Applied Composite Material Co. Ltd.

Production Standard

QJ/ACM 0001—2014

Copper Clad Aluminum Composite Busbar (Coppbar™) for the Purpose of Electrical Distribution and as Power Transmission and Transformation Equipment

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Preamble

This production standard concerns copper clad aluminum composite ("CCAC") busbars as equipment for the purpose of electrical distribution and as power transmission and transformation equipment and applies to the **Coppbar™** brand CCAC busbars fabricated by Applied Composite Material LLC ("ACM"), USA.

This production standard applies to CCAC busbars for the purpose of electrical distribution and as power transmission and transformation equipment produced by adaption of USA and international utility patent "Isothermal Processed Copper Cladded Aluminum Composite" (US patent no. US 14/491,983 and International PCT no. PCT/US2014/056696) under the trademark of **Coppbar™**, invented by and assigned to Applied Composite Material LLC., USA.

This standard is drafted in accordance with GB/T1.1-2009 rules.

This standard is proposed by Applied Composite Material Co. Ltd., Hangzhou.

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Copper Clad Aluminum Composite Busbar (Coppbar™) for the Purpose of Electrical Distribution and as Power Transmission and Transformation Equipment

1 Scope

This production standard ("Standard") stipulates the model, specifications, technical requirements, testing methodology, inspection guidelines, and delivery requirements of copper clad aluminum composite ("CCAC") busbar, trademarked as **Coppbar™**.

This standard is applicable to CCAC busbars (commonly known as copper clad aluminum bus, CCAC bar, or CCAC bus) for the purpose of electrical distribution and as power transmission and transformation equipment.

2 Normative Reference Documents

The following documents are essential for this standard. For the dated documents, the version to the date applies, for the non-dated documents, the latest version (including all amendments) applies.

ASTM D4541-09e1	Pull-off strength of coatings using portable adhesion testers
GB/T 5231—2012	Designation and chemical composition of wrought copper and copper alloys
GB/T 1196—2008	Remelting aluminum ingot
GB/T 2900.10—2001	Electrotechnical vocabulary–electric cables
GB/T 3048.2—2007	Test methods for electrical properties of cables and wires, Part 2: Test of electrical resistivity of metallic material
GB/T 4909.2—2009	Test methods of bare wires, Part 2: Size measurement
GB/T 4909.3—2009	Test methods of bare wires, Section Three: Tensile test
GB/T 4909.6—2009	Test methods of bare wires, Part 6: Bend test - single bend test

3 Terminology and Definitions

GB/T 2900.10-2001 defines the following terminology and definitions utilized in this standard.

3.1 Copper Clad Aluminum Composite Busbar

A rectangular busbar, characterized by layered structure and metallurgical bonding onto the bimetallic interface, consists of cladding copper uniformly coated over an aluminum core.

3.2 Flatness

The maximum vertical distance between the CCAC busbar surface to the reference surface while the CCAC bus is placed on the reference surface.

3.3 Volume Ratio of Cladding Copper

The ratio of the volume of cladding copper to the volume of the CCAC busbar.

3.4 Interfacial Bonding Strength

The binding force of the aluminum core and the cladding copper per unit area.

3.5 Rounded Edged CCAC Bus

The radius "R" of the rounded edge equals to the thickness "a" of the rounded edged CCAC bus.

3.6 Metallurgical Bonding

The bimetallic interfacial atomic binding through diffusion and fusion.

4 Type and Model

4.1 Type

a) The cross-section shape of CCAC bus is divided into the rounded edged type and the full rounded edged type.
b) The hardness of CCAC bus is divided into the soft type (R) and hard type (Y).

4.2 Representation of Product Models and Specifications

The CCAC Bus model is designated through the type code, category code, specification and the code number of this standard.

TLM — □□ - □□ - QB/ACM 01.01-2014

Size axb, unit: mm
Category code (cross-section, hardness)
Type code (TBLM , TLM)

a) Type code is represented by TBLM or TLM.
b) Categorye code:
   1) Cross-section: full rounded edge “Q”; rounded edge “L”.
   2) Hardness: Soft “R”; hard “Y”.

Example: The model of a full rounded edge CCAC bus under the category “hard” with a narrow edge of 6mm and wide edge of 60mm is designated as: TLM-QY-6×60-Q/ACM 0001- 2014.

5 Requirements

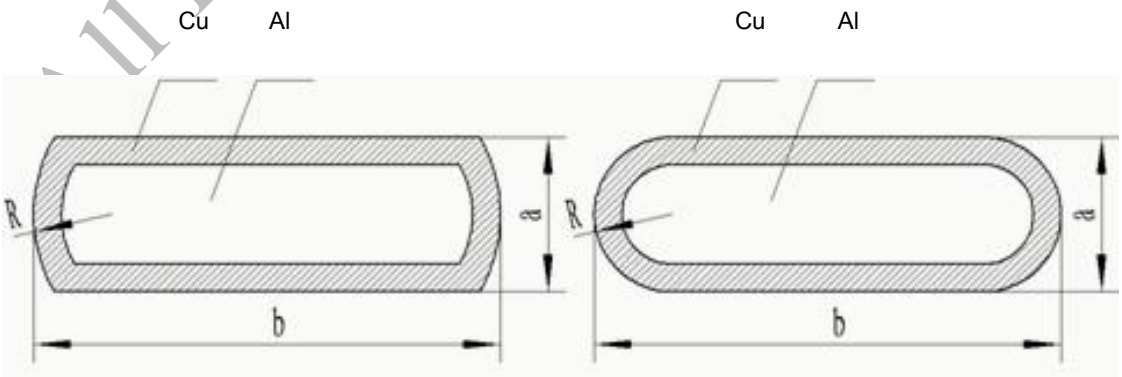
5.1 Structure and Size of CCAC Bus

5.1.1 *Material*

The cladding copper shall be in accordance with GB/T 5231– 2012: the composition of copper shall be greater than 99.90%. The core aluminum shall be in accordance with GB/T 1196-2008: the composition of aluminum shall be greater than 99.70%.

5.1.2 *Shape of Cross-Section*

The cross-sectional shape of CCAC bus is shown in Fig.1, which includes: (a) rounded edge; and (b) full rounded edge. The radius “R” and tolerance of the rounded edge and full rounded edge shall be consistent with the provisions of 5.1.5.



(a) Rounded Edge **(b)** Full Rounded Edge

Fig.1 Cross-sectional shape of CCAC bus

5.1.3 *Appearance*

The appearance of CCAC busbar shall be smooth, flat, bumpless, crackless, and free of any defects that would be found in a subpar quality industrial product.

5.1.4 *Dimension and Deviation*

a) The cross-sectional size of CCAC busbar ranges from 3 mm ≤ a ≤ 35 mm; 30 mm ≤ b ≤ 300 mm, where 'a' represents thickness of CCAC bus and 'b' represents width of CCAC bus. The recommended specification of CCAC busbar is shown on table 1.

Table 1. Recommended Specification of CCAC Bus Unit:mm

Width 'b'	Thickness 'a'										
	3	4	5	6	8	10	12	14	16	20	30
30	○	○	○	○							
40	○	○	○	○							
50	○	○	○	○							
60	○	○	○	○	○	○					
80	○			○	○	○	○				
100	○			○	○	○	○	○			
120	○	○		○	○	○	○	○			
140	○			○	○	○	○				
160	○	○		○	○	○	○		○		
175				○	○						
180	○			○	○	○	○		○		
200		○		○	○	○	○		○		
240		○		○	○	○	○		○		
280		○		○	○	○	○		○		
300				○	○	○	○		○	○	○

Note 1: Common specifications are denoted by the "○" symbol.
Note 2: Other specifications may be supplied through negotiation.

b) Tolerance of thickness "a" which relates to width "b" shall comply with table 2.

Table 2. Tolerance of thickness Unit: mm

Thickness "a"	Width "b"		
	30.00≤ b ≤ 50.00	50.00< b ≤ 100.00	100.00< b ≤ 300.00
2.50≤ a ≤ 4.75	± 0.06	± 0.08	± 0.10
4.75<a ≤ 12.50	± 0.08	± 0.10	± 0.12
12.50<a ≤ 20.00	± 0.10	± 0.12	± 0.15

20.00＜a ≤ 30.00	± 0.12	± 0.15	± 0.25

c） Tolerance of width “b” shall comply with table 3.

Table 3. Tolerance of width Unit: mm

Width “b”	Deviation
30.00 ≤ b ≤ 35.50	± 0.25
35.50＜b ≤ 100.00	± 0.50
100.00＜b ≤ 200.00	± 0.75
200.00＜b ≤ 300.00	± 1.00

5.1.5 *Radius and deviation of rounded edge and full rounded edge*

Radius “R” of a rounded edged cross-section is equal to the thickness “a”.

Radius “R” of a full rounded edged cross-section is equal to half of the thickness “a”.

The deviation of radius “R” shall be 0~12.5% of “a”.

5.1.6 *Cross-sectional area*

a) The cross-sectional area “S” of the rounded edge CCAC bus is calculated by formula (1) :

$$S = a \times b - 0.087 \times a^2 \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

b） The cross-sectional area “S” of the full rounded edge CCAC busis calculated by formula (2) :

$$S = a \times b - 0.214 \times a^2 \quad \cdots\cdots\cdots\cdots\cdots\cdots (2)$$

5.1.7 *Tolerance of flatness*

The tolerance of flatness shall not exceed 3‰ of the specified length.

5.1.7 *Volume ratio of cladding copper*

The volume ratio of cladding copper of various CCAC busbars shall be in the range of 15%~22%, the volume ratio of cladding copper of standard CCAC busbars are 15% and 20%, the allowance of tolarance is ±1%.

5.1.8 *Thickness tolerance of cladding copper*

The thickness of CCAC bus shall be even entirely and the allowance of thickness tolerance of the cladding copper is ±10% of the average thickness.

5.1.9 *Density and tolerance*

a) The density of CCAC bus is 3.94g/cm³, while the volume ratio of cladding copper is 20%. The tolerance alowance is ±3%;
b) The density of CCAC bus is 3.63g/cm³, while the volume ratio of cladding copper is 15%. The tolerance alowance is ±3%;
c) The density of copper is 8.89g/cm³; density of aluminum is 2.703g/cm³.

5.2 Mechanical Properties

5.2.1 *Temperature property*

Within the temperature range of -40C° to +110C°, the shear tensile strength of the bimetallic interface shall be in accordance with the stipulation of 5.2.2.

5.2.2 *Shear tensile strength*

There shall be no gap between the cladding copper and core aluminum of CCAC bus, and the cladding and core layers shall closely bind to form metallurgical bonding. The shear tensile strength shall be greater than or equal to 60MPa.

5.2.3 *Tensile and elongation*

The tensile strength and elongation of CCAC bus are in accordance with the table 4.

Table 4. Tensile Strength and Elongation

Tensile Strength (MPa)		**Elongation (%)**	
Y Type	R Type	Y Type	R Type
⩾110	⩾90	⩾3	⩾20

5.2.4 *Bending*

When bending broad-side at an angle of 90°, the cladding copper shall exhibit no cracks and the cladding copper and the aluminum core will not separate. The diameter "d" of the bending cylinder shall be in accordance with table 5.

Table 5. Diameter of Bending Cylinder Unit: mm

Thickness "a"	**Diameter of Bending Cylinder "d"**
3.00~4.00	16
5.00~6.00	24
8.00~10.00	40
12.00~14.00	56
16.00	64
20.00 and above	80

5.3 DC Resistivity, Conductivity and Current-Carrying-Capacity

The DC resistivity and conductivity of CCAC bus at 20℃ shall be in accordance with the table 6.

Table 6. DC Resistivity and Conductivity of CCAC bus

Model	DC Resistivity at 20℃ Ω • mm² /m		Conductivity %IACS	
	Copper Volume Ratio (%)		Copper Volume Ratio (%)	
	15	20	15	20
TBM-R	≤0.02550	≤0.02480	≥67.6	≥69.5
TBM-Y	≤0.02602	≤0.02606	≥66.2	≥68.1

NOTE: The physical parameters of CCAC bus at 20℃ shall be as follows:
a) Density: 3.94g/cm³
b) Temperature coefficient of resistance: 4.0×10^{-3}/℃
c) Linear expansion coefficient: 2.25×10^{-5}/℃

The current-carrying-capacity of rounded edged CCAC bus is specified in appendix A.

6 Testing Methods

6.1 Appearance inspection

CCAC busbar appearance will be visually inspected. The copper cladding layer shall be tightly, uniformly and continuously coated onto the aluminum core. The surface should be smooth, flat, and shall not possess any depressions, cracks, leakage of aluminum, rust, or stains.

6.1.1 *Size measurement*

The thickness of CCAC bus is measured by a micrometer and the width is measured by a Vernier caliper with accuracy no lower than 0.02mm. In a sample of 1m length, 5 uniform measurement points are taken. The average deviation shall be accordance with table 2 and table 3.

6.1.2 *Measurement of radius of the rounded edged shape*

The radius of rounded edged CCAC bus is measured by an R-gauge instrument, the measurement results should be consistent with the provisions of 5.1.5.

6.1.3 *Measurement of flatness*

The fixed length sample containing the measured surface is placed face down onto a reference plate. The maximum gap distance between the surface and the reference plane is directly measured by a feeler gauge instrument.

6.1.4 *Volume ratio of cladding copper*

The volume ratio of cladding copper is determined by the weighting method. Take a length of 200 mm flat sample with both ends flush, measure the length "l" of the sample by vernier caliper and the weight "m" by balance scale with accuracy no less than 0.1g. By considering the formula to calculate cross-sectional area as well as copper and aluminum density, the volume ratio of cladding copper can be carried out according to the formula (3) and (4) for the rounded edged and full rounded edged cross-section respectively.

$$V_{Cu}=\left[\frac{m\times 1000}{6.187l(a\times b-0.087a\times a)}-0.437\right]\times 100\% \qquad \cdots(3)$$

$$V_{Cu}=\left[\frac{m\times 1000}{6.187l(a\times b-0.214a\times a)}-0.437\right]\times 100\% \qquad \cdots(4)$$

Among it:

V_{Cu} ——Volume ratio of cladding copper;

m ——Sample weight, unit: "g";

l ——Sample length, unit:"mm";

a ——Bus thickness, unit: "mm";

b ——Bus width, unit: "mm";

6.1.5 *Thickness measurement of cladding copper*

The thickness measurement of the cladding copper is performed by preparing a small flat sample, both ends flat, placed under a microscope with a 100x magnification. The measured position is shown in Figure 2. The thickness of cladding copper is evenly measured along the circumference by order; at least sixteen measurements are taken as indicated in Fig.2. Taking the minimum measurement data as the value of thickness of the thinnest point on the cladding copper, the average thickensss is calculated according to the measurements, to find the ratio of the thinnest point of copper layer to the average copper thickness.

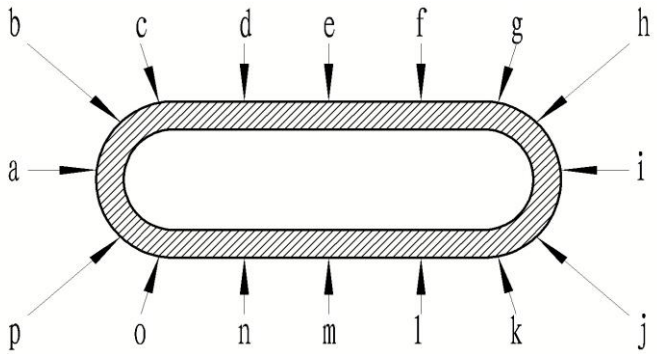


Fig.2. Method of thickness measurement

6.2 Physical property test

6.2.1 *Material inspection*

The material of CCAC bus is in accordance with the provisions of GB/T5231-2012 and GB / T1196-2008, and shall comply with the provisions of 5.1.1.

6.2.2 *Density test*

With a flat sample 100 mm long, the nominal size and length were measured in length in accordance with the provisions of GB/T4909.2-2009, and the volume was calculated and mass measured by a precision balance accurate to 1 milligram. To calculate the density by formula (5):

Density = Mess / Volume ……………………………….. (5)

6.2.3 *Temperature property test*

Three samples 200mm long underwent a thermal shocking cycling test with temperature switches between -40°C and +110°C. The CCAC busbars were placed in a freezer set at -40°C and then taken out after a 15 minute insulation. After placed in air for 10 minutes, the samples were then placed into a oven at +110°C for a 15 minute insulation and then taken out for a 10 minute natural cooling period. This pattern was repeated for 100 cycles. The test was performed according to the standard test method stipulated in 6.3. The bonding layer shear strength did not drop below the minimum qualifying 60MPa.

6.3 Mechanical strength test

6.3.1 *Bending test*

Experiment conducted on the broadside of a CCAC busbar sample. Bending test is carried out according to the bending diameter specified in Table 5. To qualify, the sample surface shall show no wrinkles or cracks.

6.3.2 *Tensile strength and elongation test*

With 3 CCAC busbar samples 300-500mm long from both class Y and class R, for the tensile strength and elongation test, the average value shall comply with the provisions of table 4.

6.3.3 *Test of interfacial bonding shear strength*

Preparing a length of 150mm, width “L1” of 20±1 mm of CCAC busbar sample, one side of cladding copper and aluminum core is removed at point “A” through

mechanical process or electric spark cutting without damage to the other side of cladding copper. Then, the cladding copper is removed on the other side of the sample at point "B" without damage to the aluminum core. At the time of the operation, the width of groove "d" should not exceed 4 mm and the distance "L2" between the two grooves should be 2± 0.1mm, as shown in Fig.3. There should be no less than 3 samplings per each specification. The sample then undergoes a tensile test through the tensile testing machine. Prior to the tensile test, the actual width "L1" and "L2" of the sample is measured by vernier caliper; during the test, the tensile speed should be between 20mm/min~200mm/min to stretch the sample until complete separation of the cladding copper and aluminium core to determine the maximum tensile force F_{max}. Then, the interfacial bonding strength (shear strength) "P" is calculated according to formula (6) .

$$P = F_{\max} / S_b \quad \cdots\cdots\cdots\cdots\cdots\cdots (6)$$

Of which:

P ——Interfacial Bonding Strength, the unit is "MPa";

F_{max} ——The maximum tensile stress during the tensile test, the unit is "N";

S_b ——The measured interfacial bonding area $L_1 \times L_2$, the unit is "mm^2"

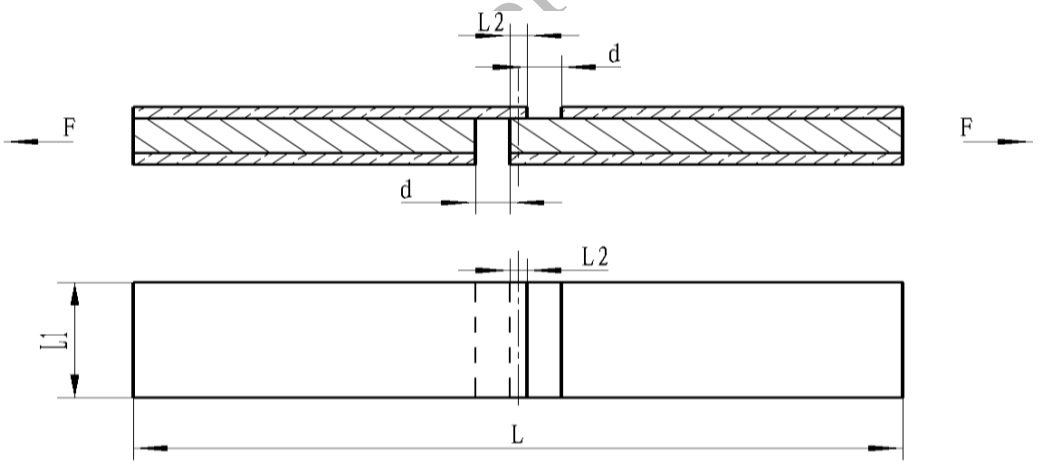


Figure 3. Schematic diagram of sample preparation for interfacial bonding shear strength test of CCAC bus

6.4 Resistivity measurement

In accordance with the provisions of GB/T 3048.2-2009, the DC resistance of CCAC busbar is measured and converted into the resistivity at 20℃. It shall comply with the provisions of 5.3.

7 Inspection Guidelines

CCAC busbar shall be subjected to quality inspection department prior to shipment and will be issued a certificate. The inspection is classified as the factory inspection and type test.

Table 7. Test Requirements

No.	Testing Contents	Standarts Coding	Factory Inspection	Test Test
1	Appearance Quality	5.1.3	√	√
2	Material	5.1.1	-	√
3	Size & Deviation	5.1.4; 5.1.5	√	√
4	Volume Ratio and Thickness of Cladding Copper	5.1.8; 5.1.9	√	√
5	Flatness	5.1.7	√	√
6	Density	5.1.10	√*	√
7	Temperature	5.2.1	-	√
8	Tensile Strength & Elongation	5.2.3	√	√
9	Bending	5.2.4	√	√
10	Interfacial Shear Bonding Strength	5.2.2	√	√
11	DC Resistivity	5.3	-*	√

7.1 Factory inspection

a) Continuously produced products are categorized by grade, material, and specification.

b) Factory inspection, listed in table 7, should include a visual appearance inspection.

7.2 Type test

Under the following conditions, a type test shall be performed:

a) When launching new products or transferring old products and the production is in the trial phase.

b) After formal production, product structure or material components has been changed.

c) Reinitializing production after more than one year of halting production.

d) When the National/state (province) Quality Supervision & Inspection Authority requires the issuance of a type test.

No less than three type test samples are randomly sampled from a batch of products out of the production line. The test content is stipulated in table 7. When the results of a type test does not meet any of the requirments of the test content in table 7, the batch is disqualified.

7.3 Acceptance test

The acceptance test is contracted on an individual basis. Acceptance tests can be carried out according to user's or buyer's request. The content of acceptance test is based on the contract terms negotiated among the parties.

8 Marking, Packaging, Transportation and Storage

8.1 Marking

Each package should be tagged with the following marks:

a) Manufacturer name, address and trademark;
b) Product name;
c) Product model and specification;
d) Product batch number;
e) Gross weight, net weight, length and number of root;
f) Delivery date: year / month / day;
g) Crane and forklift handling identifier;
h) Implementation of standard: QB/ACM 01.01—2014.

8.2 Coating and Wrapping

All CCAC busbars are coated with an antioxidant protection with life lasting no shorter than 1 year.

All CCAC busbars are wrapped with a thin insulating plastic film layer.

8.3 Length for delivery and packaging

a) For domestic delivery of CCAC busbar, the standard length of the product is 6m. For international delivery, the standard length of the product is 5.5m or 5m. A custom fixed length can be delivered and negotiated by agreement.
b) CCAC busbar should be bundled or box packaged. The packaging surface should be clearly identified. Each package shall be of the same type and same specifications. If

there is a partial segment, the length and number of partial segments shall be marked.

c) The product should be packed properly and the packaging material shall conform to requirements of anti-humidity, anti-corrosion and prevention of mechanical damage.

d) Each package should be accompanied by a product qualification certificate issued by the quality inspection department. Each batch of products should be issued with the factory inspection report by the quality inspection department of the seller.

8.4 Transportation and storage

CCAC should be transported in a manner that prevents moisture, corrosion, damage from loading and unloading, and any other incidental damages as a result of transportation. The CCAC bus should be properly stored in a warehouse which is dry, ventilated, rain-proof, water-proof and contains no alkaline substances or hazardous gases.

Appendix A

（Documentative Annex）

Current-Carrying-Capacity Table of Rounded Edged CCAC Bus

The reference value of Current-Carrying-Capacity of rounded edged CCAC bus under different temperature conditions are presented in table A with the ambient temperature less than 35℃.

Table A. Current-Carrying-Capacity Table of Rounded Edged CCAC Bus

(with the ambient temperature less than 35℃)

Specification (a×b) mm	**Current-Carrying-Capacity** (A)			
	15% Volume Ratio of Cladding Copper		20% Volume Ratio of Cladding Copper	
	25K	35K	25K	35K
4×30	329	346	338	357
4×40	337	436	347	449
5×40	377	460	388	473
5×50	464	602	478	620
6×60	611	785	628	808
6×80	777	999	799	1027
6×100	969	1301	997	1339
8×60	717	920	737	946
8×80	886	1137	911	1170
8×100	1095	1399	1126	1439
8×120	1279	1621	1315	1668
10×60	802	1028	825	1057
10×80	994	1279	1023	1316
10×100	1228	1559	1264	1603
12×120	1408	1799	1449	1850

Note 1. The Current-carrying capacity of CCAC bus is derived based on single bar placed flat;

Note 2. The test condition is under no sunshine or wind and the CCAC bus has no coating.

Appendix B.

（Documentary Annex）

Methodalagy of Sampling

B. 1 Sampling Plan

The testing items of this standard as specified in Table 7 is subject to factory inspection, in addition to appearance quality which shall be checked on any item. Other items to be checked as special inspection level S-3, acceptance quality limitation is based on AQL0.65. The number of samples and the determined value are shown in table B.1.

B. 2 Sampling Rule

When sampling, an even sampling is required during the continuous production from the continuous production line. The sampling number shall not be less than the number of samples specified in table B.1.

Table B.1 The Number of Samples and the Determined Value of a Normal Inspection Sampling

Batch No. (N) Piece(s)	Numbenr of Samples (n)	Acceptance (Ac)	Rejection (Re)
16~50	3 (3)	0	1
51~150	5 (5)	0	1
151~500	8 (8)	0	1
501~3200	13 (13)	0	1
3201~35000	20 (20)	0	1

B. 3 Judgement Rule

a) the number of testing samples should be equal to the number given by the scheme. If the number of samples is equal to or more than the batch, do 100% inspection.

b) if it is found that the unqualified number is less than or equal to the receiving number (Ac), the batch of products can be received. If it is found that unqualified number greater than or equal to the rejection number (Re), the batch of products cannot be received.

c) for individually determining the test items as specified in Table 7, if the unqualified number is greater than or equal to the rejection number, it can be double sampled according to the number of samples in parentheses. If it is found that the

unqualified number greater than or equal to the rejection number, the batch of products cannot be received.