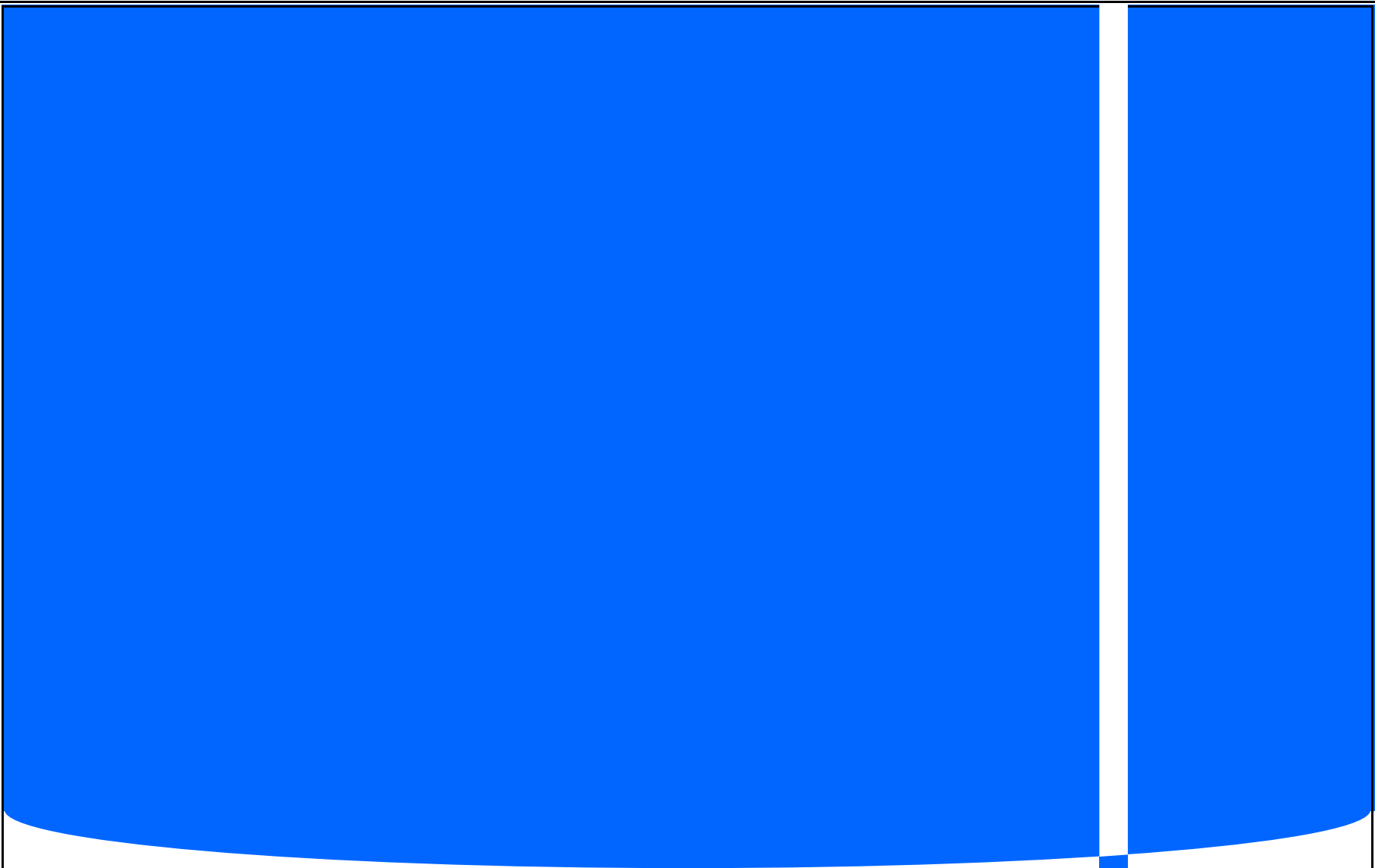
4) Coulometric Titration Yield (Precision), Exam 2

Put 10 μ l of Hydrochloric Acid reference solution on sample board using microsyringe, combust as same as real-sample, generate chlorine gas, dehydrate and titrate.

Yield : Examine within 93–103%

5) Measurement

After exam whether the yield (precision) of 3) and 4) is within the allowance, start to measure.

The logo of KDK Corporation is a stylized blue flag with a white vertical stripe on the right side. The flag is rectangular with a slightly wavy bottom edge. The white stripe is positioned towards the right edge of the flag.

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