The group feedback analysis regarding to test methodology, conditions, equipment

Andrey KOZLOV
Analysis purpose and items

The purpose of this analysis is to compare different vehicle interior air test approaches to develop PM and gas components measurement test methods.

The items

1. Vehicle Category (agreed)
2. Criteria for excluding a vehicle from tests
3. Test Vehicle age/millage
4. Meteorological Conditions
5. Test Conditions
6. Sampling Points/Sampling Lines
7. Background air pollution level
8. Cabin air filter age
9. PM and gas components to be Measured
10. Measurement Methods
11. Test equipment requirements
12. Gas Analysers Calibration
13. Test Modes
14. HVAC Modes
15. Test Procedure
16. Test Protocol

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Responses from:

- CEN/WS 103*
- OICA Members (EU Association of Supplier)
- CLEPA
- UTAC/ESTACA (Paris saclay)
- Korea Automobile Testing & Research Institute
- CabinAir Sweden AB

The full text feedback tables are in the document VIAQ-23-09
*CEN/WS 103 items from the document “Real drive test method for collecting vehicle interior air quality data” // Doc. CEN/WS 103 N. 23, 2021
## Criteria for excluding a vehicle from tests

The following checklist should be applied to all vehicles. Exclusion shall be based on a positive answer to any of the criteria below:

- Does the vehicle not have a full service history?
- Is there a Malfunction Indication Light showing on the vehicle instrument panel?
- Has the vehicle had unauthorised vehicle repairs?
- Has any part of the vehicle’s heating and ventilation system replaced with non-original parts?
- Through visual inspection of the vehicle, are there any damaged ventilation system relevant components?
- Are there any obstructions to the vehicle air intake path?
- Is the vehicle not in overall safe operating condition?
- Is there any damage to the body of the vehicle, including but not limited to doors, windows and the rear?

<table>
<thead>
<tr>
<th>Less than one month aged vehicle and vehicles without maintenance programme are excluded from tests</th>
<th>additional: - Cleanliness of Cabin - The cabin should be cleaned and free of dust or other dirt. Older than 2 years, or warranty expired.</th>
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</thead>
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<td>CLEPA</td>
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</table>

**CEN**
3. Test Vehicle age/mileage

- **Stabilized measurement vehicles:** > 3000 km - and < 160 000 km (Durability for euro 6) - OICA

- **3 000…15 000 km** - CEN

- **3 000…15 000 km** - Korea

- **In any case: Age less than 2 years. Mileage less than 25 000 km but the best is less aged** >> see also the point Cabin filter age below - CLEPA

- **The standard shall work for new vehicles (>5000 km mileage) and aged vehicles** - CabinAir

It is recommended that TVOCs should be measured regardless of vehicle age. For newer/recent vehicles, we recommend to supplement TVOC measurements with real-time speciation technics for a complete VOC characterization. - UTAC
### 4. Meteorological Conditions

<table>
<thead>
<tr>
<th>Temperature</th>
<th>10...20°C</th>
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</thead>
<tbody>
<tr>
<td>Relative Humidity</td>
<td>40...80%</td>
</tr>
<tr>
<td>Atmospheric pressure</td>
<td>85...110 kPa</td>
</tr>
<tr>
<td>Weather condition:</td>
<td>no rain, fog, snow or standing water on the carriageway</td>
</tr>
</tbody>
</table>

**CEN**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>-10...+35°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather condition:</td>
<td>no precipitations (no rain, no snow), no fog</td>
</tr>
</tbody>
</table>

**CLEPA**

Temperature, Humidity have to be monitored and registered inside and outside the car. Register as well the solar irradiation (cloudy or sunny..). **No rain conditions /15°dP or below, knowing that (85% of the mileage driven in Europe is between 5 to 25°C)**

**OICA**

Relative Humidity in the air should not be too high, tests should be done with extreme weather excluded, such as rainy and snowy weather conditions

**CabinAir**
5. Test Conditions

A valid test shall conform to the requirements indicated below:

- Driving time: Monday to Sunday, 06:00 to 20:00
- Road condition: Paved streets with no standing water, snow or ice

It is recommended to avoid long tunnels, high altitudes and construction areas. In addition, the test must be primarily conducted on city roads and urban locations. A test may be split up into multiple trips, each of which must meet the trip conditions. A trip shall start from a point at which the vehicle is stationary, with stationary defined as less than or equal to 0.5 km/h. There shall be no overlaps between the trips. A single trip shall be made up of continuous driving. Multiple trips from the same test can, in-between those trips, allow driving that does not meet the boundary conditions of this CWA. Each trip shall meet the conditions below:

- Instantaneous vehicle speed ≤ 60 km/h
- Minimum distance: 10 km
- Minimum duration: 30 min

A normal driving style shall be adopted. An involuntary stall invalidates the test, but a short period of deliberate engine-off — for example due to a stop/start system — is permitted. For a trip to be valid, all the conditions below shall be fulfilled:

- Average speed: 40...60 km/h
- Average altitude: 0...700 m

Windows, doors, sunroof or convertible soft top must be closed at all times. Heated or cooled seats should not be used. There should be the driver and one passenger present in the vehicle for the duration of the test. All outer clothing of the driver should be made of polyester to minimise particle generation from the driver. Clothing should cover both arms and legs. The occupants should avoid applying any fragrances prior to or during the test.
5. Test Conditions

Real Driving Conditions are representative of customers' expectations. This kind of test is made to figure urban or traffic situations. CO2 is monitored.

- It depends on the investigation, but each condition must be recorded. To be discussed in details in Procedure & Protocol.

1. Stationary test
   - Test vehicle standing in the roadside parking lot of Gangnam-daero with engine on and HVAC system on/off
2. City driving test
   - Slow moving traffic in Gangnam-daero (average speed of 40 km/h)
To characterize the In-cabin Air Quality it is important to define a typical (normalized) test cycle such as NEDC or WLTC for emissions. Indeed, the vehicle speed has an important influence in correlation with the ventilation type. Concerning this latter, Test with ventilation off to characterize vehicle leakages and with both modes Recirculation and OA should be achieved for a complete VIAQ characterization.

On the other hand, the engine type is also may be to define since, some authors have shown its impact. Indeed, Moreno et al, 2019). But it is impossible to say if it was the impact of the engine type or the car model that was different.

Test can be done stationary and/or Dynamic, interval should be minimum 30 min for one trip, recommend to have repeated trips to get reliable conclusion on the test result. Driving route can be city-driving or high-speed way, but need to avoid short tunnels (less than 5-10 minutes driving). It is very important that outdoor particle levels should not be significantly fluctuant and the levels should be high enough to avoid big impact from instrument measurement deviation in low PM counts. Vehicle setting should be constant, such as the airflow rate, ventilation, A/C status, etc.
6. Sampling Points/Sampling Lines

1. Following the UNECE VIAQ group, the interior sampling point should be a **head-height between the front headrests**.

2. The external sampling point should be **as close as reasonably possible to the ventilation air intake**. Sampling should be isokinetic.

The sample lines should be made of a near-zero-loss material such as PTFE for gas and anti-static material for particulates.
6. Sampling Points/Sampling Lines

1. **Inside**: inside: between headrest from seat
2. **Outside**: To be defined (climate system air intake preferred position)

This point is very sensitive and we think that we have to investigate on measurement quality depending on probe type/orientation, sampling lines for dynamical measurements (air flowing around sampling probes). We started a complete study through the PhD project of Nadir Hafs combining laboratory measurements and CFD simulations to improve our knowledge about this point.

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**headrest sampling point** might be interfered by movements of driver or passenger sitting on the other seat!! No co-passenger should sit there!

At least one point in cabin and one point outdoor (if possible at the HVAC external air intake). To be discussed in details in Procedure & Protocol.

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1. **Interior sampling point**: Head-height between the front headrests
2. **Outer sampling point**: Not measured, and used PM10 and PM2.5 data from real-time roadside monitoring stations (www.airkorea.or.kr by MOLIT) during heavy-concentrations of fine dust

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Not longer than 1 m and with no sharp bends, indoor sampling inlet should be fixed in the mid between two front seats and avoid breathing impact from human. Outdoor sampling inlet should be placed close to the outdoor air intake area with protection from direct outdoor wind, such as under the hood.

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**OICA**

**CLEPA**

**UTAC**

**CabinAir**
7. Background air pollution level

- PN concentration 5000...100,000 #/cm³
- PM$_{2.5}$ concentration, 5...100 µg/m³

The worst air pollution level might be the best for the investigations, but anyway need to be documented & recorded.

External average concentration has to be defined PM$_{2.5}$ (> 10 µg/m³) and Maximum (200 µg/m³) - Limit to be discussed. To be measured outside the car to observe HVAC efficiency - background measurement station (all substances shall be measured outside and inside to determine an efficiency).

- 24-hour moving average of PM$_{10}$: 81 ~ 150 µg/m³ ("BAD" case according to Korea air quality index)

Coarser particles are also generated by traffic abrasion and particles resuspension (Gehrig et al., 2010). Thus the circuit should be chosen in terms of road infrastructure type (freeways, tunnel, ring road) but also with a known road pavement coating type and year of construction since the abrasion and particles resuspension contribute to the background air pollution level.

- Average outdoor PM$_{2.5}$ should be greater than 30 µg/m³, without sharp/big fluctuations
8. Cabin air filter age

**HVAC filter age:** New, OEM-approved.
If a vehicle is not installed with a filter by the OEM, the vehicle is within the scope of this methodology, to be tested with no filter present.

**Normal filters use for 3000 km or Ageing procedure for the test:**
Road side ageing on the base (100 hours) of the suppliers procedure (to be defined)

**Original OEM HVAC filter with max. 3000 km --&gt; type and age of filter must be documented**
As example, less than one year, or less than 10'000 km (in high polluted areas less than 5'000 km)

Divergences appear concerning whether the filter should be newer or not. Some investigations have recommended to change the filter for a better filtrations and others have shown that the accumulation of pollutants that deposited in filters decrease the porosity and enhance the filter efficiency. We would be inclined to favour this latter, since the older vehicle that we tested during our CAPTIHV project (Mehel et al., 2019) was not the one with the most important pollutants infiltration. At the same time, vehicle models were not the same.

**Case 1:** New filter and Standard manufacture-installed particulate filter
Case 2: Aged filter out of filter replacement cycle which driving mileage 10,000km ~ 15,000km

**New filter,** the test method shall be applicable for aged filters as well as long as the aged method can be controlled and repeated.
9. PM and gas components to be measured

- PN (10 nm to 10 μm), #/cm³
- PM₁₀, μg/cm³
- CO₂, ppm
- NO₂, ppb

CEN

- PM₂.₅, NO₂,
- CO,
- (Air quality Standard)

OICA

- PM₂.₅, PN
- CO, CO₂
- tVOC
- NOₓ (NO₂ & NO)
- Optionally: NH₃, O₃

CLEPA

- PM₂.₅ and PM₁₀

Korea

Pollutants that are still found with important concentrations depend on local area, e.g., presence of particular pollutant emission sources (chemical, industrial areas) and road type (urban or rural). Most common pollutants founds in automotive cabins are: NOₓ, COV, O₃, PAH, PM, PN. One should also to consider CO₂ even if it is not considered as a pollutant since it indicates the degree of containment.

UTAC

Small fraction PM (0.1-1 μm), PM₂.₅

CO₂ (as an index to ensure the ventilation is under control, on the other hand in-cabin CO₂ shall not be too high which pose risk to safe driving.)

CabinAir
## 10. Measurement Methods

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Method</th>
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<tbody>
<tr>
<td>PN concentration</td>
<td>Condensation particle counter (10 nm to 10 μm)</td>
</tr>
<tr>
<td>PM concentration (&lt;10 μm)</td>
<td>Mini Wide Range Aerosol Spectrometer or Aethalometer</td>
</tr>
<tr>
<td>CO₂ concentration</td>
<td>Non-dispersive infra-red</td>
</tr>
<tr>
<td>NO₂ concentration</td>
<td>Non-dispersive ultra-violet or chemiluminescent detector</td>
</tr>
<tr>
<td>PN(0.3-2.5 μm)</td>
<td>shall be measured with optical counter, small fraction particles PN(0.1-1 μm) can be measured with SMPS or Mini Wide Range Aerosol</td>
</tr>
</tbody>
</table>

**CO:** e.g. Infra Red (or electrochemical cell)

**NO₂:** e.g. chemiluminescence technology

**PM 2.5:** backscattering light technology

**PM:** 90° light scattering & filter-sampling

Preference for measurement methods with fast reaction instead of ultra high lower detection limit in order to see time dependent effect more better. Continuous measurement ideally at 1 Hz, but not less than 0.1 Hz. Good frequency must be privilege versus high accuracy.
### 11. Test equipment requirements

#### Detection range:
- PN concentration (10 nm to 10μm): 0 to 1,000,000 #/cm³
- PM concentration (<10 μm): 0 to 1 mg/m³
- CO₂ concentration: 0 to 5,000 ppm
- NO₂ concentration: 0 to 0.5 ppm

#### Detection limits:
- PM 2.5: 1 μg/m³
- NO₂: 1-2 ppb;
- CO: 1 ppm (include the time resolution)

#### Temperature and RH sensors, gas sensors, PM sensors
Adapted to the above elements. This can not be technology prescriptive

#### Particle measurement instruments should be with valid calibration, internal and external instruments should be calibrated together (ensure no system errors)
For in-field calibration of the gas analysers, a zero and span calibration shall take place at the start of the test and a zero and span check shall be made at the end of each test that is under two hours in length. For tests longer than two hours, mid-test checks of zero or zero and span may be made (such that the time between checks does not exceed two hours); the analyser may be adjusted to the calibration gases if necessary.

Annual calibration following supplier recommendation + verification before each test

CEN approach seems reasonable. It is required for each sensor. Calibration to be done before and after
13. Test Modes

1. **Urban driving** (CEN)

   Urban driving (CEN) is the most interesting and challenging mode // stationary tests are not representative due to the lack of air movements and overpressure conditions around the car. By Urban driving standstill periods e.g. waiting at a traffic light are already included. Focus on urban situations.  

2. **Real driving conditions** (Define maximum speed, drive rule motorway etc) (OICA)

1. **Stationary test**
2. **City driving test** (Korea)

Both **Stationary and Dynamic driving** test method shall work, but the test method should be remarked (CabinAir)
During each individual trip, the HVAC system should be in **automatic mode with 21°C temperature setting**, with ventilation flaps fully open and directed straight ahead.

If the vehicle does not have an automatic mode, the HVAC system should be set to **fresh air mode**, with air conditioning switched on at 50%/medium temperature, fan speed 50%/medium, and ventilation flaps fully open and directed straight ahead.

**Automatic setting at 23°C (HVAC Display)** - To Be confirmed after comparative tests with different vehicles

For manual HVAC: xx% fresh, yy% in recirc (i.e. in tunnel/traffic jam); air flow (tbd.) (to be harmonised with MR3 part 3)

CEN sounds reasonable. **A/C must be OFF** because of the undefined and not reproducible influence of wet evaporator!!!

It depends on the investigation. **A/C OFF** when evaluating cabin air filter performance. To be discussed in details in Procedure & Protocol.

CLEPA
14. HVAC Modes

Fresh air (totally outdoor air intake), fan speed should be in medium and it is recommended to measure the exact airflow rate through HVAC.

CEN proposal is a good starting point. To be discussed in details with all above elements.

1. Stationary test
   (Step1) Window full open for saturation of external atmospheric concentration and close(5min.) →
   (Step2) Ventilation with fan off (15min.) →
   (Step3) Window full open for saturation of external atmospheric concentration and close(5min.) →
   (Step4) Ventilation with fan setting 'medium'(15min.) →
   (Step5) Window full open for saturation of external atmospheric concentration and close(5min.) →
   (Step6) Recirculation with fan off(15min.) →
   (Step7) Window full open for saturation of external atmospheric concentration and close(5min.) →
   (Step8) Recirculation with fan setting 'medium'(15min.)

2. City driving test
   The same modes with "Stationary test"
1. Cold start operation shall be excluded. To ensure this, the first 10 minutes or the first 2 km of driving under internal combustion engine operation shall be excluded from any test, whichever comes later. This restriction does not apply to vehicles with no internal combustion engine.

2. A test is a continuous stretch of driving that can contain multiple trips.

3. A test may be split up into multiple trips, each of which must meet the trip conditions. A trip shall start from a point at which the vehicle is stationary, with stationary defined as less than or equal to 0.5 km/h. There shall be no overlaps between the trips. A single trip shall be made up of continuous driving. Multiple trips from the same test can, in-between those trips, allow driving that does not meet the boundary conditions of CWA.

4. For test results to be deemed adequate for use in comparing interior air quality performance between models within the scope of this CWA, it shall be required to collect:
   • at least 3 valid trips in total
   • in the required fan speed/ventilation modes
   • on 1 vehicle of its type.
We recommend achieving **measurements with two consecutive vehicles**: We have shown from our previous in-cabin Air quality measurements campaign that the type of the upstream vehicle that is found ahead of it has a strong influence. Indeed, the upstream vehicle is continuously changing and its emission directly infiltrate the following test vehicle (Mehel et al., 2019). On the other hand, the distance between the test vehicle and the upstream one has also an influence on pollutants infiltration (Mehel et al., 2019).

**Air intake position:** On the other hand, we have also shown using wind tunnel measurements that the air intake position has an influence on I/O concentrations ratios. An Air intake that is positioned at the right side and left side have greater infiltration ratio in comparison to the centre one (Mehel, 2020).

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**CEN proposal is a good starting point. To be discussed in details with all above elements.**

**The test shall include several repeated trips, and for each trip the driving shall be continuous and valid** (weather condition, test condition, background air pollution level, requirement on test device, etc. shall fulfill agreed requirements). Test setup shall be standardized and clearly registered.

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**UTAC**

**CabinAir**
16. Test Protocol

1. Vehicle Information

2. Test Condition Information

3. Reporting of Trip Results

The cabin air quality index for PN is the “PN Filtration Rate” and is the ratio of the integrated interior PN concentrations and integrated exterior PN concentrations, thus:

$$CAQI_{cabin} = \frac{\int_{t_0}^{t_f} C_{cabin}(t) dt}{\int_{t_0}^{t_f} C_{outside}(t) dt}$$
16. Test Protocol

Should contain all data from inside and outside measurement, number of passengers, car registration number, testing date, driving locations, filter type and age.

All parameter should be documented. All available data must be recorded. To be discussed in details with all above elements.

Particle filtration performance of a test vehicle shall be calculated based on the average indoor and outdoor PM levels measured simultaneously. Repeatability (of repeated valid trips) shall be considered.
Conclusions

1. The VIAQ IWG members (CEN, Korea, OICA, CLEPA, UTAC/ESTACA, CabinAir) presented their vision of future vehicle interior air quality test methodology and test conditions taking into account outer air pollution.

2. We have similar approaches on some working items, but some items need more in-depth analysis and additional investigation.

3. Any contribution to clarifying and harmonizing testing approaches and methodology are welcomed in the frame of our work.
Thank you for your attention!