OICA contribution to HV safety

provisional version

Part 1: OICA replies to NHTSA‘s question

Part 2: OICA's proposal for low energy content in Y-capacitances for in-use (i.e. active driving mode) and post-crash situations

provisional version

Part 1: OICA replies to NHTSA‘s questions for HV Safety

provisional version

0.2 J low energy option for current duration greater than 10 msec: The 60479-2 Section 11.4.2 suggests using IEC 60479-1 Figure 20. I questioned the validity of using Figure 20 instead of Figure 22 on IEC 60479-1. I believe it was OICA who reanalyzed and said that the answers are the same whether Figure 20 or 22 are used – the 0.2 J energy values fall in AC-2 and DC-2. We did this analysis and we get different results if Figure 20 is used instead of Figure 22. We would like discussion/clarification on this matter. Our thought is that since the capacitor discharge is unidirectional, Figure 22 (DC current) should be used.

REPLY: The statement is correct, Figure 22 of IEC 60479-1:2018 from should be used.

provisional version

DC AND AC TIME/CURRENT ZONE GRAPH COMPARISON, IEC 60479-1:2018

Sample calculated energy plots shows the .2 joule limit crosses into the zone 3 boundary on the AC signal graph.

- Coordinates plotted are:

1. (50mA, 160ms)-> .2 Joules
2. (100mA, 40ms) -> .2 Joules

- Based on this data, there is a difference in safety assessment using Figure 20 and Figure 22 of IEC 60479-1.

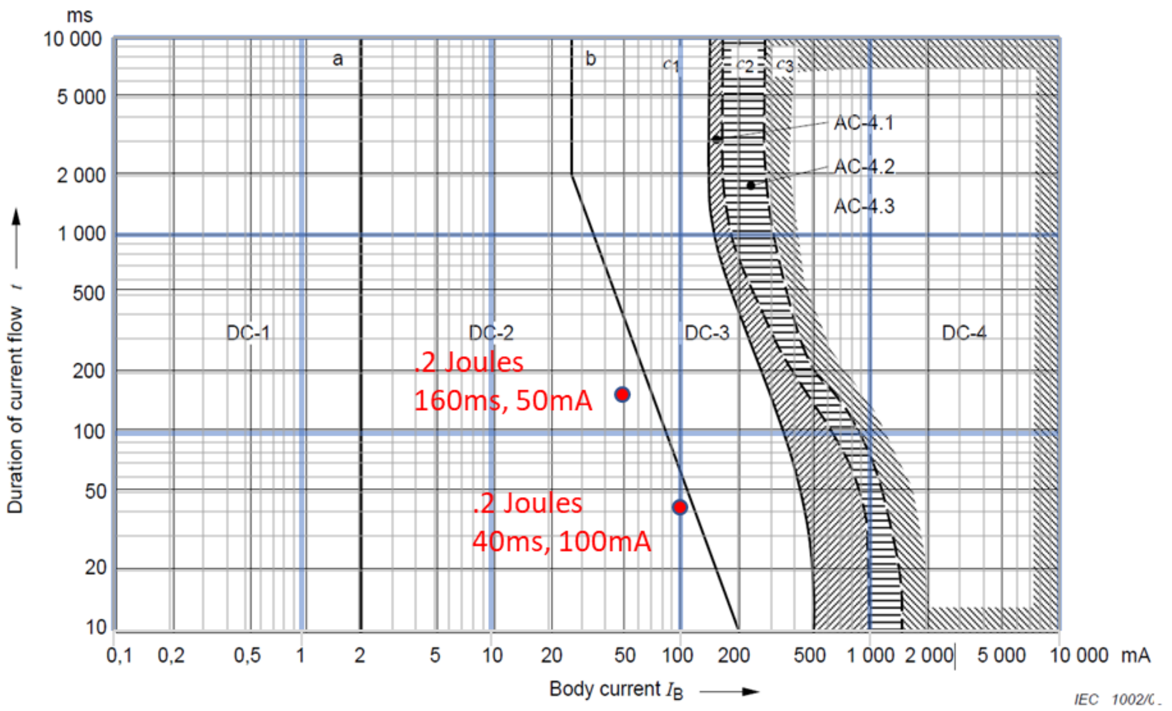

Figure 22 – Conventional time/current zones of effects of d.c. currents on persons for a longitudinal upward current path (for explanation see Table 13)

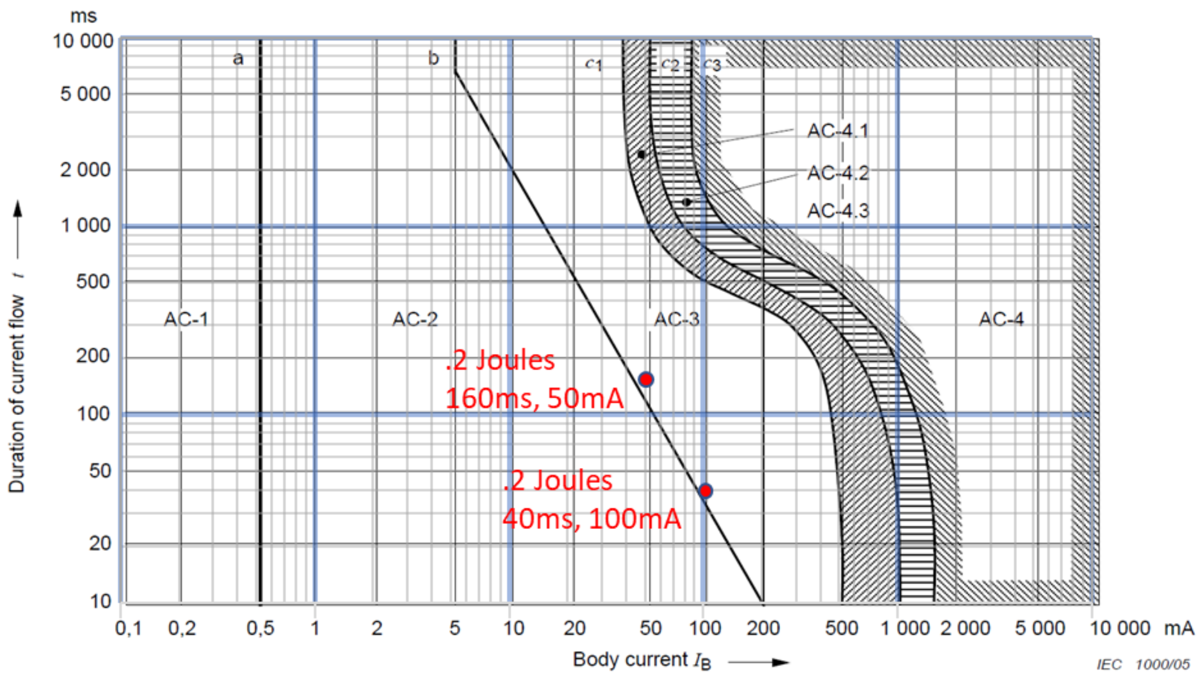

Figure 20 – Conventional time/current zones of effects of a.c. currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (for explanation see Table 11)

provisional version

NHTSA Comment on Industry Proposal

NHTSA Comments

- **GTR does not reference ISO 6469-3 for the "energy option" requirements. The GTR rationale references IEC 60479/2.**

Industry Proposal

General remark:

„in use" is too general, we should consider a) „active driving mode" (or „driving") and b) „charging" separately.

For case a):

Do not use 0.2 J from ISO 6469-3, but use values from SAE 1772-2017. SAE values are based on IEC 60479/2 and are scientifically based. See next slides.

For case b):

Further investigations are necessary (see expected presentation from U.S.) to define a value.

IEC 60479/2 mentions only areas; the concrete derivations of energy borders was done explicitly in SAE 1772-2017.

provisional version

NHTSA Comments on the proposed energy limit driving mode

Correct derivation of maximum capacitance

SAE J1772-2017 (maximum capacitance for vehicle and charging column)

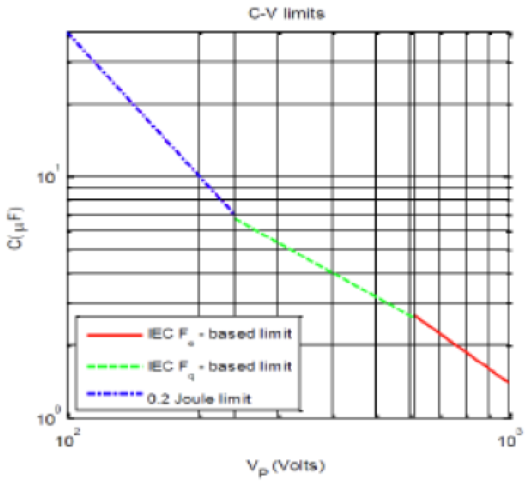

Figure 14 - Combined Y capacitance limit

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APPENDIX J – DC Y CAPACITANCE REQUIREMENT DERIVATION - INFORMATIVE

J.1 INTRODUCTION

This appendix describes the derivation of Y capacitance limits, as a function of voltage, from the limits given in IEC 60479-2. The IEC standard references quantities called specific fibrillating energy and specific fibrillating charge:

derived from C1 limit (IEC 60479-2):

$$C_{t,\max} = \begin{cases} \dfrac{0.4}{V_{\max}^2} & \text{for} \quad V_{\max} < 240 \\ \dfrac{0.0016}{V_{\max}} & \text{for} \quad 240 \le V_{\max} < 612 \\ 0.01387 \cdot V_{\max}^{-4/3} & \text{for} \quad 612 \le V_{\max} \end{cases}$$

0.2J (V < 240V)

0.5J (V = 612V)

0.7J (V = 1000V)

V_{max}	$C_{t,max}$
500 V	3,2 µF
1000 V	1,387 µF

*(Ct,max = sum of capacitances of both HV potentials, contains **1 µF** for charging column; see also IEC 61851-23:2014)*

Please note: detailled derivation of formulae and figure can be found in SAE J 1772-2017, Appendix J.

Mitigation from current energy requirement of 0.2J

provisional version

NHTSA Comments
- Is the industry proposing that the 0.2J energy limit should only apply to bus voltages less than 240V in active driving mode?

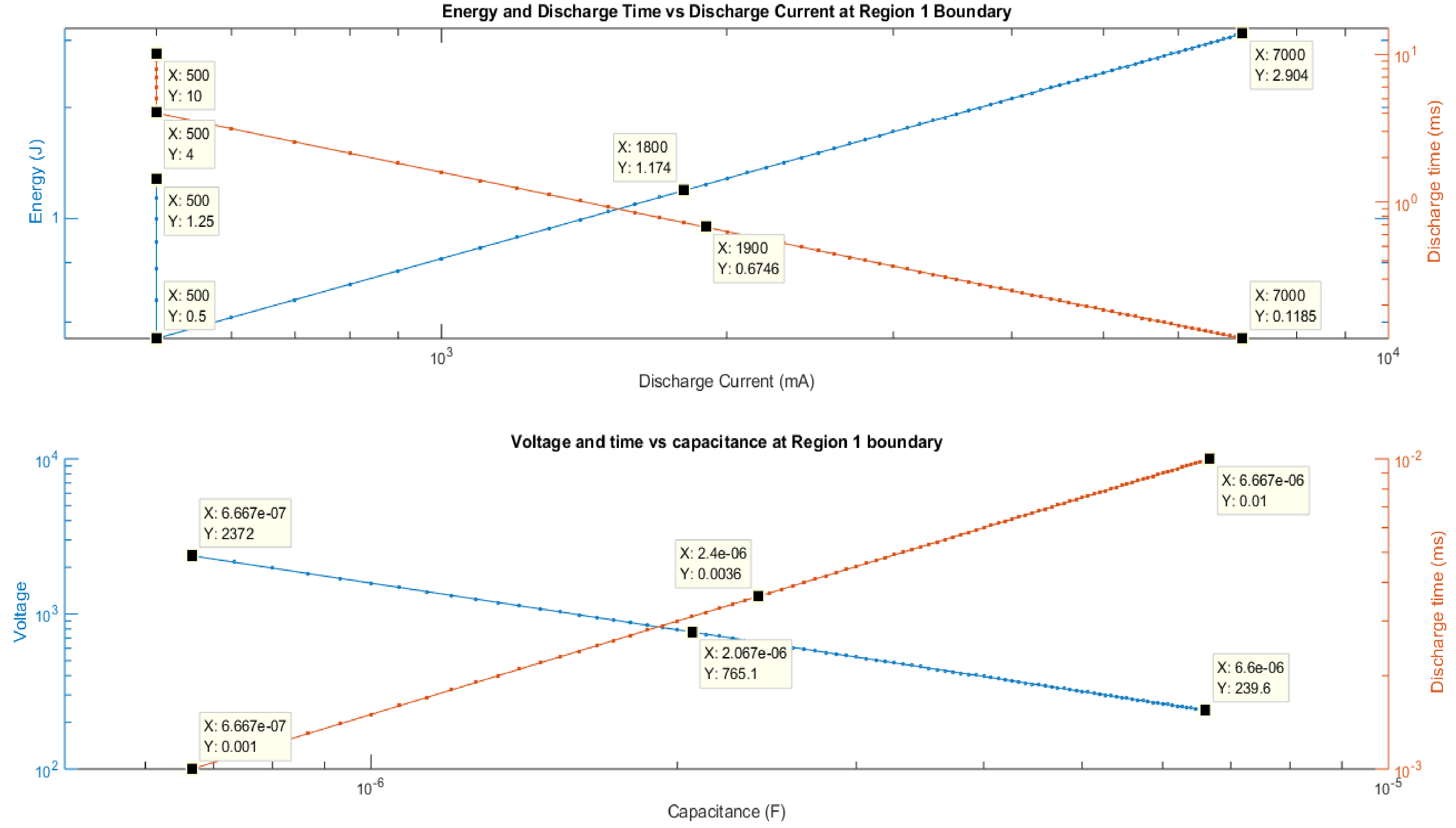
OICA: YES.

- 240V is the maximum voltage assuming 10ms discharge time or 6.67uF capacitance. This voltage limit can be increased with lower capacitor values without having to shift the energy threshold.
  - Refer to Voltage plot on slide 5. These values were derived using SAEJ1772 equations.

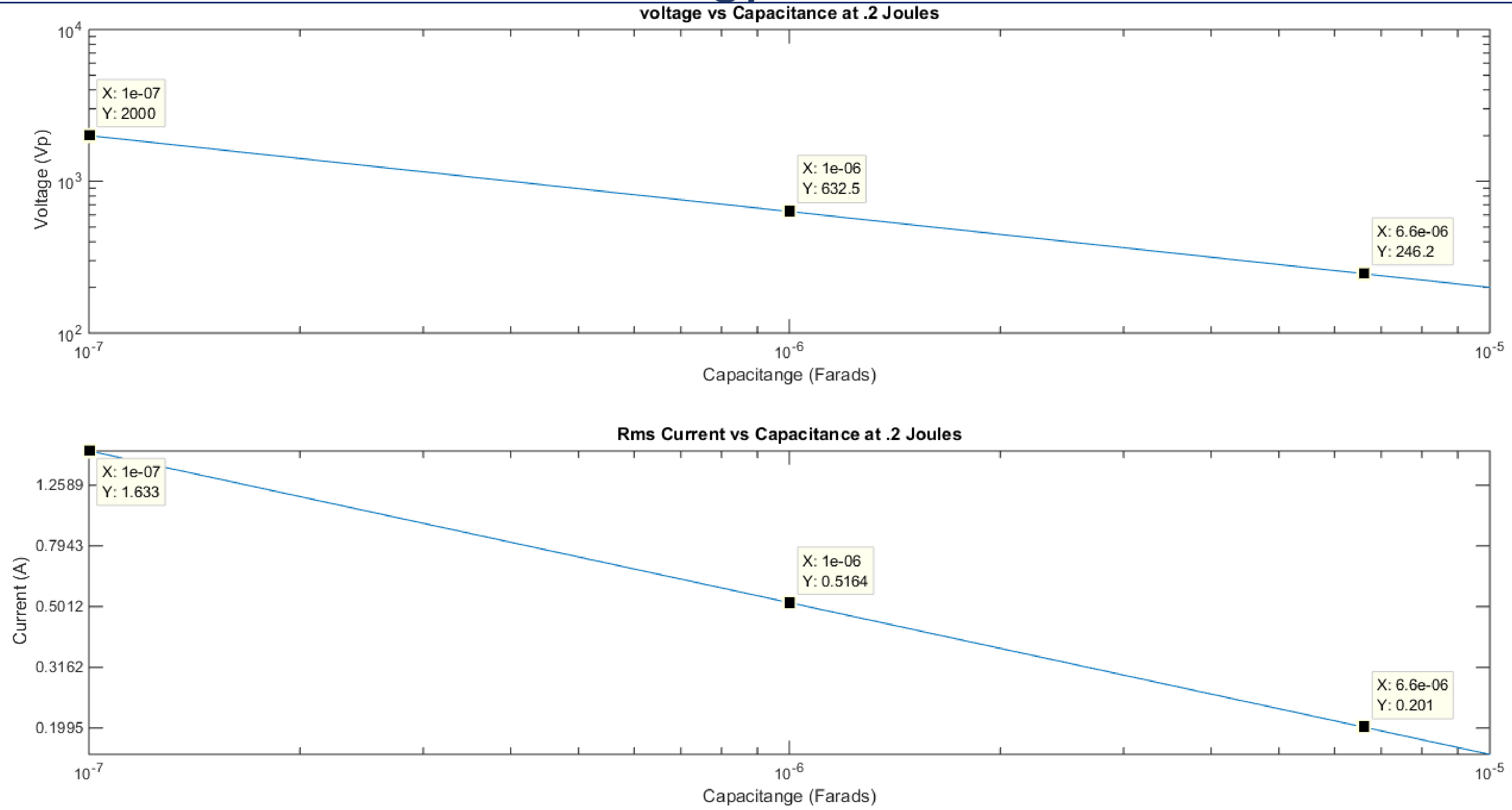
- Where do .5J and .7J lie on the IEC 60470-2 Figure 20 boundary map, compared to .2J?

See Figure "22 – Threshold of perception and threshold of pain for the current resulting from the discharge of a capacitor (dry hands, large contact area)"
IEC TS 60479-2, Edition 4.0 2017-10 (all of those values are not shown there)

NHTSA Energy and Voltage plots based on SAEJ1722 along the C1 boundary in Fig 20 of IEC 60479-2



NHTSA Voltage vs Capacitance plots based on SAEJ1722 for Energy = 0.2 J



provisional version

NHTSA Comments on Chinese Isolation Resistance proposal

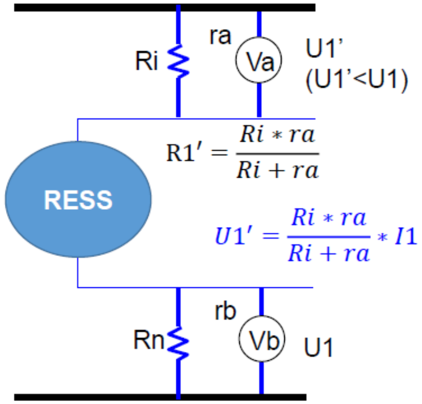
NHTSA Comments

- **This new proposal introduces and additional uncertainty which reduces the accuracy of the measurements.**
- **The current GTR Method only requires measuring one reference point to chassis when conducting the test.**
- **Based on these considerations, we believe the method currently used in the GTR is preferred.**

8

The isolation resistance calculation formula proposed by China should be revised.

Derivation of isolation resistance calculation formula



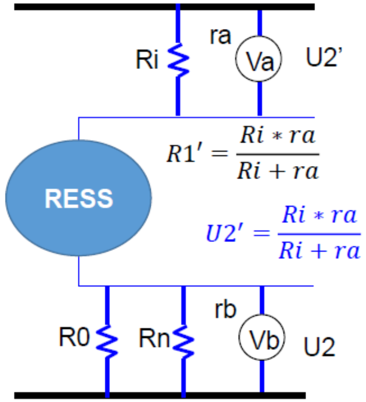
$$R1' = \frac{Ri*ra}{Ri+ra}$$

$$U1' = \frac{Ri*ra}{Ri+ra}*I1$$

$$R1 = \frac{Rn*rb}{Rn+rb}$$

$$U1 = \frac{Rn*rb}{Rn+rb}*I1$$

$$\frac{U1'}{U1} = \frac{\frac{Ri*ra}{Ri+ra}}{\frac{Rn*rb}{Rn+rb}}$$



$$R1' = \frac{Ri*ra}{Ri+ra}$$

$$U2' = \frac{Ri*ra}{Ri+ra}*I2$$

$$R1 = \frac{Rn*R0*rb}{R0*rb+Rn*rb+R0*Rn}$$

$$U2 = \frac{Rn*R0*rb}{R0*rb+Rn*rb+R0*Rn}*I2$$

$$\frac{U2'}{U2} = \frac{\frac{Ri*ra}{Ri+ra}}{\frac{R0*Rn*rb}{R0*rb+Rn*rb+R0*Rn}}$$

Revised calculation

➢ Supposed condition : ra ≠ rb

ra, rb: internal resistance of voltmeters

$$\frac{U1'}{U1} = \frac{\frac{Ri*ra}{Ri+ra}}{\frac{Rn*rb}{Rn+rb}} = \frac{Ri*ra*(Rn+rb)}{Rn*rb*(Ri+ra)}$$

$$\frac{U2'}{U2} = \frac{\frac{Ri*ra}{Ri+ra}}{\frac{R0*Rn*rb}{R0*rb+Rn*rb+R0*Rn}} = \frac{Ri*ra*(R0*rb+Rn*rb+R0*Rn)}{R0*Rn*rb*(Ri+ra)}$$

$$R0\left(\frac{U2'}{U2}-\frac{U1'}{U1}\right) = \frac{Ri*ra*(R0*rb+Rn*rb+R0*Rn)}{Rn*rb*(Ri+ra)} - \frac{R0*Ri*ra*(Rn+rb)}{Rn*rb*(Ri+ra)}$$

$$= \frac{Rn*Ri*ra*rb}{Rn*rb*(Ri+ra)} = \frac{Ri*ra}{Ri+ra}$$

$$\frac{1}{R0\left(\frac{U2'}{U2}-\frac{U1'}{U1}\right)} - \frac{1}{ra} = \frac{Ri+ra}{Ri*ra} - \frac{1}{ra} = \frac{1}{Ri}$$

⇨

Correct calculation formula

$$\mathbf{Ri} = \frac{\mathbf{1}}{\frac{\mathbf{1}}{\mathbf{R0}\left(\frac{\mathbf{U2'}}{\mathbf{U2}}-\frac{\mathbf{U1'}}{\mathbf{U1}}\right)} - \frac{\mathbf{1}}{\color{red}{\mathbf{ra}}}}$$

There is no need to use two voltmeters which have the same internal resistance.

NHTSA Comments

- We would like to open a discussion regarding the use of high impedance voltmeters for this test. Possibly >100Mohm.

- The use of these high impedance meters would make the measurements more reliable by making '1/ra' more negligible.

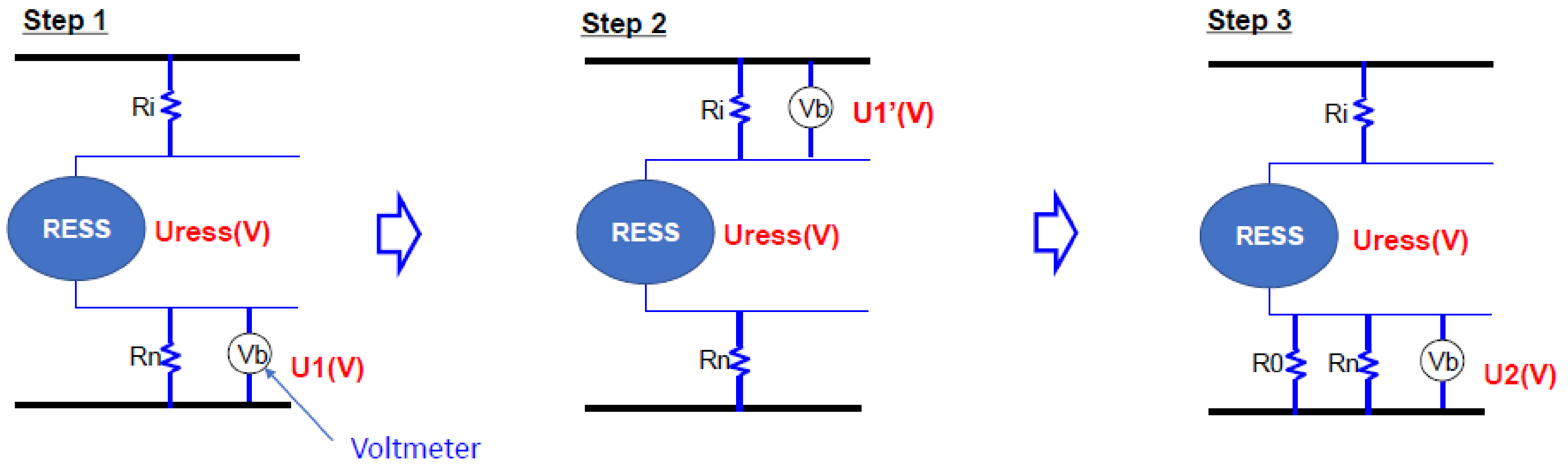
NHTSA: “In response to the Chinese proposal on an alternative method of calculating electrical isolation by using two different voltmeter readings, JARI showed that the resistance of the two voltmeters need not be the same but that the voltmeter resistance influences the computed electrical isolation value. We would like to discuss the need for including such a method in the GTR as JARI suggested. We are concerned that if the voltmeter resistance is not high enough, it could result in inaccurate values of electrical isolation and reduce the reproducibility of the assessment.”

OICA REPLY:

see next slides (as provided by Kinoshita-san)

provisional version

GTR20 measurement procedures



- The place of a voltmeter needs to be changed several times for the isolation resistance measurement.
- *Rn > Ri >> Internal resistance of the voltmeter* → Measured voltage values (U1 and U2) are almost zero.
  → In some cases, the values may be too huge for a proper calculation.

$$\mathrm{Ri} = \mathrm{R0} \times \mathrm{Uress} \times \left(\frac{1}{\mathrm{U2}} - \frac{1}{U1}\right)$$

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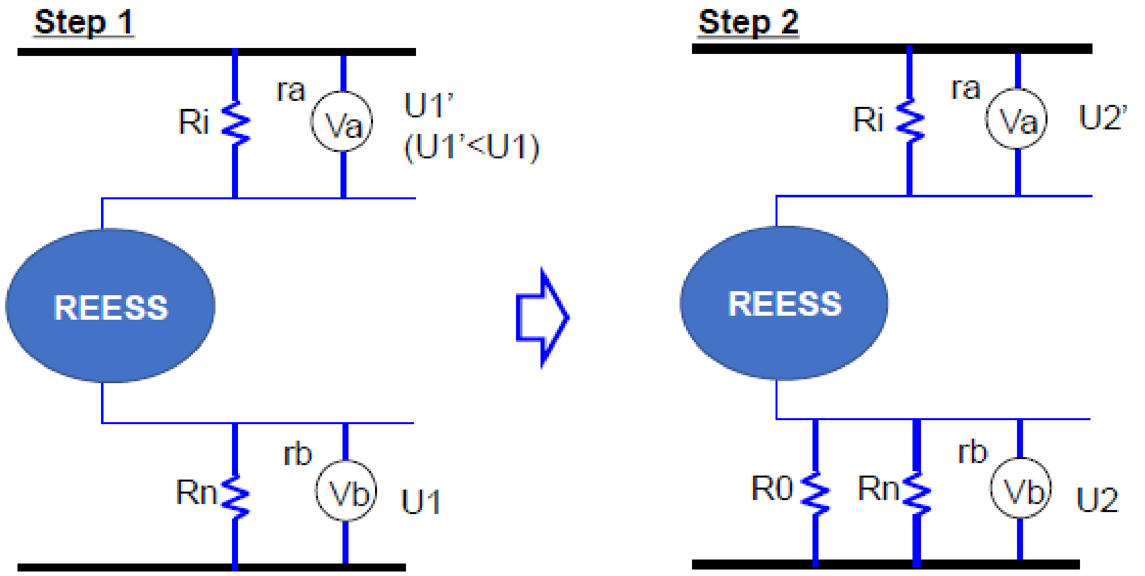
Measurement procedures proposed by China



- Two voltmeters can stay as they are during the isolation resistance measurement.
- *Rn > Ri >> Internal resistance of the voltmeter*
  → Measured voltage values (U1,U2, U1',U2') are no problem for calculation.

$$Ri\_f = \frac{1}{\frac{1}{R0\left(\frac{U2'}{U2} - \frac{U1'}{U1}\right)} - \frac{1}{10M\Omega}}$$

Appropriately sized values for calculation

provisional version

Voltmeter Specifications

Internal resistance of voltmeters are commonly around 10 Mohms.

YOKOGAWA DIGITAL MULTIMETER (TY520, TY530)

3.2 確度

温度／湿度：23 ± 5℃，80%RH 以下　確度：± (% of reading+digits)
　※ 応答時間は，各レンジ内で確度に入る時間

直流電圧測定 ⎓V

レンジ	分解能	確度	入力抵抗	最大入力電圧
600mV	0.1mV	0.09+2	10M Ω	1000V DC
6V	0.001V		11M Ω	
60V	0.01V		10M Ω	1000V rms AC
600V	0.1V			
1000V	1V	0.15+2		

NMRR：60dB 以上 50/60Hz ± 0.1%
CMRR：120dB 以上　50/60Hz(Rs=1kΩ)
応答時間：1 秒以内

HIOKI DIGITAL MULTIMETER (DT4281, DT4282)

2 直流電圧 (DCV、DCmV)

レンジ	確度	入力インピーダンス
60.000 mV	±0.2% rdg. ±25 dgt.*1	1GΩ以上 : 100 pF以下
600.00 mV	±0.025% rdg. ±5 dgt.*1	1GΩ以上 : 100 pF以下
6.0000 V	±0.025% rdg. ±2 dgt.	11.0MΩ ±2%: 100 pF以下
60.000 V	±0.025% rdg. ±2 dgt.	10.3MΩ ±2%: 100 pF以下
600.00 V	±0.03% rdg. ±2 dgt.	10.2MΩ ±2%: 100 pF以下
1000.0 V	±0.03% rdg. ±2 dgt.	10.2MΩ ±2%: 100 pF以下

Result: OICA supports NHTSA‘s concerns.

provisional version

Part 2: OICA's proposal for low energy content in Y-capacitances for in-use (i.e. active driving mode) and post-crash situations

provisional version

General situation

In the 18th IWG meeting, the question came up whether requirements for Y-capacitances for in-use and post-crash situations should be treated separately and if OICA suggested a change in post-crash requirements (despite of intensive discussions in GTR 20 phase 1).

After internal reflections, OICA suggests:

- **to align** post-crash and in-use requirements for Y-capacitances on **SAE 1772-2017 level**
- to go away from an energy criterion and to define **a charge amount criterion**
- but taking into account that this is only an additional possibility and always to allow other technical solutions that protect the customer.

Justifications for new OICA proposal (1)

- the Biegelmeier curves represent the reference point for the determination of a danger for a human being
- thus, the omnipresence for a 0.2 J criterion is not justified by medicine
- moreover, with the advent of higher voltages and large amount of energy stored in up-to-date HV batteries, the 0.2 J criterion can become a burden for future progress in electromobility
- medicine shows that the decisive danger is not the transferred energy but the transferred charge

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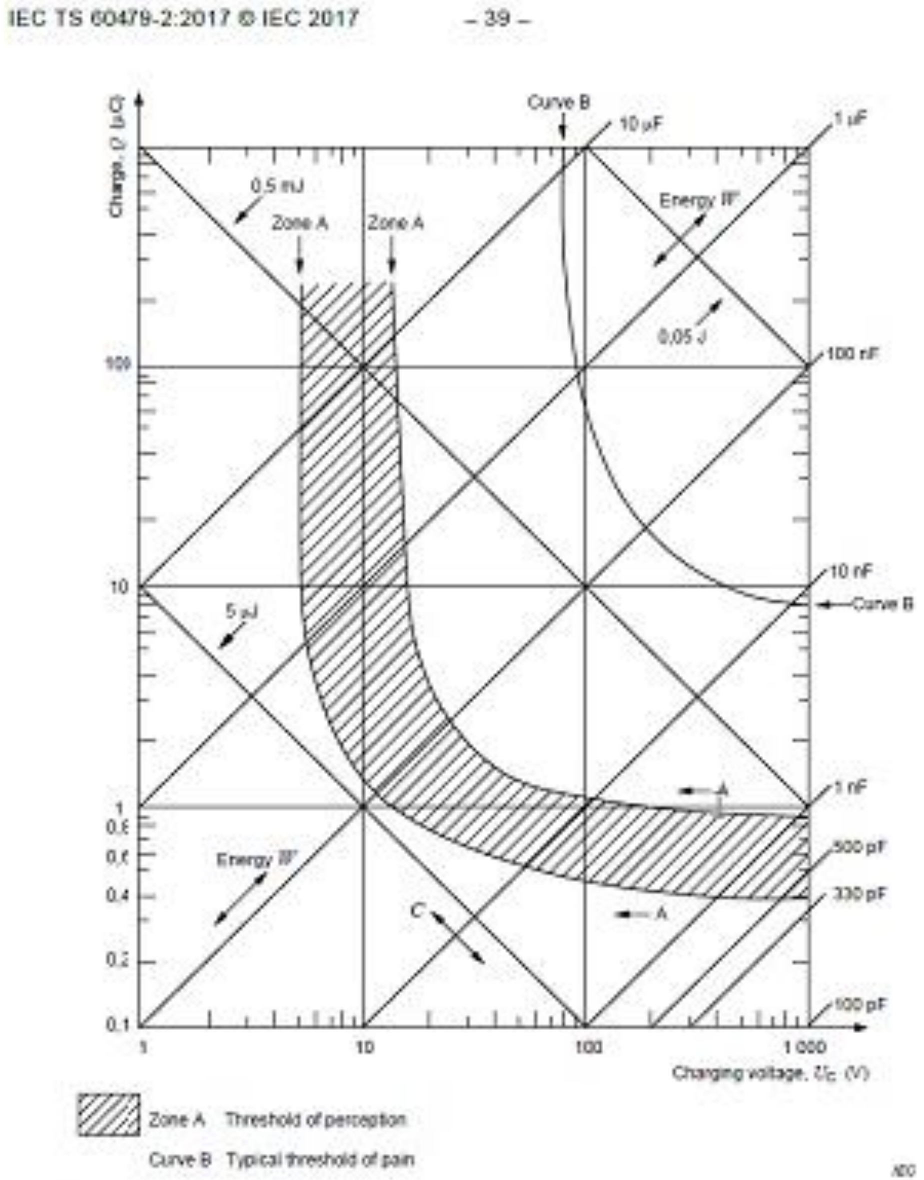
Justifications for new OICA proposal (2)



As the corresponding diagram shows, a pure energy criterion can rule out technical solutions that don‘t lead to danger for human beings, but cannot rule out certain situations that can be hazardous for human beings.

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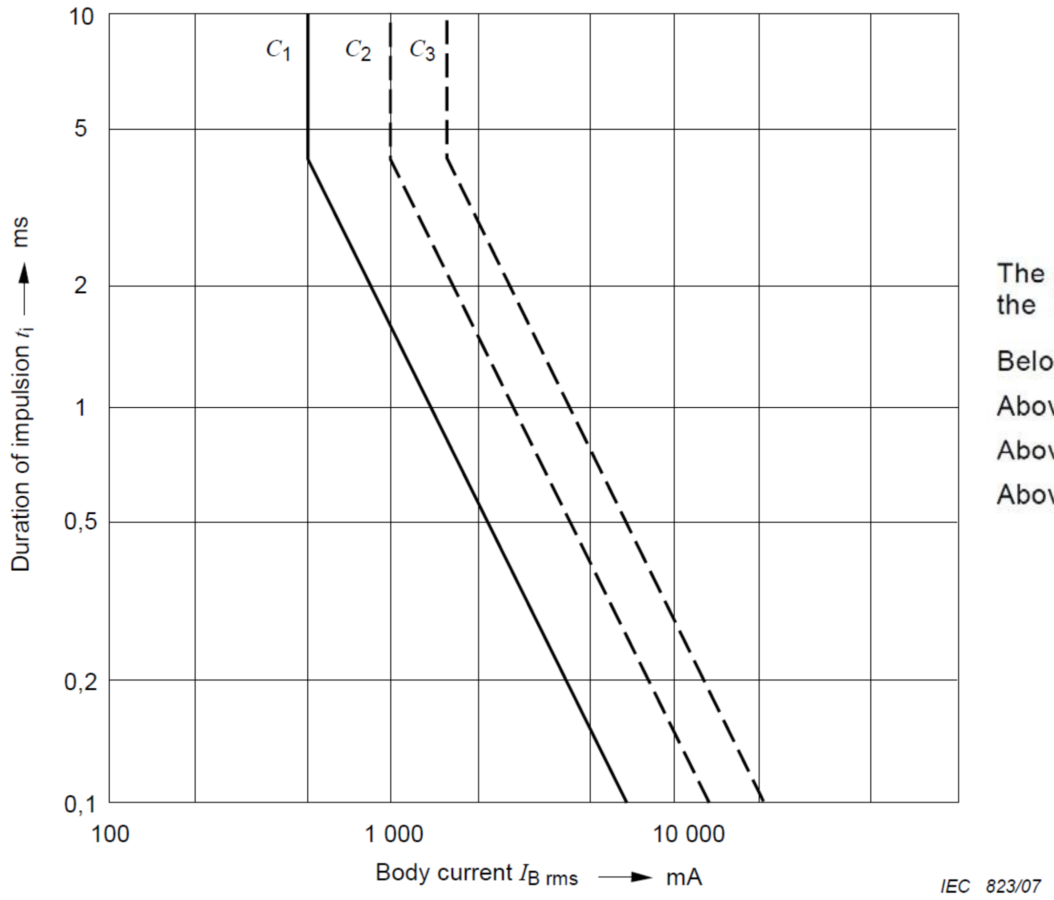
Backup

provisional version

Rationale for IEC 60479-2

IEC 60479-2 („Biegelmeier curves“)



The curves indicate the probability of fibrillation risk for current flowing through the body from the left hand to both feet. For other current paths, see 5.9 in IEC 60479-1.

Below C_1:	no fibrillation;
Above C_1 up to C_2:	low risk of fibrillation (up to 5% of probability);
Above C_2 up to C_3:	average risk of fibrillation (up to 50% of probability);
Above C_3:	high risk of fibrillation (more than 50% probability).

Figure 20 – Threshold of ventricular fibrillation

Correct derivation of maximum values

SAE J1772-2017 (maximum capacitance for vehicle and charging column)

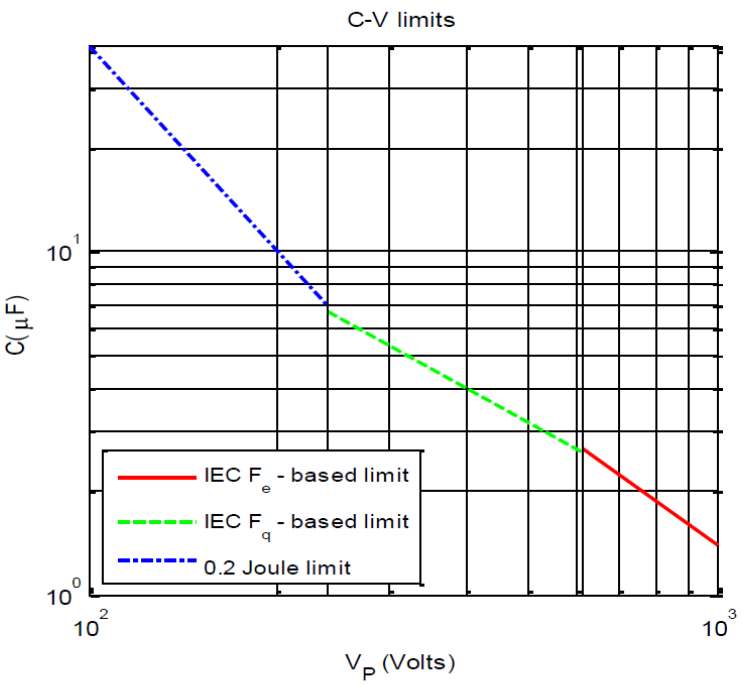


Figure 14 - Combined Y capacitance limit

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APPENDIX J – DC Y CAPACITANCE REQUIREMENT DERIVATION - INFORMATIVE

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V_{max}	$C_{t,max}$
500 V	3,2 µF
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Please note: detailled derivation of formulae and figure can be found in SAE J 1772-2017, Appendix J.

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