Automotive parts - Current capacity of low-voltage cables

Introduction

The content of this standard has not been reviewed since it was last revised in 2001. However, since **JASOD 611** and **JASO D603** were revised recently, it became necessary to add the current capacities for newly added cables. Therefore, in addition to adding the method for determining the current capacities of these cables, a complete review of the standard was also conducted.

1. Scope

This standard specifies the method of determining the allowable current, the reduction coefficient of the allowable current due to cable bundling, and the method of determining the overcurrent limit for the low-voltage cables used in automobiles (hereinafter referred to as “cables”).

2. Definitions

The following standards, when referred to in this standard, constitute a part of the specifications of this standard. As required, the most recently updated version of the applicable standard (including addenda) shall be applied.

JASO D603	Automotive parts – Low-voltage aluminum cables
JASO D611	Automotive parts – Low-voltage cables
JASO D618	Automotive parts – Test methods for low-voltage cables
JIS C30058	Test methods for rubber or plastic insulated wires and cables
JIS C34068	Low-voltage cables for automobiles

3. Definitions

The definitions of the main terms used in this standard shall be as follows.

3.1 Current capacity of cables

This is a collective term for the allowable current, overcurrent limit, current value multiplied by the reduction coefficient of the allowable current due to bundling of cables, and the like.

3.2 Allowable current

When a cable circuit is designed, this is the limit value of the current that can practically and safely be carried by the cable from the standpoint of the service lifetime of the cable. It also considers the degradation of the insulation around the cable due to temperature. However, this value shall be specified in accordance with the usage time, in addition to other factors such as the insulation material of the cable, the ambient temperature, and the like.

3.3 Overcurrent limit

When a cable carries a current that temporarily exceeds the allowable current due to external factors or other causes, this is the specified limit value of the overcurrent in accordance with the period of time that the current is carried through the cable.

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3.4 Reduction coefficient

When multiple cables are used in a bundle, this is the coefficient by which the allowable current is multiplied.

4. Types of cables

Table 1 shows the types of cables covered by this standard.

Table 1 Types of cables

Type		Name	Symbol	Applicable standard
Thick insulation		Low-voltage cables for automobiles	AV	**JIS C3406**
		Vinyl insulated low-voltage cables for automobiles	AV [(a)] HEB HDEB	**JASO D611**
		Halogen-free insulation low-voltage cables for automobiles	HF	**JASO D611**
		Thick insulation aluminum low-voltage cables for automobiles	AL	**JASO D603**
Thin insulation 1		Thin insulation low-voltage cables for automobiles type 1	AVS	**JASO D611**
Thin insulation 2		Thin insulation low-voltage cables for automobiles type 2	AVSS CAVS CAV	**JASO D611**
		Very thin halogen-free insulation low-voltage cables for automobiles	HFSS	**JASO D611**
		Compact-stranded wire very thin halogen-free insulation low-voltage cables for automobiles	CHFS	**JASO D611**
		Thin insulation aluminum low-voltage cables for automobiles	ALSS	**JASO D603**
Thin insulation 3		Thin insulation low-voltage cables for automobiles type 3	CAVUS	**JASO D611**
		Compact-stranded wire super thin halogen-free insulation low-voltage cables for automobiles	CHFUS	**JASO D611**
		Super thin insulation aluminum low-voltage cables for automobiles	ALUS	**JASO D603**
For grounding		Low-voltage grounding cables for automobiles	EB	**JASO D611**
Heat-resis-tant 1	Thick insulation	Heat-resistant cross-linked vinyl insulated low-voltage cables for automobiles	AVX AVFX HEBX	**JASO D611**
	Thin insulation 1	Heat-resistant cross-linked thin vinyl insulated low-voltage cables for automobiles	AVSX AVXS	**JASO D611**
	Thin insulation 2	Heat-resistant cross-linked very thin vinyl insulated low-voltage cables for automobiles	AVSSX	**JASO D611**
		Heat-resistant very thin vinyl insulated low-voltage cables for automobiles	AVSSH	**JASO D611**
	For grounding	Heat-resistant cross-linked vinyl insulated low-voltage grounding cables for automobiles	EBX	**JASO D611**
Heat-resis-tant 2	Thick insulation	Heat-resistant cross-linked polyethylene insulated low-voltage cables for automobiles	AEX	**JASO D611**
	Thin insulation 2	Heat-resistant cross-linked very thin polyethylene insulated low-voltage cables for automobiles	AESSX	**JASO D611**

Note: [(a)]
Cables with a structure not specified in **JIS C3406**.

5. Preconditions and allowable current

5.1 Preconditions

The allowable current specified in this standard shall be based on the following conditions. In the case of an allowable current that has different preconditions, the allowable current shall be re-defined in accordance with those conditions.

a) Total period of current conduction

The total period of current conduction of the design of the cable shall be 10,000 hours[(1)].

b) Allowable cable temperature

The maximum temperature of the cable during use shall not exceed the allowable cable temperature listed in **Table 2**. In this case, the determination of degradation of the insulation due to the temperature shall be a rate of elongation of 100%[(2)] or be determined by performing a voltage-resistance test after coiling[(3)].

Note: [(1)]

This value was set under the assumption that the vehicle is used for 3 hours each day over a period of 10 years.

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Note: [(2)]

This is in accordance with **5.3** (Insulator tension test) of **JASO D618**. However, for the cables with the AV symbol that are specified in **JIS C3406**, the condition shall be in accordance with that specified in **4.16** (Tension on insulation and sheathing) of **JIS C3005**.

Note: [(3)]

Applicable to cables with insulation material that is made from halogen-free compounds and the test shall be in accordance with the specifications in **5.9** (Heat resistance test 2) of **JASO D618**.

Table 2 Allowable temperatures for each type of cable

Type		Symbol	Insulation material	Allowable cable temperature T_1
Thick insulation		AV, HEB or HDEB	Vinyl chloride compounds	80°C
		HF	Halogen-free compounds	80°C
		AL	Vinyl chloride compounds	80°C
			Halogen-free compounds	80°C
Thin insulation 1		AVS	Vinyl chloride compounds	80°C
Thin insulation 2		AVSS, CAVS or CAV	Vinyl chloride compounds	80°C
		HFSS or CHFS	Halogen-free compounds	80°C
		ALSS	Vinyl chloride compounds	80°C
			Halogen-free compounds	80°C
Thin insulation 3		CAVUS	Vinyl chloride compound	80°C
		CHFUS	Halogen-free compounds	80°C
		ALUS	Vinyl chloride compound	80°C
			Halogen-free compounds	80°C
For grounding		EB	Vinyl chloride compound	80°C
Heat-resistant 1	Thick insulation	AVX, AVFX or HEBX	Cross-linked vinyl chloride compounds	100°C
	Thin insulation 1	AVSX or AVXS	Cross-linked vinyl chloride compounds	100°C
	Thin insulation 2	AVSSX	Cross-linked vinyl chloride compounds	100°C
		AVSSH	Heat-resistant vinyl chloride compounds	100°C
	For grounding	EBX	Cross-linked vinyl chloride compounds	100°C
Heat-resistant 2	Thick insulation	AEX	Cross-linked polyethylene compounds	120°C
	Thin insulation 2	AESSX	Cross-linked polyethylene compounds	120°C

5.2 Allowable current

The allowable current shall be calculated in accordance with Equation (1).

$$I_p^2 r_{T1} = (T_1 - T_2)/R \quad \text{.....(1)}$$

where, I_P: allowable current of cable (A)

r_{T1}: conductor resistance of cable at T_1°C (Ω/cm)

T_1: allowable cable temperature (°C)

T_2: ambient temperature (°C)

R: thermal resistance (°C·cm/W)

In addition, the conductor resistance r_{T1} of the cable at T_1°C shall be calculated in accordance with Equation (2).

$$r_{T1} = r_{20}[1+\alpha_1(T_1-20)] \quad \text{.....(2)}$$

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where, r_{20}: conductor resistance of cable at 20 °C

The conductor resistance value specified in the applicable standard shown in **Table 1** (**JASO D603**, **JASO D611**, or **JIS C3406**) shall be used for this value.

α_1: temperature coefficient of the conductor resistance at 20 °C (1/°C)

In the case of a copper conductor this shall be 0.00393 and in the case of an aluminum conductor this shall be 0.00400.

The thermal resistance R shall be calculated in accordance with Equation (3).

$$R=R_1+R_2 \quad (3)$$

where, R_1: thermal resistance of insulation (°C·cm/W)

R_2: surface radiation thermal resistance (°C·cm/W)

The thermal resistance of the insulation shall be calculated in accordance with Equation (4).

$$R_1=(P_1/2\pi)\log_e(d_2/d_1) \quad (4)$$

where, P_1: specific thermal resistance of insulation (°C·cm/W)

For vinyl chloride compounds and cross-linked vinyl chloride compounds this shall be 600, for cross-linked polyethylene compounds this shall be 400, and for halogen-free compounds this shall be 450.

d_1: outside diameter of conductor (mm)

d_2: outer diameter of insulated cable (mm)

The surface radiation thermal resistance shall be calculated in accordance with Equation (5).

$$R_2=10P_2/\pi d_2 \quad (5)$$

where, P_2: specific surface radiation thermal resistance of cable (°C·cm^2/W)

When $d_2 \leq 12.5$ mm, then $P_2=300+32\,d_2$

When $d_2>12.5$ mm, then $P_2=700$

Note:

The equation for calculating the voltage drop for the allowable current value of the cable shall be as follows.

$$E=I_p r_{T1}\times 10^5$$

where, E: voltage drop of cable (mV/m)

I_P: allowable current of cable (A)

r_{T1}: conductor resistance of cable at T_1°C (Ω/cm)

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6. Reduction coefficient of allowable current due to cable bundling

When multiple cables are bundled together for use, **Table 3** shows the reduction coefficient by which the allowable current is multiplied. However, this reduction coefficient is only applicable to the cables that are carrying current at the same time and it is not related to the total number of cables that are bundled together. It also does not apply to cables carrying small currents, such as in control circuits and electronic circuits, which do not contribute to a rise in temperature.

Table 3 Reduction coefficients of allowable current due to cable bundling

Number of current-carrying cables in bundle	1	2	3	4	5	6 to 7	8 to 10	11 to 12
Reduction coefficient	1.00	0.80	0.70	0.60	0.55	0.50	0.45	0.40

7. Preconditions and overcurrent limit

7.1 Preconditions

The overcurrent limit is specified based on the limit temperature of the cable. This is the temperature at which the insulation begins to emit smoke or deform due to the rise in the temperature of the cable conductor. In the case of an overcurrent limit that has different preconditions, the overcurrent limit shall be re-defined in accordance with those conditions.

Table 4 specifies the limit temperatures to be used when calculating the overcurrent limit.

Table 4 Limit temperatures for each type of cable

Type		Symbol	Insulation material	Allowable cable temperature T_3	Phenomenon
Thick insulation		AV, HEB or HDEB	Vinyl chloride compounds	140°C	Smoke emission
		HF	Halogen-free compounds	150°C	Deformation
		AL	Vinyl chloride compounds	150°C	Smoke emission
			Halogen-free compounds	150°C	Deformation
Thin insulation 1		AVS	Vinyl chloride compounds	150°C	Smoke emission
Thin insulation 2		AVSS, CAVS or CAV	Vinyl chloride compounds	150°C	Smoke emission
		HFSS or CHFS	Halogen-free compounds	165°C	Deformation
		ALSS	Vinyl chloride compounds	165°C	Smoke emission
			Halogen-free compounds	165°C	Deformation
Thin insulation 3		CAVUS	Vinyl chloride compounds	150°C	Smoke emission
		CHFUS	Halogen-free compounds	165°C	Deformation
		ALUS	Vinyl chloride compounds	165°C	Smoke emission
			Halogen-free compounds	165°C	Deformation
For grounding		EB	Vinyl chloride compounds	140°C	Smoke emission
Heat-resistant 1	Thick insulation	AVX, AVFX or HEBX	Cross-linked vinyl chloride compounds	170°C	Smoke emission
	Thin insulation 1	AVSX or AVXS	Cross-linked vinyl chloride compounds	170°C	Smoke emission
	Thin insulation 2	AVSSX	Cross-linked vinyl chloride compounds	170°C	Smoke emission
		AVSSH	Heat-resistant vinyl chloride compounds	170°C	Smoke emission
	For grounding	EBX	Cross-linked vinyl chloride compounds	170°C	Smoke emission
Heat-resistant 2	Thick insulation	AEX	Cross-linked polyethylene compounds	190°C	Smoke emission
	Thin insulation 2	AESSX	Cross-linked polyethylene compounds	190°C	Smoke emission

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7.2 Overcurrent limit

The overcurrent limit shall be calculated in accordance with Equation (6).

$$I_o^2\ r_{T3}=(T_3-T_2)/R(1-e^{-\alpha_2 t}) \quad \text{.....(6)}$$

where, I_0: overcurrent limit of cable (A)

r_{T3}: conductor resistance of cable at T_3°C (Ω/cm)

T_3: limit temperature of cable (°C)

T_2: ambient temperature (°C)

R: thermal resistance (°C·cm/W)

α_2: reciprocal of the thermal time constant (τ)

t: time (s)

In addition, the conductor resistance r_{T3} of the cable at T_3°C shall be calculated in accordance with Equation (7).

$$r_{T3}=r_{20}[1+\alpha_1(T_3-20)] \quad \text{.....(7)}$$

where, r_{20}: conductor resistance of cable at 20°C

The conductor resistance value specified in the applicable standard shown in **Table 1** (**JASO D603**, **JASO D611**, or **JIS C3406**) shall be used for this value.

α_1: temperature coefficient of the conductor resistance at 20°C (1/°C)

In the case of a copper conductor this shall be 0.00393 and in the case of an aluminum conductor this shall be 0.00400.

The thermal resistance, R, shall be calculated in accordance with Equation (3).

The thermal resistance of the insulation shall be calculated in accordance with Equation (4).

The surface radiation thermal resistance shall be calculated in accordance with Equation (5).

The thermal time constant τ and the thermal capacity C shall be calculated using Equation (8) and Equation (9) respectively.

$$\tau = CR \quad \text{.....(8)}$$

$$C=\sum(WH)=H_1W_1+H_2W_2 \quad \text{.....(9)}$$

where, W_1: mass of conductor (g/cm)

W_2: mass of insulation (g/cm)

H_1: thermal capacity of conductor material (J/°C·g)

H_2: thermal capacity of insulation material (J/°C·g)

Note:

The measured values for the mass of the conductor and mass of the insulation shall be used.

Table 5 shows the thermal capacities of the related materials.

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