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Joint Research Centre

# JRC Opinion on vibration test procedure and profile

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European Commission

# Outline

- Opinion basis
- Purpose of the vibration test (requirement) in GTR No. 20
- Overview of the different proposals by Contracting Parties
- Overview of vibration profiles and test conditions in standards and regulations
- JRC Opinion

# Opinion basis

Information gathered from the following sources and taken into consideration for the formation of the JRC opinion:

- Presentations shared by Contracting Parties (CPs), such as China, OICA and Japan
- Relevant standards and regulations
- Technical scientific data (open scientific literature)

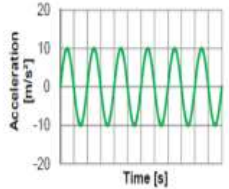
# Purpose of the vibration test in GTR No. 20

6.2.2.1 in GTR No. 20

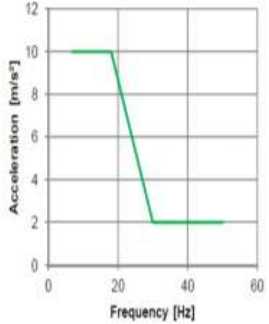
"*The purpose of this test is to verify the safety performance of the REESS under a vibration environment, which the REESS will likely experience during the normal operation of the vehicle*"

# Current proposals of China and OICA

## EVS-GTR

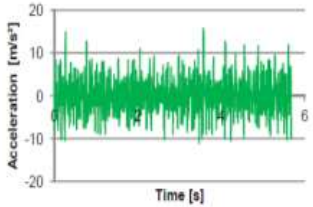



Sinus sweep

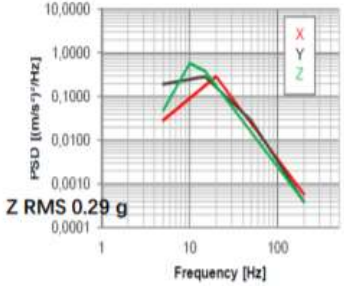



Direction: Z

## OICA

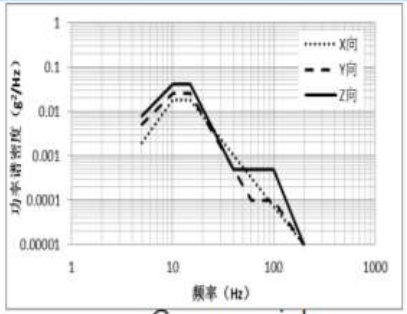



Noise

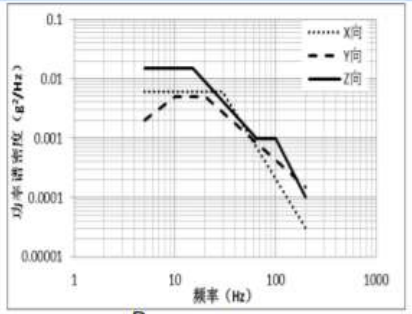



Direction: Z,X,Y

## China




Commercial




Passenger

| Random | | | | | | |
|---|---|---|---|---|---|---|
| Directions | Z-axis | | Y-axis | | X-axis | |
| Vehicle category | Passenger | Commercial | Passenger | Commercial | Passenger | Commercial |
| RMS | 0.64 g | 0.73 g | 0.45 g | 0.57 g | 0.50 g | 0.52 g |
| Time | 12 h | 12 h | 12 h | 12 h | 12 h | 12 h |
| **Constant Frequency** | | | | | | |
| Amplitude | ±1.5 g | ±1.5 g | ±1.0 g | ±1.5 g | ±1.0 g | ±2.0 g |
| Frequency | 24 Hz | 20 Hz | 24 Hz | 20 Hz | 24 Hz | 20 Hz |
| Time | 1h | 2 h | 1h | 2 h | 1h | 2 h |

Direction: Z,X,Y

(Adopted from "EVS19-HACT0410 [CN]Report on the discussion of vibration in CN-JP-OICA web-meeting")

(1 g = 9.81 m/s² ; 1 g²/Hz = 96.24 (m/s²)²/Hz)

# Purpose/concept & grounds of each profile

| Items | | China proposal | OICA proposal |
|---|---|---|---|
| Concept of vibration test | Purpose of vibration test | Assurance over life time mileage | Detection of initial failures and design problems |
| | Assumed load condition | Average vibration input to REESSs in the market vehicles ⇩ Average value of PSD lines of test vehicles | Development of realistic minimum safety profile<br>* LIVs of profiles are calculated and compared |
| Test vehicle | -- | 22 types of vehicles | 74 measurements on different vehicles of different size and battery and from 5 manufactures |
| Rough road condition | Rough road types | 9 types | Will be supplied later |
| | Driving condition (speed, time, range) | See the "EVS1419-401.pptx" for details | |
| | Rational of road conditions for international regulation | | |
| Profile development | G measuring points | At least 4 sensors are fixed distributed at different installation points | |
| | Data processing | Extraction of max. G data<br>Making PSD profile for each road<br>Calculation of average PSD | |
| Vibration test time | Test structure | Random_12hr * 3 directions<br>+Sinusoidal_1hr * 3 directions | |
| | Time acceleration | Applied (Life time rough road driving time is accelerated to 12hrs) | |

(Adopted from "EVS19-HACT0410 [CN]Report on the discussion of vibration in CN-JP-OICA web-meeting")

# Overview of vibration profiles and test conditions in standards and regulations (1/3)

| Region of applicability | International | | | | EU and further countries | USA | | | | India | China |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S&R / Vibration parameters | SAE J2929*** | | ISO 6469-1*** | IEC 62660-2(3) | UN ECE R100.02 | UL 2580 | | USABC | Freedom CAR | AIS-048[35] | GB 38031:2020 |
| Level (C, M, P) | C M P | | RESS/RESS subsystem | C | C M P | C | M[##] P | C M P | | M | P or System |
| Type of profile | Random | Sine wave | Random | Random | Sine wave logarithmic sweep | Random | | [###] or Sine wave or Random | | Sine wave | Random + (Sinusoidal at fixed frequency) |
| Frequency range (Hz) | 10-190* | 7-200[+] | 5-200 | 10-2,000[++] | 7-50** | 10-2,000[++] | 10-190* | 10-190* | | 30-150 | 5-200 (24) |
| PSD wave random $(m\ s^{-2})^2/Hz$ | 0.4-11* | | 0.0004-0.5774 | 0.14-20[++] | | 0.14-20[++] | 0.4-11* | 0.4-11* | | | |
| Loading range sine wave $(m\ s^{-2})$ | | 9.81-19.6 (>12 kg)[+] 9.81-78.5 (<12 kg)[+] | | | 2-10** | | | 7-49 | | 30 | z-/x-/y-axis 14.72/9.81/9.81 |

Test conditions for the vibration test at cell (C), module (M), pack (P) and vehicle (V) and System level (Adapted from Ruiz et al. (2018) and updated to reflect the current landscape)

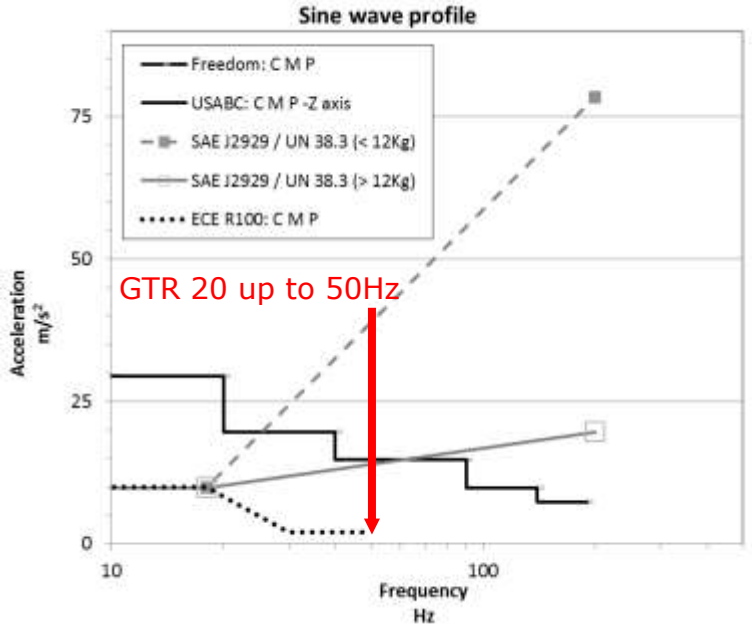
# Overview of vibration profiles and test conditions in standards and regulations (2/3)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Axis** | Vertical, longitudinal, lateral | Three mutually perpendicular mounting positions of the cell | Vertical, longitudinal, transversal | | Vertical | | Vertical, longitudinal, lateral | | | Vertical axis and horizontal | loading sequence^, ^^; z-axis random and z-axis fixed, y-axis random and y-axis fixed, x-axis random and x-axis fixed frequency |
| **SOC (% rated capacity)** | 95-100% max. normal vehicle operation | | Max. normal operation SoC | 80 (HEV) 100 (BEV) | >50 % normal operating range | 80 (HEV) 100 (BEV) | 100 & 20 (Z-sine, random) 60 (X & Y-sine, random) | 100 & 20 (Z-sine, random) 60 (X & Y-sine, random) | | 100 | >=50 % of normal working range specified by the manufacturer |
| **Vehicle level (V)** | SOC at normal vehicle operation | | | | | | | | | | |

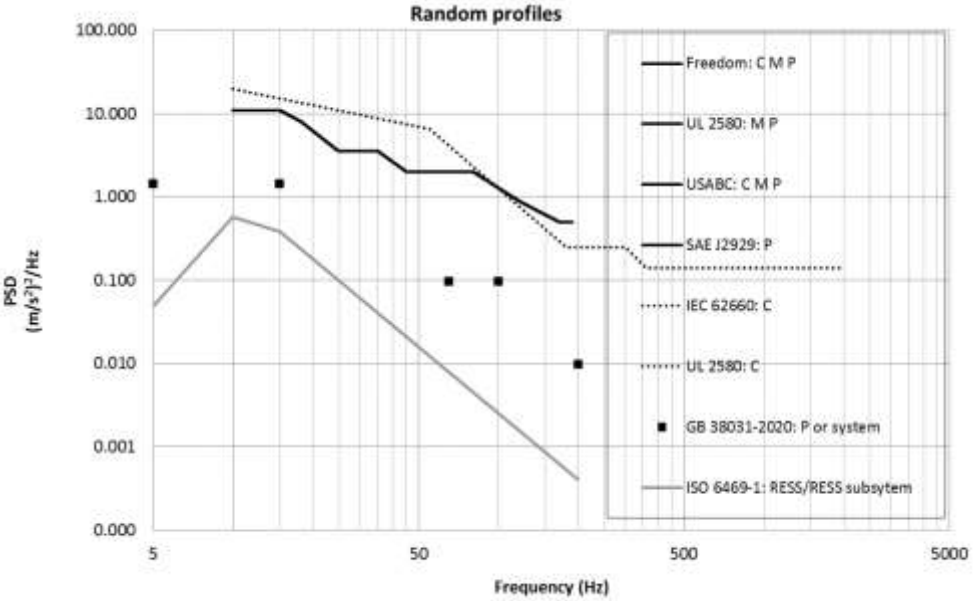
PSD: Power spectral density, * based on SAE J2380. **Higher can be requested by manufacturer. *** A profile 'which reflects the application' may be used as alternative. [+]based on UN 38.3, [++]based on IEC 60068-2-64. [##] At the module level for those electric energy storage assemblies intended for use in applications larger than passenger vehicles. The module level testing shall be representative of the electric energy storage assembly. [###] Vibration endurance test in accordance with the anticipated end application vehicle vibration profile. ^ The testing bodies can also choose their own sequence to shorten the conversion time. ^^ The vehicle running direction is x-axis direction and other horizontal direction perpendicular to the running direction is Y-axis direction.

Test conditions for the vibration test at cell (C), module (M), pack (P) and vehicle (V) and System level (Adapted from Ruiz et al. (2018) and updated to reflect the current landscape)

# Overview of vibration profiles and test conditions in standards and regulations (3/3)




Comparison of sine wave testing profiles for various standards and regulations (Adapted from Ruiz et al. (2018))




Comparison of random vibration profiles (PSD vs. Frequency – logarithmic plot) for various standards and regulations

(1 g = 9.81 m/s² ; 1 g²/Hz = 96.24 (m/s²)²/Hz)



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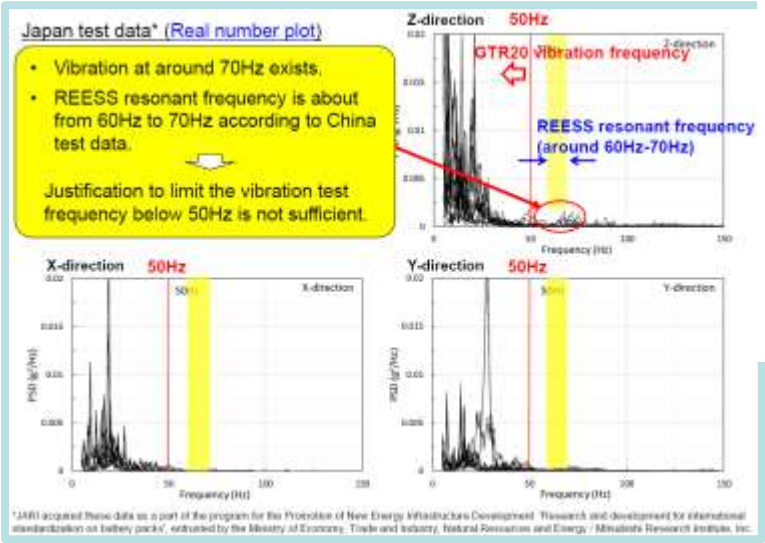
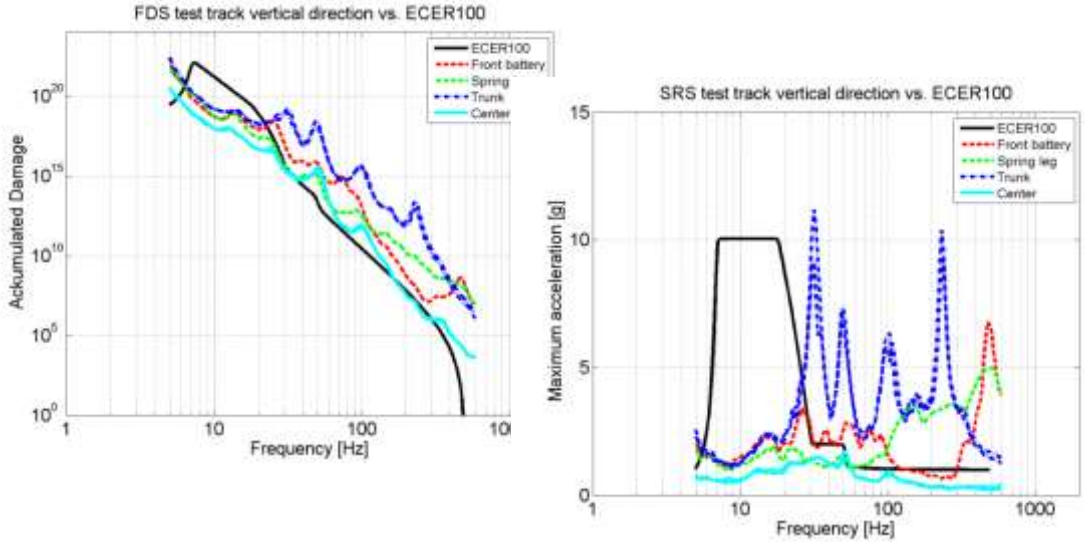
# Upper/lower frequency – field measurements comparison with ECE R 100.2 (and GTR 20)




Japan test data: PSD vs. frequency plots (Adopted from "EVS18-E2VP-0100 [JP]Japan comments on REESS Vibration Test.pdf"; Tokyo, 6/2019)



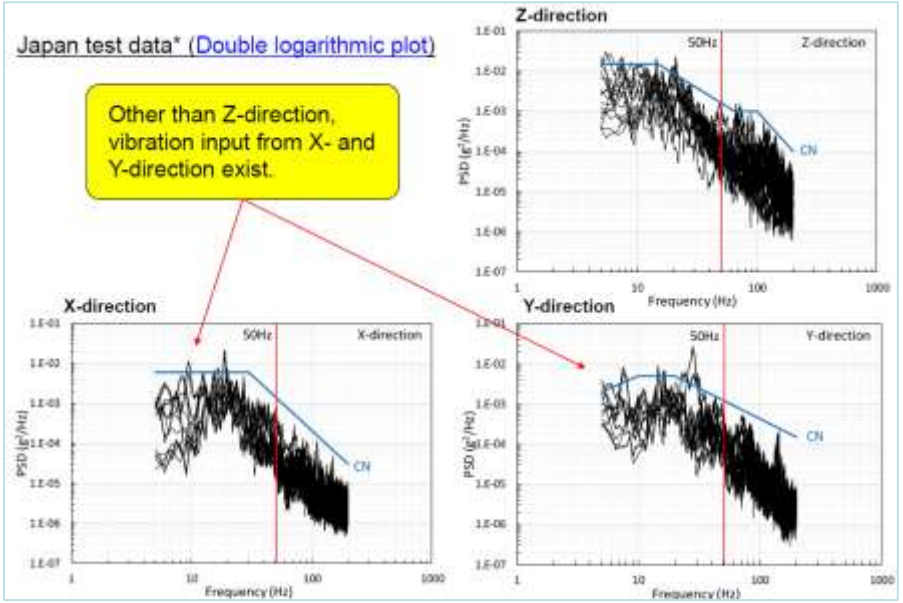

Kjell, G., Lang, J.F., In: Proceedings of the World Electric Vehicle Symposium and Exhibition (EVS27), Barcelona, Spain, 17-20 November 2013; pp. 1-11.

ECE R100 (and GTR 20) test is only more severe than real service if the resonance frequencies of the test object is between 5 and 20Hz.

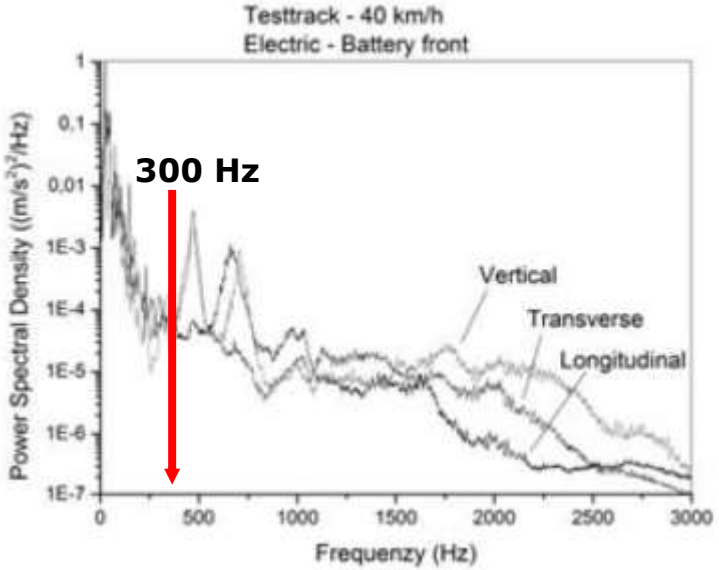


(1 g = 9.81 m/s$^2$ ; 1 g$^2$/Hz = 96.24 (m/s$^2$)$^2$/Hz)

# REESS vibration test in 3 directions (1/2)




Japan test data and comments on REESS Vibration (Adopted from "EVS18-E2VP-0100 [JP]Japan comments on REESS Vibration Test.pdf"; Tokyo, 6/2019)




Lang, J.F., Kjell, G., Int. J. Electric and Hybrid Vehicles, 7 (3) 2015

No comparable PSD values above 300 Hz in all 3 directions.

Vibration **loads in x- and y-directions are almost 50-70% of the ones in z-direction**, suggesting vibration test in 3 directions makes sense



(1 g = 9.81 m/s² ; 1 g²/Hz = 96.24 (m/s²)²/Hz)

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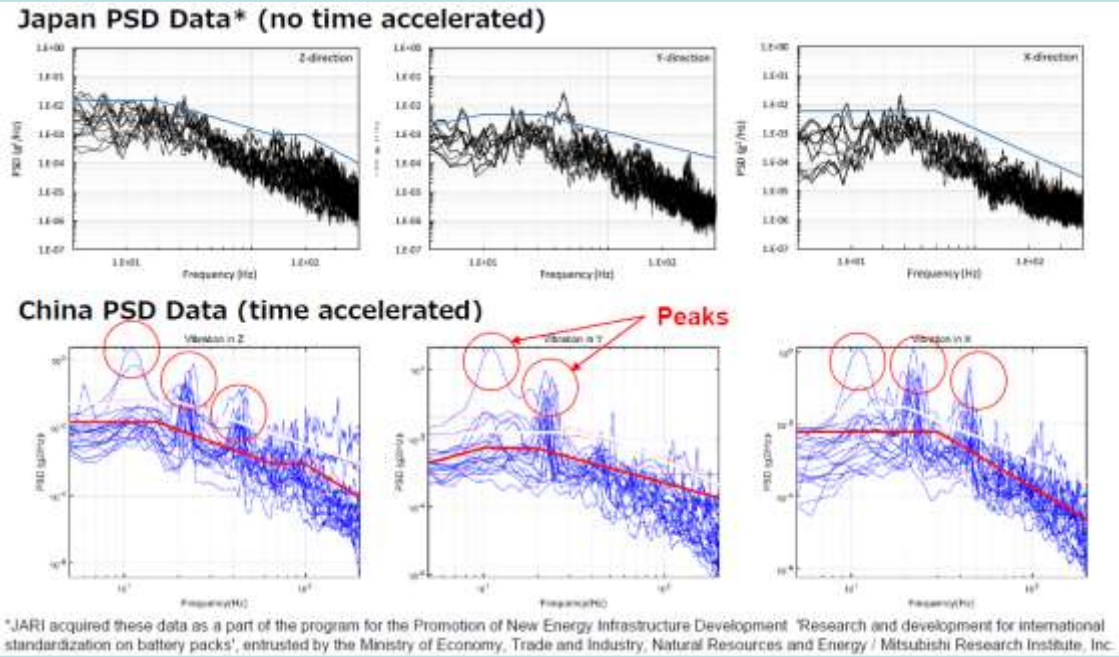
# REESS vibration test in 3 directions (2)




Resonance peaks at different frequencies in different directions can be seen, suggesting vibration test in 3 directions makes sense

Japan test data: PSD vs. frequency plots
(Adopted from "EVS18-E2VP-0100 [JP]Japan comments on REESS Vibration Test.pdf"; Tokyo, 6/2019)



(1 g = 9.81 m/s$^2$ ; 1 g$^2$/Hz = 96.24 (m/s$^2$)$^2$/Hz)

# JRC opinion (1/2)

Please refer to the JRC Opinion document at the GTR-EVS website

- The vibration test within the GTR-EVS is an “in-use” test of the REESS, which is likely to experience vibrations during its operation potentially resulting in a safety hazard
- JRC would agree to keeping a vibration test in GTR, considering it a **minimum safety requirement** - vibration test profile more representative of what a battery is typically exposed to in an electric vehicle
- JRC would be in favor to allow for **manufacturer vibration test profiles** to be applied, based on **vehicle-specific vibration inputs**

# JRC opinion (2/2)

Please refer to the JRC Opinion document at the GTR-EVS website

- **Vibration test in 3 directions makes sense** - one could also explicitly suggest that vibration test could be done simultaneously in all 3 directions (if instrumentation allows)
- If a **random vibration test profile** would be considered as an alternative to the current GTR No.20 sine wave test profile, JRC could agree on the **lower and upper frequency values, i.e., 5 Hz and 200 Hz**, respectively
- JRC is in favor of performing the vibration test at:
  - the maximum normal operating SOC
  - room temperature, defined as 22ºC±5ºC (REESS-level tests; current GTR No.20)
- JRC would be in favor of requiring different vibration test parameters for category M1, N1 vehicles as compared to vehicles of other categories

# Thank you for your attention!

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Additional information and references can be retrieved from the JRC Opinion document at the GTR-EVS website

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