<u>Feedback to the GTR proposal submitted to the PMP IWG on 17.06.2022</u>

[23.06.2022] BOSCH-1. 7.6. **Comment:** The graph on page 14 indicates a splitter for TPN10 and SPN10 like also mentioned for 3 probes layout. We have a 4-point sampling in a 200 mm tube but two of the sampling probes are dedicated to other add on measurements (ELPI+ and OPS). Could SPN and TPN be taken out of one probe with a splitter also for the 4 Probes sampling? In case reasonable could this be mentioned as an alternative.

Response. Agreed. Indeed, it is possible to use a flow splitter also with the 4-probes setup. The text has been corrected accordingly to indicate that TPN and SPN are not mandated to be sampled with different probes.

[23.06.2022] BOSCH-2. 13.2. **Comment:** I cannot find impactor cascades for PM10 and PM2,5 determinations which was referenced in the 07/20221 recommendations. According to that we are using the ISO23210 certified Dekati Impactor cascade that incorporates pre impaction (removal) of > PM10 comparable to the pre-classifying cyclones. Bouncing effects are minimized by grease on the impactors. Could this kind of PM determination by impaction devices be added – in case separation efficiencies of pre impactors as defined are met and the device is ISO certified? In case not, are there some negative experiences?

Response. Testing of full friction brakes (ICE vehicles) results in filter loadings of 2.0-5.0 mg of PM_{10} and 1.0-2.0 of $PM_{2.5}$. As a rule of thumb, impactor substrates shall not collect more than 1 mg because they can introduce clogging or bouncing phenomena. The high masses observed in brake testing are the result of very long tests of 4.5h. For this reason, TF2 unanimously decided to mandate the use of cyclones.

[23.06.2022] BOSCH-3. 12.2.2.2. (g) & (q) PCRF shall be monitored in real time according to the text.

Comment: We consider this as impossible. A dilution system or VPR can measure and monitor the dilution ratio but not the PCRF. PCRF determination requires addition and loss determination with several monodisperse particles which is absolutely impossible during measurement cycles.

Response. This has been rephrased in the version to be released. The dilution ratio shall be monitored in real-time. Then, the PCRF (Dilution factor x average PCRF) shall be reported by the VPR system. So, it is a matter of automating a single calculation for reporting the requested parameter.

[23.06.2022] BOSCH-4. **Comment:** Brake pads can acquire significant amounts of water in humid conditions that will not be lost quickly after deposition in the air conditioned room. It might be necessary to store them for days to condition them for weighing or dry them @1h 100°C and store them in the constant climate afterwards for 24 h. before weighing. We found moisture accumulation of ca. 0,5 g after storage in high humidity like in tropical regions.

Response. This is the first time such a phenomenon is reported. Actually, this is exactly the opposite of what we observed during the ILS. ILS data showed that brake particles are dry and solid. If more data showing the opposite becomes available, we will consider amending the respective part in the text.

[23.06.2022] CLEPA-1. Definitions.

Comment: Consider defining "Regenerative braking" as follows: means the decelerating of the vehicle when the battery vehicle energy management system diverts part of the kinetic energy at the wheel to charge the battery pack or drive batteries REESS.

Response. Agreed.

[23.06.2022] CLEPA-2. Definitions.

Comment: Add "Rechargeable Energy Storage System (REESS)" means the rechargeable energy storage system that provides electric energy for electric propulsion.

Response. Agreed.

[26.06.2022] CATALYTIC INSTRUMENTS-1. 14. Calibration.

General comment: Silver particles shall be included in the Brake GTR—brake dust is not soot, and emery oil is a legacy CPC calibrant. It stands to reason that silver is at least added to a list of advised/permitted calibrants. As a metal it is far closer to the solid emissions from brakes than soot would be.

Response. Agreed. Several instrument manufacturers have requested the addition of silver to soot and emery oil.

[30.06.2022] AVL-1. Definitions – "Brake inertia dynamometer" means a technical system that imposes, controls, and records the mechanical and electrical work from the brake under testing while operating with a pre-programmed test procedure.

Proposal: Use "Brake dynamometer". Brake inertia dynamometer could be interpreted as a mandatory flywheel dyno. Restricting implicitly to one specific dynamometer technology is neither necessary from a technical point of view (see ILS results, recuperation requirements) nor acceptable.

Response. Agreed.

[30.06.2022] AVL-2. Definitions – "Standard conditions" means pressure equal to 101.325 kPa and temperature corresponding to 293 K.

Proposal: 273.15K, as in subsequent clauses!

Response. Agreed.

[30.06.2022] AVL-3. Table 7.1 – Minimum length to the next disturbance and downstream of the airflow measurement element per paragraph 7.2.3.

Comment: The 5d upstream and 2d downstream of the flow measurement device should refer to the diameter of the flow measurement device or the pipe diameter in which the flow measurement is taken. This is not necessarily the same as the sample duct diameter.

Response. The 5d upstream and 2d downstream of the flow measurement device refers to the diameter of the duct in which the flow measurement is taken. This has been clarified in the document.

[30.06.2022] AVL-4. Table 7.1 – The radius of the bend downstream of the sampling plane (or upstream of the sampling plane in a different layout) per paragraph 7.5.

Comment: No definition of R1 in 7.5. Has never been discussed in TF2. No need for any definition here, irrelevant for measurement results.

Response. This is correct. Reference to R1 has been removed.

[30.06.2022] AVL-5. 7.2.2.2.2 – Perform the pre-test verification with the PN measurement system operating at the dilution ratio selected for the corresponding brake emissions test.

Comment: Please add "PN measurement system" to the definition section.

Response. Agreed. A definition has been added.

[30.06.2022] AVL-6. 7.2.2.2.3 – Perform a zero verification of the PN measurement device.

Comment: Definition of the PN measurement device missing. Should be PNC to stay consistent with GTR15 and clause 12 of this document.

Response. Corrected.

[30.06.2022] AVL-7. 7.3 – "Brake inertia dynamometer and Automation Systems".

Proposal: Use "Brake dynamometer". Brake inertia dynamometer could be interpreted as a mandatory flywheel dyno. Restricting implicitly to one specific dynamometer technology is neither necessary from a technical point of view (see ILS results, recuperation requirements) nor acceptable.

Response. Agreed.

[30.06.2022] AVL-8. 7.3 – The brake inertia dynamometer is a technical system that provides the controlled kinetic energy to the brake under test.

Proposal: Use "Brake dynamometer". Brake inertia dynamometer could be interpreted as a mandatory flywheel dyno. Restricting implicitly to one specific dynamometer technology is neither necessary from a technical point of view (see ILS results, recuperation requirements) nor acceptable.

Response. Agreed.

[30.06.2022] AVL-9. Figure 7.2 – "Brake inertia dynamometer and Automation Systems in the overall test layout".

Proposal: Use "Brake dynamometer". 7.2-2 seems to indicate a flywheel? Should be technologically neutral!

Response. Agreed.

[30.06.2022] AVL-10. 7.3 – The automation, control, and data acquisition system performs all the functions that enable the brake emissions test. It accelerates the brake during acceleration events, maintains constant speed during cruise events, and modulates the frictional torque during deceleration events to reduce the kinetic energy of the rotating masses (Figure 7.2–2).

Proposal: See previous comment. Dynos don't necessarily need flywheels; they can operate purely electromagnetic. Should be technologically neutral! Restricting implicitly to one specific dynamometer technology is neither necessary from a technical point of view (see ILS results, recuperation requirements) nor acceptable (see comments on previous clause 3 from April 2022). Delete component 7.2-2. Alternatively mark 7.2-2 as optional.

Response. Element 7.2-2 is not mandated. It is mentioned in the text that "The different elements and subsystems in Figure 7.2 are indicative; therefore, exact conformance with the figure is not mandatory.".

[30.06.2022] AVL-11. Figure 7.4.2 – The cooling air shall enter and exit the enclosure only in the horizontal direction (i.e. the major axis of the enclosure – plane A1 – shall align with the airflow direction). The tunnel ducting shall be horizontal for at least two duct diameters (2·di) upstream of the enclosure's inlet.

Proposal: Definition is not consistent to the Fig. 7.1. Clear definition needed. Should be "straight" instead of "horizontal". AVL opinion: no real need for straight pipe in front of the enclosure since the verification of unified flow inside the enclosure is mandatory anyway.

Response. Agreed. The text has been corrected to include straight. JRC believes that for harmonization purposes all layouts shall have a minimum of two ducts upstream of the enclosure.

[30.06.2022] AVL-12. Figure 7.5 – The provisions for the ducts described in points (a), (b), (c), and (d) of this paragraph shall apply to the overall test layout (including the ducts connecting to and from the climatic conditioning unit, fans, flow restrictors, and filter boxes).

Proposal: This is inconsistent with the previous definitions. There is no technical justification for this. The wording of this point is completely misleading. This is technically not possible for several elements in the system (filter boxes, fans, flowmeters, etc.). Is not consistent with previous clause 9 (clean final) as discussed in TF2. What was the intention for adding this point?

Response. Agreed. This point was added to verify that ducting shall be the same from two diameters before the enclosure to two diameters after the flow measurement device. The text has been amended accordingly.

[30.06.2022] AVL-13. 12.1.2.2 – Select sampling lines with a constant inner diameter (ds) of at least 10 mm and a maximum of 20 mm (10 mm ≤ ds ≤ 20 mm). A sampling line with a constant inner diameter close to 15 mm is highly recommended.

Proposal: Not necessary. Delete sentence since it causes unnecessary confusion. What is "close to 15mm"?

Response. We do not see the confusion. Some TF2 partners suggested that sampling lines of 15 mm and higher are optimal. JRC wouldn't like to mandate only 15 mm; therefore, we allow for 10-20 mm and recommend the use of 15 mm.

[30.06.2022] AVL-14. 12.1.2.3 – The method of measuring the volumetric flow of the sampling system (QPM2.5 and QPM10) shall have a maximum permissible error of ±2.5 per cent of the reading or ±1.5 per cent of the full-scale, whichever is the smallest, under all operating conditions.

Proposal: Better use flow instead of volumetric flow.

Response. Corrected.

[30.06.2022] AVL-15. 12.1.2.3 – Use a volumetric flow measurement device calibrated to report flow at both operating and standard conditions (273.15 K and 101.325 kPa).

Proposal: Better use flow measurement device instead of volumetric flow measurement device.

Response. Corrected.

[30.06.2022] AVL-16. 12.1.4 – Store the filter in a closed petri dish or sealed filter holder until testing. Use the filter within 12 hours of its removal from the weighing chamber (or room).

Proposal: AVL submitted data of blank filters used during the ILS, which have been stored in a petri dish for 3 weeks without any significant change in mass (<5µg). For the sake of better automation, it should be allowed to place the filters in the holders before starting the bedding.

Response. Agreed. The elapsed time for empty filters has been set to 24h.

[30.06.2022] AVL-17. 12.1.4 – Post-sampling conditioning and weighing – Take the filters to the conditioning room within 8 hours after testing is completed.

Proposal: See previous comment.

Response. Although we understand the need for increasing elapsed time for empty filters (supported also by data) we don't see any reason for exposing loaded filters before they weigh for a long time.

[30.06.2022] AVL-18. 12.2.2.3 – A bend may be applied to the outlet lines provided that the bending radius rp shall be at least twenty-five times the outlet line diameter (25·dtl).

Proposal: Make wording consistent with headline and figure 12.2. "PN Internal Transfer Line"

Response. Corrected.

[30.06.2022] AVL-19. 12.2.3.2 – Use a volumetric flow measurement device calibrated to report flow at both operating and standard conditions (273.15 K and 101.325 kPa).

Proposal: Better use flow measurement device instead of volumetric flow measurement device.

Response. Corrected.

[30.06.2022] AVL-20. 12.2.3.2 – The actual normalized sampling volumetric flow (NQTPN10 and NQSPN10) shall not deviate more than ±10 per cent of the average value for the given test.

Proposal: See previous comment.

Response. Corrected.

[30.06.2022] AVL-21. 12.2.3.2 – Register the actual normalized sampling volumetric flow and report it at a frequency of 1Hz in the Time-Based file.

Proposal: Better: actual sampling flow normalized to standard conditions.

Response. Corrected.

[30.06.2022] AVL-22. 14.2 – "Brake inertia dynamometer".

Proposal: Change to "Brake Dynamometer", see previous comments.

Response. Agreed.

[30.06.2022] TSI-1. Figure 12.2.

Comment: The figure indicates two pre-classifiers are used, one for the TPN and one for SPN. However, 12.2.1.1 (b-e) provides provision for the use of a single probe for both TPN and SPN. There is no mention, however, of a single cyclone being permitted, or prohibited.

Proposal: Change the note after 12.2 (g) to say: “TPN10 and SPN10 sampling shall use different probes as specified in 12.2.1.1 (a). The same sampling probe and pre-classifier can be used provided that the pre-classifier fulfils the requirements specified in paragraph 12.2.2.1 for the total flow of the two devices and the applied flow splitter fulfils the requirements specified in paragraph 12.2.1.1 (b-e).

Response. Agreed. The text has been amended to include provisions for both single- and two-probes setup. The provisions for the cyclonic separators have been added to 12.2.2.1 (pre-classifier).

[30.06.2022] TSI-2. **Comment:** The particle transfer tube is defined as a tube to transfer particles from the probe’s outlet to the pre-classifier when the pre-classifier is not directly connected to the probe’s outlet. However, no provision is mentioned for the case in which the PTT is directly connected to the probe outlet.

Proposal: Change 12.2 (c) to say “A suitable tube (Particle Transfer Tube – PTT) transfers particles from the sampling probe to the pre-classifier, or when the pre-classifier is directly connected to the probe’s outlet, the PTT transfers particles from the pre-classifier to the sample conditioning system. The specifications for the design of the PTT are described in paragraph 12.2.1.4” Proposal: Change 12.2.1.4 to say “When the pre-classifier is not directly connected to the probe’s outlet, a suitable transfer tube (PTT) shall be used to transfer particles from the probe’s outlet to the pre-classifier. When the pre-classifier is directly connected to the probe’s outlet, the tube connecting the pre-classifier to the sample conditioning system shall function as the PTT. A PTT may be permitted upstream or downstream of the pre-classifier, but only a single PTT may be used...”

Response. Correct. The text has been amended accordingly.

[30.06.2022] TSI-3. **Comment:** For 12.2.2.2 (g) and (q) it states that the arithmetic average PCRF must be monitored in real time and reported at a frequency of at least 1 Hz and references the method described in paragraph 14.5.1. As PCRF is physically a product of the sample conditioning system losses and dilution factor (and any inaccuracies in either), without monitoring the diluted and undiluted concentration, the only way this could be monitored in real time would be to measure dilution factor in real time and then use a static loss correction factor to calculate PCRF in real time. However, this is not indicated in the method prescribed. Paragraph 14.5.1 describes measuring PCRF at each dilution setting and particle size, and calculating PCRF as the ratio of upstream to downstream concentration in Eq 14.1. Using this method, there’s no way to separate out dilution factor from loss correction factor and a static PCRF must be used. Eq. 14.3 seems to indicate that DF multiplied by the ratio of outlet/inlet concentration may be used to calculate “particle penetration Pr(dx) at a particle size dx) but the value particle penetration is not mentioned elsewhere in the standard. Proposal: PCRF be defined as: PCRF= DF*LCF. Where PCRF is calculated in real time by DF as measured in real time, and LCF, a static loss correction factor determined by the following for a given dilution setting. LCF = fr/DF at a given dilution setting as defined by Eq. 14.2

Response. This requirement intends to monitor and report possible changes in the dilution factor (and the arithmetic average PCRF) without introducing further signals in the Time-Based file and without further complicating the calculations. The specification has been amended and reads as follows: “It shall monitor the dilution factor variation in real-time to report the arithmetic average PCRF (fr-SPN10) at a frequency of at least 1 Hz. The calculation of the arithmetic average PCRF shall follow the method described in paragraph 14.5.1”. So, indeed the PCRF definition is as given by you but since this is common understanding we think it is not necessary to verify it. Does it make sense?

[30.06.2022] TSI-4. **Comment:** For the system level zero check mentioned in 12.2.5 (c) does “the inlet of the entire particle sampling system” refer to the nozzle on the probe inlet? Or the sample and conditioning system inlet? Or a filter on the entire tunnel?

Response. This refers to the sample conditioning system. The text has been corrected accordingly.

[30.06.2022] TSI-5. **Comment:** 12.2.3.2 (a-d) reference that a volumetric flow measurement device be implemented to report measured volumetric flow. 12.2.3.2 (c) references use of a critical orifice as an option to ensure a stable flow. This seems to imply that a device *other* than the critical flow orifice be used to measure flow. Is this the intent? Or is implementing a calibrated critical orifice with pressure monitoring (to verify flow remains choked) and temperature and pressure measurements to convert to standard conditions as specified in (b) acceptable?

Response. Correct, a separate flow measurement device shall be used to monitor the flow rate. Note that the device must not be necessarily a volumetric flow meter (it could be a mass flow meter correcting for pressure and temperature). The wording has been amended accordingly and the word “volumetric” from 12.2.3.2 b (and other parts where it was not relevant) has been deleted.

[30.06.2022] TSI-6. 13. **Comment:** Our interpretation of registration frequency vs reporting frequency is as follows. Is this correct?

- Registration frequency is the frequency at which a value is written to the time based file at the frequencies shown in table 13.2 for example, 10 Hz for CPC.
- Reporting frequency is the frequency at which individual parameters are reported to the measurement system. For example, >0.5 Hz as specified in 12.2.3.1 (e)
- Therefore, for while data may be written at 10 Hz, the values may only be changing at 0.5Hz

Response. Registration frequency is the frequency at which the automation system measures and registers the given parameter (reported to the measurement system based on your interpretation). This can be up to 250 Hz for certain parameters. Reporting frequency is the frequency at which the parameters are registered in the different files described in paragraph 13. Obviously, for the Time-Based File, the reporting frequency is always 1Hz since the file shall include 15826 entries corresponding to the WLTP-Brake duration. For the Event-Based File, data are reported; and therefore averaged, for each braking event. A clarification has been added to clarify that data shall be reported as explained above.

[30.06.2022] TSI-7. **Comment:** Regarding the email correspondence on 28, June 2022 indicating that the PCRF flow path components shall contain PND1, CS. PND2, <u>and CPC</u>. The concept of including the CPC in the measurement of PCRF is not clear to us. Is the intention that the specific CPC being used with the specific sample conditioning system be used as the downstream concentration reference in the PCRF measurement? Our interpretation as written is that PCRF should be measured for PND1, CS, and PND2, and that is done using upstream and downstream concentration, but that the CPC itself is not a component for which PCRF is included. Please confirm if this is true or if we have some misunderstanding.

Response. Correct, this was an error in the email communication. Indeed, the PCRF should be measured for PND1, CS, and PND2.

[01.07.2022] BREMBO-1. Fig 7.1.

Comment: This layout is not aligned with the specs of clause 12. Clause 12 allows at one 90° bend downstream of the enclosure and upstream of the sampling plane and the length L1 was not mentioned at all.

Response. The Figure illustrates one of the two possibilities (i.e. layout without a bend in the sampling tunnel). It is mentioned (also in the figure caption) that the figure is indicative and that an alternative layout with a bend of certain specifications is allowed in the sampling tunnel. The Figure has been corrected to remove the element not compliant with the overall specifications which were R1. L1 has been mandated in the enclosure's paragraph 7.4.2 (ex-7.2 (f)).

[01.07.2022] BREMBO-2. 7.2.2.2.3: equations 7.1 and 7.2.

Comment: I would add: TPN10 average background concentration, for all the concentrations listed.

Response. Agreed. A clarification has been added in point (d) after equations 7.1 and 7.2 "Calculate and report the background particle concentration values per distance driven only at the test level both pre- and post-test…".

[01.07.2022] BREMBO-3. 7.2.3. When using air filters to protect the airflow measurement device from contamination, install the filter at least five diameters upstream of the flow measurement device. Follow the recommendations regarding the type and specifications of the filter from the manufacturer of the flow measurement device.

Comment: Does this mean that there are not instruments on the market able of measuring the airflow with the specs above in "dirty" air? The usage of filters in the case of airflow measurements can severely affect the measure, filters are always associated with a decrease in the air speed, moreover this variation varies along the test, from the beginning with a new and clean filter to the end with a dirty one.

Response. The specification has been added to "protect" the flow measurement device from dirt that would possibly affect the measurement capacity or even destroy the sensors. The specification for placing such filters at least 5 diameters before the sensor has been added to avoid influencing the flow measurement.

[01.07.2022] BREMBO-4. 7.2.3. A system leak check covering the ductwork and the enclosure shall take place before testing. Set the cooling airflow at 50 per cent of the test setup's maximum capacity. If the average measured flow in the sampling tunnel is within ±5 per cent of the set value proceed with the testing. If the flow fluctuates beyond ±5 per cent of the set value cease testing activities, verify the flow measurement device, identify possible sources of the leak(s), take corrective action to resolve the issue, and resume testing by first performing a successful leak check.

Comment: How much does this leak check take? Is the 5% variation calculated on a time based? I would define the minimum duration of this phase, as done for the PN background check. Moreover, to perform a better leakage test two sensors are required, one at the inlet and one at the outlet of the enclosure.

Response. Agreed. A clarification that the check shall last at least for 2 min after the airflow is stabilized has been added. Indeed, two sensors would be better for complete leak checks. This is not prohibited in the protocol. However, when the testing facility can verify that the measured flow downstream of all elements is the one set by the system we see it as a passed leak check, too.

[01.07.2022] BREMBO-5. 7.4.1. The inlet transition volume (Figure 7.3 – 1) is defined as the section of the enclosure between planes A and B and is illustrated with a grey colour. The enclosure may have flow straighteners or diffusion plates placed between planes A and B.

Comment: If flow straighteners are mandatory, why do we need a duct with a length of 2 diameters before the inlet (L1 in Fig. 7.1)?

Response. Flow straighteners or diffusion plates are optional (not mandated) in this protocol. Therefore, the request for two diameters before the enclosure has been mandated to ensure some comparability and for harmonization purposes.

[01.07.2022] BREMBO-6. 7.4.2. The airflow at the entrance of the enclosure shall remain turbulent with a Reynolds number of at least 4000 for all airflow testing settings to ensure sufficient mixing.

Comment: If the target is to achieve a turbulent flow at the entrance I have not clear the aim of the length L1 and of the flow straighteners.

Response. Turbulent flow coming out of a bend will travel downstream differently when compared to turbulent flow coming out of a straight duct. The latter flow in turn travels differently compared to turbulent flow passing through flow straighteners. The specification in question talks about the necessity of having turbulent flow for proper mixing INSIDE the enclosure. The elements referred to in the comment are about flow controls at the INLET to create maximum exposure to the brake and for particle transport downstream.

[01.07.2022] BREMBO-7. 7.4.2. Apply Computational Fluid Dynamics (CFD) to calculate the airspeed values at nine positions of plane C as defined in Figure 7.4. Use the entire cross-section area of plane C to determine the calculation positions. Define plane C considering a disc diameter of 450 mm. Carry out the computation at three different cooling flows representing the minimum, 50 per cent, and the maximum of the operational range of the test system. Simulate for a period sufficient to detect any instability in the airspeed pattern that may affect the airspeed values. Conduct the simulation without a brake assembly or a brake fixture installed. Airspeed at each position shall not vary by more than ±20 per cent of the arithmetic mean of all measurements for a given flow.

Comment: Is this procedure needed to ensure that the turbulence inside the enclosure are due to the disc movement only? Why do we need a turbulent flow at the inlet and then we are requested to check the flow uniformity in this section?

Response. Please see the previous answer on this topic.

[01.07.2022] BREMBO-8. It is strongly recommended that the testing facilities conduct measurements instead of the simulations to verify the airspeed uniformity defined in point (k) of this paragraph.

Comment: Measuring the airspeed without introducing a significant perturbation will be really hard and challenging, is there someone inside the PMP group able to perform this kind of measurements?

Response. Indeed this is a challenging measurement. However, it will need to be carried out once at the installation of the enclosure. There are PMP members who have verified that they can perform this kind of measurement.

[01.07.2022] BREMBO-9. 7.5: A maximum of one bend of 90° or less may be applied downstream of the brake enclosure and upstream of the sampling plane provided that the specifications for the design and the minimum distancing described in (f) and (g) are met.

Comment: This sentence does not agree with the description of Fig 7.1, maybe will be better to clarify that Fig. 7.1 is not representing the minimum specifications but it is for demonstrative purpose only.

Response. Agreed. See the previous comment on the subject.

[01.07.2022] BREMBO-10. 8.1.1: Vehicle Test Mass (M_{veh}): It is the mass in running order (MRO) of the vehicle (kg) on which the tested brake is mounted plus.

Comment: It would be better to define more in detail the MRO definition, for example by adding a reference here (i.e. as defined in GTR 15).

Response. This has been moved to the definitions section: "Mass in running order" is the mass of the vehicle, with its fuel tank(s) filled to at least 90 per cent of its capacity, including the mass of the driver, fuel, and liquids, fitted with the standard equipment in accordance with the manufacturer's specifications and, when they are fitted, the mass of the bodywork, the cabin, the coupling and the spare wheel(s) as well as the tools."

[01.07.2022] BREMBO-11. 8.2.1: Perform acceleration events to reach different linear speeds (5 km/h, 50 km/h, and 135 km/h) and record residual torque during the acceleration to the set speed and after cruising at the target speeds for 10 seconds (at zero brake pressure). Verify that this spinning torque remains less than 20 N·m. If the spinning torque exceeds this value check again the LRO, running clearance (including thermocouples wiring), and brake bleed, in that order of diagnosis.

Comment: Are the 20 N m calculated excluding the torque absorbed by the dyno-bench bearings?

Response. Correct. The spinning torque of 20 Nm does not include the torque absorbed by the dyno-bench bearings. A clarification has been added to the text.

[01.07.2022] BREMBO-12. 8.2.1: Perform not more than three stops using mild test conditions for speed and deceleration to verify data collection, test parameters, brake test inertia, and overall system operation.

Comment: I suggest to add the exact parameters for these stops (for example use the first three stops of the Trip 1 or repeat the first stop three time, as done for the warm-up snubs during cooling air adjustment).

Response. Agreed.

[01.07.2022] BREMBO-13. Table 10.2.

Comment: Maybe a topic for future discussion/improvement and possible GTR amendment; if from future testing campaigns/ILS (with the harmonized testing layout) the airflow data will show small differences between the different labs, could the cooling airflow be also harmonized? In theory, a single airflow will simplify the GTR but we think that the decision has to be taken on the basis of future experimental data.

Response. The development of the cooling adjustment method has been based on real-world vehicle data tested under the WLTP-Brake cycle. Laboratory data demonstrated that a common airflow would not provide realistic temperature regimes for all brake applications. This is why we developed the different WL/DM groups (following the industry's suggestion) and elaborated on the target temperatures for every group always allowing for some flexibility to account for different designs, properties, uncertainty, etc. The GRPE-81-12 adopted a similar approach which was further elaborated and refined to include more experimental data. Any simplification step in future versions of the GTR will need to be tested, verified, and proven robust with experimental data. Additionally, this data will need to come from well-defined systems in the context of this GTR.

[01.07.2022] BREMBO-14. 12.1.2.2: Use sampling lines made of conductive stainless steel applying the appropriate fittings. Alternatively, flexible antistatic PTFE sampling lines may be used.

Comment: Will only PTFE lines be allowed? Will silicon conductive pipes be permitted?

Response. Due to the material properties and the manufacturing process, these hoses contain plasticizers and separating agents. Over a period of 5h sampling, it can accumulate a good amount of mass (background artefact) on the PM filters, even at room temperature. For the sake of not introducing additional uncertainties, conductive silicon hoses for filter-based PM applications are not allowed.

[01.07.2022] BREMBO-15. 12.1.2.2: The overall length of the sampling line from the cyclonic separator to the tip of the filter holder shall be as short as possible. In any case, do not use sampling lines longer than the maximum allowed length of 1 m.

Comment: Just a question here, from my understanding the maximum overall length of the sampling line is 2 m (1 m from the tip of the nozzle to the inlet of the cyclone + 1 m from the outlet of the cyclone to the inlet of the filter holder), am I right?

Response. This is not correct. For PM sampling the cyclonic separators shall be mounted directly to the outlet of the sampling probe (paragraph 12.1.2.1 (c)). Therefore, the specifications are for the sampling line from the outlet of the cyclonic separator to the tip of the filter holder.

[01.07.2022] BREMBO-16. 12.1.4: Store the filter in a closed petri dish or sealed filter holder until testing. Use the filter within 12 hours of its removal from the weighing chamber (or room).

Comment: We have a system able to store the filters inside a particle free and conditioned glovebox, will the storage in this system be allowed?

Response. Agreed. An equivalent option has been added to the text.

[01.07.2022] BREMBO-17. 12.2.1.1: When applying a flow splitting device, demonstrate that the penetration with and without the splitter remains within ±5 per cent at all operating conditions. Perform the comparison by measuring the particle penetration at 15 nm and 1.5 µm with and without the flow splitter using at least one brake system.

Comment: In my opinion, it is not clear how to evaluate the penetration at 15 nm and 1.5 µm with and without the flow splitter. Moreover, should this evaluation be reported?

Response. This is a validation that the testing facility shall perform once. Two particle generators shall be used: one for bigger particles (1.5 µm) and one for smaller particles (15 nm). Indicatively, TOPAS, PALAS, etc. provide such generators (ISO 16890). The testing facility shall not report the results but verify (in the report) that the validation has been performed and the difference in the flow is within the specifications. It shall also be in the position to demonstrate compliance whenever asked.

[01.07.2022] BREMBO-18. 12.3: Use a weighing scale of a resolution of at least 0.01 g or better for parts below 30 kg of total weight. Install the weighing scale in a room with controlled air and humidity to standard laboratory conditions of (22 ± 2) °C and (45 ± 8) per cent RH.

Comment: These balances are hard to find and particularly expensive, in the end measuring with a 0.01 g resolution components heavier than 15 kg shall be challenging. Do we really need such a high resolution up to 30 kg?

Response. While this is the case for most full friction brakes, it will be very challenging to measure brake wear for regenerative brakes. There, a weighing scale with the proposed resolution will be required.

[01.07.2022] BREMBO-19. 12.3: Wear measurement specifications and methodology have been adopted from the SAE J2986:2019 Recommended Practice. It is not required that the test facility reports the wear measurement results.

Comment: Are you referring to the thickness or mass measurements?

Response. This refers to the thickness measurement (wear measurement in the text). Mass loss shall be reported as specified in Paragraph 13.

[01.07.2022] BREMBO-20. 13.1: Tab 1 shall include all raw data registered by the brake dynamometer throughout the entire test.

Comment: If this Tab shall include all the raw data acquired with a fast sampling rate (at 250 Hz) Excel can not open it (too many rows to be handled). What do you mean exactly with raw data in the Event based file?

Response. Registration frequency is the frequency at which the automation system measures and registers the given parameter (reported to the measurement system based on your interpretation). This can be up to 250 Hz for certain parameters. Reporting frequency is the frequency at which the parameters are registered in the different files described in paragraph 13. Obviously, for the Time-Based File, the reporting frequency is always 1Hz since the file shall include 15826 entries corresponding to the WLTP-Brake duration. For the Event-Based File, data are reported; and therefore averaged, for each braking event. A clarification has been added to clarify that data shall be reported as explained above.

[01.07.2022] BREMBO-21. 13.1. **Comment:** Please note that in the example file named "Event-based File template" only Tab1 is included?

Response. Agreed. It has been corrected (also in the Time-Based File).

[01.07.2022] BREMBO-22. Table 13.2: Linear Speed Actual.

Comment: Is this the overall speed trace? Is the 250 Hz acquisition used only for the averaging of the Brake speed in the Event based file? The same comment is valid for all the 10 Hz parameters listed here with a similar parameter recorded at 250 Hz for the Event-based file.

Response. Agreed. A clarification has been added (see the previous comment).

[01.07.2022] HORIBA-1. Figure 7.1.

Comment: Layout shows bending radius r_b with three times duct diameter ($3*d_i$) – should be two times diameter as described in chapter 7.5, see below.

Response. Agreed. Actually, this is a bend after the sampling tunnel; therefore, the specification for the bend does not apply. It has been corrected in the Figure.

[01.07.2022] HORIBA-2. 7.2. The provisions for the ducts described in points (a), (b), (c), and (d) of this paragraph shall apply to the overall test layout (including the ducts connecting to and from the climatic conditioning unit, fans, flow restrictors, and filter boxes).

Comment: This point (i) should be cancelled or at least not apply to the overall test layout but (a), (c) and (d) should apply from two duct diameters (2·di) upstream of the enclosure's inlet until from two duct diameters (2·di) downstream the airflow measurement element (inside red frame in Layout below). Point (b) should only apply for the mandatory horizontal section of the test layout to avoid particle losses – its not necessary to have the complete ducting electro polished. Beside this there is no evidence, that the whole ducting needs to be electro polished. If point (i) is required this would cause dramatic issues to upgrade existing dynos with their climatic conditioning units for GTR brake dust measurement. As far as I know this point wasn't discussed by PMP.

Agreed. This point was added to verify that ducting shall be the same from two diameters before the enclosure to two diameters after the flow measurement device. The requirement for electropolished ducts has been removed for parts other than those in contact with the aerosol. The text has been amended accordingly.

[01.07.2022] HORIBA-3. 12.2.1.1 Sampling plane: (g) When applying a flow splitting device, demonstrate that the penetration with and without the splitter remains within ±5% at all operating conditions. Perform the comparison measuring the particle penetration at 15 nm and 1.5 µm with and without the flow splitter using at least one brake system.

Comment: There is no particle generator that can provide aerosol with particle size 1.5 µm. The requirement is impossible to fulfilled. We would propose to verify splitter using procedure for PCRF determination- simply provide PCRF for both outlets of splitter und put limitation ±5% between two outlets.

Additional comment: There are no data to prove that proposed methodology for production and measurement of 1,5 µm particles could provide repeatability with recommended ±5% tolerance. JRC has to provide experimental data for those type of technology. Additionally, the topic was never discussed by TF2 or PMP meetings.

Response. There is a particle generator for bigger particles; however, not the same as for smaller particles. Therefore, the requirement can be fulfilled. Indicatively, TOPAS, PALAS, etc. provide such generators (ISO 16890). We don't believe that flow-splitters are an ideal solution for PN measurement; however, we understand that it facilitates the design and simplifies the overall layout. However, we need to make sure that whenever they are used they have been adequately validated. Additionally, data from the CARB project show that the PN distribution shows one peak at 1.0-2.0 µm, therefore, the validation of effective penetration of 1.5 µm particles is necessary for a correct measurement.

[01.07.2022] HORIBA-4. 10.1.2 PN sampling probes: (d) The overall length of the probe(s) from the sampling nozzle tip to the inlet of the particle transfer tube shall not exceed 1 m.

Comment: There was a discussion to increase the length to 2 m of transfer tube. Could you please correct text?

Response. The discussion in "Comments and Responses on Clause 10" page 1 relates to the 10.1.4 "Particle transfer tube" and not the 10.1.2 "PN sampling probes". For the probe, we never agreed to anything different than what is proposed.

[01.07.2022] HORIBA-5. 12.2.1.4 Particle Transfer Tube: When the pre-classifier is not directly connected to the probe's outlet, a suitable transfer tube (PTT) shall be used to transfer particles from the probe's outlet to the pre-classifier.

Comment: In the document well defined PTT, on picture marked as a blue ellipsis. Our comment about definition of line, marked with red ellipsis, connecting outlet of pre-classifier and inlet of dilution system for TPN or VPR by SPN? What length is allowed? Are there same requirements as for PTT or as for internal lines?

Response. In TF2 it has been clear since the beginning that one tube can be allowed at this point in the layout. The text has been amended accordingly to reflect this requirement and reads as follows: "When the pre-classifier is not directly connected to the probe's outlet, a suitable particle transfer tube (PTT) shall be used to transfer particles from the probe's outlet to the pre-classifier's inlet. When the pre-classifier is directly connected to the probe's outlet, the PTT shall be used to transfer particles from the pre-classifier's outlet to the sample conditioning system's inlet. **In any case, only a single PTT may be used and the testing facility shall ensure that its design meets the following requirements for both TPN10 and SPN10 sampling**".

[01.07.2022] HORIBA-6. Chapter 12.2.3.1 Particle Number Counter: Report PCRF-corrected PN concentrations at standard conditions at a reporting frequency equal to or greater than 0.5 Hz;

Comment: We have to distinguish between CPC and instrument for measurements of particles including CPC + dilution + VPR(optional). CPC is not able to provide any information including PCRF and /or dilution for system before CPC. CPC is able only provide measured particle concentration. All factors like for dilution and/or PCRF should be applied by instrument that will automate dilution line and CPC. At same time the instrument will be able to provide all type of checks mentioned in Chapter 10. Taking to account all requirements from Chapter 10.3.1 I would expect that you are writing requirements for CPC but not for instrument. Maybe it may sense to move requirement "(e) Report PCRF-corrected PN concentrations at standard conditions at a reporting frequency equal to or greater than 0.5 Hz"; To the chapter 10.3.4 PN system check procedures, and call chapter" Requirements for PN system".

Response. Corrected.

[01.07.2022] HORIBA-7. 13.2: "This clause describes the specifications for the PN concentration measurement during brake emissions testing. The PN sampling and measurement systems enable the quantification of the PN concentration generated by the friction couple during the test. The measured PN concentrations along with the parameters from the test provide the emissions factors for the brake under test in number of particles emitted per driven km. The test system shall be capable of measuring Total-PN (TPN10) and Solid-PN (SPN10) at nominal particle size of approximately 10 nm electrical mobility diameter and larger using separate measurement systems".

Comment: Should be to different instruments provided for measurements? What is the reason for it? We could provide one instrument with two different dilution lines (of course with different PCRF for each line) and separate CPC for TPN10 as well as for SPN10. Application of such instrument will reduce cost for customer and provide more flexibility for measurements at test bench. Could be restriction for 2 separate system applied for 2 separate CPC with separate dilution line?

Response. Corrected.

[01.07.2022] HORIBA-8. 12.2.1.4 Particle Transfer Tube: When the pre-classifier is not directly connected to the probe's outlet, a suitable transfer tube (PTT) shall be used to transfer particles from the probe's outlet to the pre-classifier.

Comment: Could you please provide requirements for transfer tube that will connect outlet of pre-classifier and inlet of diluter for TPN, respectively VPR for SPN?

Response. This has been clarified in other comments, too. The paragraph applies both to TPN10 and SPN10. Thermal treatment follows afterwards (downstream of the cyclone) so there is no reason to provide separate specifications.

[01.07.2022] HORIBA-9. 12.2.1.3. PN Sampling Nozzles.

Comment: We did not get so far clear evidence why nozzles for PN isokinetic sampling have to be used. Could you please provide such information?

Response. TF2 agreed to define (relaxed) isokinetic specifications also for PN sampling and measurement. Nobody objected to the proposed target of 0.6-15 and this is the reason we define the need also for isokinetic nozzles. Size distribution data show peaks at 1.0-2.0 µm. Overall, brake particles are larger than exhaust; therefore, this decision is fully justified.

[01.07.2022] HORIBA-10. 12.2.2.2. Sample Conditioning: It shall monitor the arithmetic average PCRF (fr-TPN10) in real-time and report it at a frequency of at least 1 Hz. The calculation of the arithmetic average PCRF shall follow the method described in paragraph 14.5.1.

Comment: According to paragraph 14, PCRF should be measured in advance to Brake Dust measurements by calibration of the instrument. Does it mean that we should report the same PCRF but only with frequency 1 Hz or you mean dynamical PCRF? If dynamical PCRF should be reported what is requirements for it? We never discussed dynamical PCRF at PMP.

Response. This has been clarified in other comments, too. Sample Conditioning, subsection (q) requires real-time monitoring of the PCRF. Although it will be quite stable during the test small variations will need to be registered to make sure no problems are encountered during testing. For Horiba instruments it shall be straightforward (DF real-time * PCRF average).

[01.07.2022] JASIC-1. **Comment:** Japan do not accept full WLTP cycle. We only accept the cycle without Extra High phase, which is allowed as CP option in GTR15 (WLTP). So, the new Brake GTR should describe two options of tests (w/, w/o Extra High) as in GTR15.

Response. This is the first time the topic is brought up in the context of the GTR development. Japan mentioned some concerns in a previous PMP meeting but this was a long time before we receive the mandate to develop a GTR (2019). In the meantime, the topic was never brought up again either during the ILS exercise (JARI participated). Finally, the PMP has not received such a request or any data that could support the development of any alternative proposal.

Unlike all exhaust regulations, the WLTP-Brake cycle does not have distinct L/M/H/ExH sections. It is a mixed cycle where the "Extra high phase" is part of Trip 10. More specifically, there are 953 s at a velocity of >110 km/h from which the 663 s are with a velocity of 112 km/h (marginally higher than 110 km/h) and the rest 320 s are with a velocity of 132.5 km/h. Overall, the extra-high part is approximately 6% of the entire cycle duration (15826 s). Please note that Trip 10 contains also urban and rural parts so it cannot be eliminated as a whole like with the WLTP exhaust cycle.

Unlike exhaust regulations, cruising at velocities >110 km/h does not affect brake emissions which are the target measurement parameter of this GTR. So, whereas we understand the need for different cycles in the GTR15 (pollutants are emitted during cruising) this is not the case for brake emissions. Indeed, in the WLTP-Brake cycle, two brake events are starting at a velocity of >110 km/h: One starting at 112 km/h (marginally higher than the 110 km/h) and another starting at 132.5 km/h. The first brake event is a situation that may occur in Japanese motorways since the difference from 110 km/h is marginal. The second event is an outlier for the Japanese driving style; however, it could be considered an "extreme" or "emergency-type" event. This would be in line with the intention of the GTR to test the worst-case scenario.

In fact, based on the ECE/TRANS/WP.29/2021/150, the second development phase defines ***(a) "Definition of a real-world cycle/s for use in the laboratory"***. The item proposed by JASIC could very well fit this phase and therefore be examined in this context.

[01.07.2022] JASIC-2. **Comment:** In this case, we need to determine the new verification parameter (which events should be included).

Response. The cooling adjustment method is ***an artificial test*** applied to define the proper cooling airflow for the brake under testing. In principle, the method shall target the same testing airflow for two identical brakes tested in two identical layouts. In other words, the cooling adjustment method shall provide at minimum comparable airflows for the same brake. The application of a different version of the WLTP-Brake cycle does not and shall not influence the cooling adjustment method.

[01.07.2022] JASIC-3. **Comment:** Japan thinks that the second inter-lab test is essential to evaluate the new methodology. The test should be performed either before or after submitting the final version of a new GTR.

Response. We don't believe that another ILS before the testing facilities finalize the design of their new test layouts makes sense. The PMP could discuss the possibility of another ILS after the GTR is adopted. We believe that a series of similar activities will anyway follow the adoption of the GTR.

[01.07.2022] JASIC-4. **Comment:** 7.2.2.2.3 (e) "brake emissions measurement section per paragraph 12.2.3.3" should be "…. per paragraph 12.2.2.4)".

Response. Corrected.

[01.07.2022] JASIC-5. **Comment:** 7.4.3 (g) "The maximum axial depth ・・・shall be between 400mm and 500mm" should be "The maximum is ・・・shall be under 500mm" because it restricts maximum.

Response. During the T2 discussion on this topic, there was a request from several members to further restrict the possible available options for all dimensions. In this context, we proposed also lower limits for all dimensions (length, height, depth) based on the available designs from the ILS. This is the reason why a minimum depth of 400 mm has been proposed.

[01.07.2022] JASIC-6. **Comment:** 8.3 (d), (e) Adding reference source or information will help to understand why the thermocouple is set 0.5mm±0.1mm depth from the surface.

Response. The ISO 26867 performance test indicates 0.5 mm depth. TF1 adopted this requirement as it has been a common practice in the industry. The ±0.1mm is to allow for some flexibility.

[01.07.2022] JASIC-7. **Comment:** 8.4.2 Adding reference source or information will help to understand why the caliper is set on 12-o'clock position.

Response. This is a step for harmonizing the method. We would like to ensure that all testing facilities apply the same orientation and flow direction and not to introduce another source of uncertainty. In our point of view, here the vehicle behavior is irrelevant since the enclosure is a closed system (unlike the vehicle's wheel) where we aim to collect the particles efficiently, direct them towards the sampling plane, and keep the temperature regimes at certain levels.

[01.07.2022] JASIC-8. **Comment:** 12.2 (f) Using "An outlet line" or "PN internal transfer line" instead of "A particle line" will be better.

Response. Corrected.

[01.07.2022] UBA-1. Definitions.

Comment: We would appreciate a separate definition for "sampling train", according to section 7.1.

Response. Agreed. A definition has been added.

[01.07.2022] UBA-2. 6. Brake emissions measurement. This section includes one performance of the WLTP-Brake cycle. The emissions measurement section is described in detail in Paragraph 12.

Comment: Only 1 execution of brake emissions measurement? Please explain how this can adequately represent the statistical variations on the three execution approach used before.

Response. The purpose of 3 emission measurements during the ILS was i. to verify the stabilization of the emission behaviour, ii. Understand the repeatability within the testing facilities. The vast majority of the tests showed that there is no difference between the first, second, and third measurements. We don't believe that adding an extra testing burden will give any added value to the test.

[01.07.2022] UBA-3. 7.2. The system can combine two variable flow fans (one to push and one to pull) to provide a slight negative pressure inside the sampling tunnel.

Comment: Reference to definition for "slight negative pressure"?

Response. A typical negative pressure that could be achieved with two variable flow fans is -0.5 kPa. Higher values could be achieved with an increased power blower; however, are not considered necessary.

[01.07.2022] UBA-4. 7.2.1. The testing facility shall continuously monitor the temperature and humidity of the conditioned cooling air. For that reason, the testing facility shall install temperature and humidity sensors in the last segment of the duct before entering the brake enclosure.

Comment: In Fig. 7.1 there are two segments between the sensors and the enclosure (straight, bend). Please clarify.

Response. This is left open to the testing facility to decide based on their design. We don't expect any difference in the measured values as long as we stay upstream of the enclosure. According to Fig. 7.1, the sensors are placed before the bend in a straight section. We would not advise placing it on the bend but in any other suitable place.

[01.07.2022] UBA-5. 7.2.1.1. The instantaneous cooling air temperature may deviate up to ±5 °C of the nominal value (15 °C ≤ T ≤ 25 °C), for no longer than the 10 per cent duration of the test (cooling sections not included), provided that the average temperature meets the requirements defined in point (a) of this paragraph.

Comment: What is the required recording frequency of the temperature/humidity? Are there some details on the sensor (inertia) beyond it's a PID-sensor?

Response. According to Table 14.2, the registration frequency for these parameters is 10Hz. Data shall be reported at 1Hz (averaging the 10Hz values). No additional details are specified for the sensors. The sensors shall meet the defined requirements for accuracy.

[01.07.2022] UBA-6. 7.2.2.2.1. Perform the background verification at three different tunnel flow settings representing the operating range of the test facility. The minimum, 50 per cent, and maximum operational airflow of the system shall be tested. The test facility may use a single nozzle size for sampling PN during the system background verification with the different airflow settings

Comment: Free choice of nozzle diameter? Background concentration can be significantly under- or overestimated.

Response. Based on our analysis there is no such risk. Nozzles are selected to define isokinetic sampling and minimize losses of bigger fine particles. When testing for background these particles are not relevant since they are only produced during brake testing.

[01.07.2022] UBA-7. 7.4.3. Cleaning and maintenance of the brake enclosure shall follow the specifications provided by the manufacturer regarding the frequency and means.

Comment: Necessity to clean box/duct/probes/etc. depends sometimes strongly on the emission level of the brake. In order not to falsify the measurement result, regular cleaning should be a matter of course - but may have to be defined. Cleaning shall be mandatory between and only between brake emission tests. Cleaning intervals and procedure should not be open to manufacturers specifications.

Response. Agreed. A specification has been added that the testing facility shall ensure the enclosure is clean before commencing a brake emissions test.

[01.07.2022] UBA-8. 8.1.1: The brake force distribution per the default method on the UN Regulation No 90 for decelerations below 0.65 g shall be applied only whenever the vehicle manufacturer’s specific value is not available.

Comment: The car’s actual brake force distribution should be a prerequisite for performing an emissions test. Is this a realistic scenario? This generic approach might be not the mandatory worst-case.

Response. It is not always the case that the brake force distribution is always known (e.g. a third-party testing facility). Whenever it is not possible to obtain this information there still needs to be a robust and harmonized way for testing. The R90 is a well-established regulation that provides values for similar cases in the context of a different regulation. It does not represent the worst-case scenario but rather an average realistic scenario.

[01.07.2022] UBA-9. 8.4: **Comment:** Should the parking brake be dismounted?

Response. A common design of EPB for example carries a big 'box' on the caliper that is likely to block particles from going airborne. So, one should use a caliper without PB for disc brakes. For harmonization, the same shall be applied to the drum brakes. In reality, the same disc and pads can be used with a conventional caliper or an EPB caliper on a given vehicle platform. So, it becomes imperative to quantify PM EFs for the worst-case scenario brake-friction. A sentence has been added to clarify this part.

[01.07.2022] UBA-10. 8.4.2: The testing facility shall position the calliper to minimize potential interference with the incoming cooling air. Install the calliper above the disc in a 12-o’clock position as illustrated in Figure 8.6 irrespective of the mounting position of the vehicle. Other calliper orientations (i.e. vehicle's mounting position) are not allowed and will invalidate the test.

Comment: What about special forms of construction regarding section 8.4.2? E.g.,pad mounting via cast-on guide on wheel carrier?

Response. The reasoning behind the selection of 12 o'clock relates to the need for harmonization. The real use case of the vehicle is not so relevant for this particular part of the testing method. In the vehicle, particles are spread around in a relatively open environment. In this case, we need to direct the particles in a common direction outside the enclosure. Therefore, we need a uniform layout that applies to all tested brakes. In this context, every configuration at the 12 o'clock position is allowed. All other configurations are not allowed and a clarification has been added to the text.

[01.07.2022] UBA-11. 10.1.2: For rear brake systems of M1 and N1 vehicle categories the nominal (or set) cooling airflow defined for the corresponding front brake application (i.e. same vehicle data) shall be applied.

Comment: Why using the airflow from corresponding front brake for rear brake? Is the thermal design comparable between both axes of a vehicle? Or will the rear brake run significantly cooler/warmer (depending on type of brake) and therefore not comparable to real thermal behavior? Does this represent the worst case?

Response. This has been proposed mainly for harmonization and simplification purposes. At the moment we don't have enough data to prepare corresponding WL/DM classes for rear brakes. If this becomes the case in the future and the PMP identifies a need we could propose an amendment to the protocol. Furthermore, it has been requested by many participants for simplification purposes. All testing facilities will first test front brakes; therefore, the cooling flow will be already known and will not lead to an additional testing burden. Taking into account that rear brakes are tested under a much lower load, the temperature differences are not expected to be significant with the application of the front brake flow.

[01.07.2022] UBA-12. 10.1.2: For rear brake systems of M1 and N1 vehicle categories the nominal (or set) cooling airflow defined for the corresponding front brake application (i.e. same vehicle data) shall be applied**.**

Comment: Do you mean "disc brake systems"? If not, please clarify the difference between (b) and (c).

Response. Agreed. It has been corrected to "disc brake systems".

[01.07.2022] UBA-13. 11: The bedding procedure shall be carried out with the same brake parts used during the cooling adjustment section or with completely new brake parts.

Comment: Is there a maximum number of cooling test repetitions to be allowed to continue with the same friction pairing specified? - e.g.: 5x Trip10 = 324 km, as during and thus a good 1/3 of the actual bedding distance (961 km). - For "standard friction pairings", which are run in after just under 1000 km WLTP Brake Cycle and emit reproducibly, the number of cooling tests is probably negligible; Coated discs that have not necessarily reached their run-in condition after 1000 km of WLTP Brake Cycle could be helped to a more favorable emission behavior via a longer history (cooling tests). Should there be a stop criterion for the number of trips in the cooling adjustment section? (see. "n" x Trip in Fig 6.1).

Response. No, the GTR does not foresee a maximum number of cooling test repetitions. Experience shows (including the ILS) that the testing facilities can define the correct airflow after a maximum of two or three iterations. Therefore, we do not expect that there will be significant deviations from this number. Additionally, ILS data showed that emission levels are quite stable between the 6th, 7th, and 8th WLTP-Brake repetition, therefore, we don't believe it would make any difference if one or i.e. four iterations are carried out.

[01.07.2022] UBA-14. 11.1: If the brake parts are disassembled after the beginning of the bedding procedure, they are no longer suitable for completing bedding and emissions measurements. In that case, the testing facility shall replace with new brake parts and repeat the bedding procedure from the beginning.

Comment: What about opening the enclosure and cleaning, see comment in section 7.4.2 (m).

Response. Agreed. In general, it is not allowed to interfere with the enclosure and the brake during the entire emission test. In case of interruption, the testing facility shall inspect and decide if cleaning the enclosure is necessary for starting bedding from scratch. A provision has been added for inspecting the enclosure between brake emission tests (see respective comment above).

[04.07.2022] OICA-1. GTR drafter's statement. "Agreement on the method's target measurement parameters. TF2 agreed unanimously that both PM (PM10 and PM2.5) and PN (≥10 nm) emissions shall be addressed"

Comment: There was no general agreement - it was only adopted for the ILS campaign.

Response. The scope of the testing method was defined during the first TF2 meeting. It has been analysed and published in the document "M#01-Definition of the Scope.pdf" (https://wiki.unece.org/display/trans/PMP+TF2+on+Brake+Emissions). Therein, both PM_{10} and $PM_{2.5}$ are clearly defined as target measurement parameters. The same applies to PN. The TF2 has carried out all its work based on the agreement that these shall be the target measurement parameters without ever receiving any objection from any of its members.

[04.07.2022] OICA-2. "5.2 Definition of Brake Family".

Comment: Brake family concept is welcomed, but it has to be elaborated, discussed, and worked out together with vehicle manufacturers. Concepts and the text have to be based on data.

Response. The objective is to discuss this topic in the next months and finalise it until the submission of the final working document in October. Any data or proposal from OICA in this context is more than welcome.

[04.07.2022] OICA-3. "Figure 7.1 Indicative layout for performing brake emissions test in the laboratory".

Request: Delete TPN10 and PM2.5: Total particle number showed high variability during the ILS. From exhaust legislation there is only a calibration procedure for SPN10. PM2.5 adds complexity. The ILS analysed PM10 in detail, only.

Response. $PM_{2.5}$ has been defined as a target parameter very early in the procedure (see answer above). $PM_{2.5}$ is a critical pollutant and the GTR shall provide the means to measure it. $PM_{2.5}$ comprise about 35-40% of the overall PM_{10}, whereas the ILS data demonstrate a similar behaviour regarding the $PM_{2.5}$ and PM_{10} variability. We do not see the additional complexity since $PM_{2.5}$ is measured exactly like PM_{10}, whereas it does not require any significant investments or adaptations in the overall setup.

The ILS has demonstrated the need for measuring TPN10 from brakes. Data have shown that certain brakes may emit two to three orders of magnitude higher particle number concentrations. It is not possible to capture these brakes if only SPN10 is tested. As for $PM_{2.5}$, the GTR shall provide the means to measure also TPN10. The ILS demonstrated that the same calibration procedure as for SPN10 can be applied successfully. If more data in the future become available, the method could be further fine-tuned.

There were concerns expressed about the high variability of TPN (but also $PM_{2.5}$ and PM_{10}) but the uncertainty is typically taken into account in the emission limits (for any of the four metrics that will be regulated by the Contracting Parties that will adopt the regulation).

[04.07.2022] OICA-4. "7.2.1.1. Cooling Air Temperature".

Comment: Cooling adjustments. Temperature should be 23 ºC, aligned with exhaust testing facilities.

Response. The cooling air temperature has been set at 20 ºC since the beginning of the development phase. As a result, the TFs and the PMP have carried out all their analysis related to the cooling adjustment method on this value. At this point we see no added value in making such a change particularly when we don't have a dataset that could support the change – on the contrary ILS1 data (TF1) showed that a shift of 5°C in the cooling settings resulted in a similar shift of brake temperature regimes, thus making it important to have data before changing the temperature. Exhaust testing foresees full vehicle testing on a chassis dyno and follows an entirely different approach. The proposed GTR does not foresee any brake emissions testing on the chassis dyno for any reason in the future. Therefore, temperature alignment for that reason is not a strong argument to make the change.

[04.07.2022] OICA-5. "7.2.1.2. Cooling Air Humidity".

Comment: Relative humidity should be replaced by absolute humidity (as described for exhaust PMP).

Response. To our knowledge, the PMP method (GTR15) does not define humidity requirements for the dilution air in the tunnel (in some cases, air from the test cell is used for the dilution tunnel, but nevertheless, the absolute humidity requirements are broad). Absolute humidity requirements are set for the test cell air that may have an impact on the engine NOx emissions. In brake emissions, relative humidity has been used as the metric for humidity since the inception of the development phase. Again, all analysis has been conducted using this parameter. Unlike temperature, in this case, shifting from RH to absolute humidity does not introduce uncertainty in the proposed method since we are not changing the settings of the parameter but only the way to read its values. However, this analysis would require pressure corrections to translate RH to AH and this data might not be available – at least the PMP has not received any data. At this point, we would not be in favour of this change: 1. Due to lack of measured values and study of the behavior with the absolute humidity, 2. Due to a relatively small proportion of tests that did not fulfil the specification during the ILS (<5%). Interested parties are invited to provide full datasets with both values to further examine the feasibility for the future (for example laboratories at different altitudes and respective impact of relative – absolute humidity on brake emissions).

[04.07.2022] OICA-6. "7.4. Brake Enclosure Design" and "7.5. Design of the Sampling Tunnel".

Comment: The brake enclosure should have tighter specifications. This must include less variability and reduction of duct losses. OICA/ACEA will provide a proposal for adjustment. CFD simulation for air speed is questionable. A validation by measurement is needed.

Response. We generally agree with the need for an enclosure as standardized as possible; however, also take into account the different testing needs. For that reason, we have mandated the design of one specific layout (i.e. symmetrical layout). Additionally, we have restricted the options for the minimum and maximum dimensions including length, height, and depth based on the ILS available systems. Additional limitations in the transition angle and the h_i/h_c ratio have been introduced. Any further suggestion for improvement along these lines is welcome. The PMP will discuss in September – and before the submission of the final working document – the possibility of mandating the validation by measurement instead of the CFD simulation.

Similarly, the flexibility in the design of the sampling tunnel has been reduced and allows only for accommodating the different testing needs (i.e. 3 or 4 sampling probes).

[04.07.2022] OICA-7. “3.1.10. "Road Loads" means the total force or power required to move the vehicle on a level and smooth surface at a specified speed and mass. Road loads take account of transmission friction, rolling friction, and air resistance. In this GTR, a reduction of the brake nominal inertia by a fixed percentage of 13 per cent is considered to account for road loads in full-friction brakes emissions testing.”

Comment: The proposal of 13 % does not reflect the higher road load of LCVs. The method of the investigation of the road loads, e.g. use of F-Terms instead of a fixed number, needs to be discussed and agreed.

Response. The PMP has not received any data or analysis of brake emission tests performed with the application of the F-Terms. On the other hand, all data we have processed apply the correction of 13% (more than 400 full emission tests including the ILS). Therefore, the proposal to apply the 13% correction was taken on the basis of existing data and also for harmonization purposes. If there are data demonstrating that the proposal of 13 % does not reflect the average road load of LCVs, the PMP shall take them into account and examine the possibility of applying a different correction for these vehicles. Please note that a one-to-one comparison with the exhaust regulation is not possible or correct in this case. There, a full vehicle is being tested on the chassis dyno; therefore, the application of the correct road loads is of high relevance, especially for CO_2.

[04.07.2022] OICA-8. “8. Test Preparation Requirements, 8.1. Input Parameters and 8.1.1. Full-friction brakes”.

Comment: Depending on the revision of section 3.1.10, the wheel load reduction (13 %) should be revisited and adjusted accordingly. This needs to be adjusted for paragraphs (d) and (g).

Response. Please see previous reply on the topic.

[04.07.2022] OICA-9. “3.1. Vehicle and Brake Dynamometer settings”.

Comment: Non friction braking contributions should be extended (i.e. by powertrain friction, regenerative braking etc.). Exception for ICE-only vehicles: engine friction can be omitted for simplicity and with reference to ILS data.

Response. The current proposal foresees a placeholder for all relevant definitions under “3.7. Reserved [Pure electric, pure ICE, hybrid electric]”. The definitions under 3.7 will then be distributed accordingly to the paragraphs they belong to (mostly in 3.1 as suggested in your comment). Please submit your comments to further complement this part.

[04.07.2022] OICA-10. “9. WLTP-Brake Cycle and 9.1. General Information”.

Comment: Description for vehicles with speed limitation is missing. A proposal could be to limit the speed to maximum vehicle speed for those brake events.

Response. This is the first time the topic is brought up in the context of the GTR development. The PMP has not received such a request or any data that could support the development of any alternative proposal. Based on the ECE/TRANS/WP.29/2021/150, the second development phase defines ***(a) “Definition of a real-world cycle/s for use in the laboratory”***. The item proposed by OICA could very well fit this phase and; therefore, be examined in this context provided that data will be brought to the PMP for consideration.

[04.07.2022] OICA-11. “9.2.2. Bedding Section”.

Comment: A less time-consuming bedding procedure should be considered, following up on ILS data. Several repetitive emission measurements should be allowed. The decision of the valid emission measurement will be done in agreement with the technical service - due to improper bedding.

Response. The PMP has discussed this topic thoroughly in both TF1 and TF2. The PMP never received completed and robust data from different testing facilities demonstrating the feasibility of a shorter bedding procedure for the purpose of the GTR. ILS data provided contradicting results. Furthermore, the ILS demonstrated through the execution of three measurements that the current bedding methodology provides a well preconditioned and stable brake in terms of PM and PN emissions (i.e. difference in emission levels among the three measurements was very low).

[04.07.2022] OICA-12. “10.1.1. Definition of Brake Groups and Verification Parameters (b) For rear brake systems of M1 and N1 vehicle categories, the nominal (or set) cooling airflow defined for the corresponding front brake application (ie. same vehicle data) shall be applied;”

Comment: Further clarification is needed. For example, what about a rear brake with different front brakes. Cooling air adjustments are not clear, yet. Do they only apply to front brakes?

Response. The cooling air adjustment is always carried out with front brakes. Rear brakes are tested for their PM and PN emissions by applying the cooling settings of the corresponding front brake. When a rear brake is combined with different front brakes it shall always be tested taking into account the worst-performing combination of front-rear brakes. This will be further clarified in the definition of families.

[04.07.2022] OICA-13. “12. Particle Emissions Measurements Section and 12.1. Measurement of Particle Mass (PM) Concentration”.

Request: Delete all references to PM2.5. PM2.5 has not been analysed for variability in the ILS.

Response. See the comment above regarding the necessity and feasibility of measuring $PM_{2.5}$. $PM_{2.5}$ variability has been analysed and is at the same level as PM_{10}. Data will become publicly available in the period to follow. In any case, the ILS variability was never defined as a prerequisite for the inclusion of the metric in the GTR. This could not have been the case taking into account the uncertainty of the calculated variability due to the non-compliance of almost all testing facilities with the TF2 protocol.

[04.07.2022] OICA-14. “12.1.3.1. Filter Holder”.

Comment: Multiple PM measurements should be possible, i.e. switch system for PM measurement flexibility across lab working shifts etc.

Response. A brake emissions test lasts more than 24h all sections included. Once the test is completed, the testing facility shall remove the brakes (and the filters) and mount new ones to proceed with another test. Therefore, we don’t understand the need for the measurement flexibility described in your comment in the context of the GTR. The reason for not allowing this option in the proposal relates to the application of a flow splitting mechanism in these systems. Flow splitters have been shown to have a negative impact on the PM_{10} measurement. The reason relates to the relatively big size of brake particles compared to any other particles regulated in the automotive section. These particles are prone to higher losses when flow splitters are applied. This is the reason for not allowing their use anywhere between the sampling probe and the filter when it comes to the PM measurement.

The PMP could discuss the possibility of allowing such a system in the GTR if the method for testing regenerative braking requires the execution of back-to-back emission measurement sections. However, in this case, it has to be proven that the particle losses are negligible in order to avoid having particle loss correction factors for these systems. Any experimental data shall be brought to the PMP group.

[04.07.2022] OICA-15. “12.2. Measurement of Particle Number (PN) Concentration”.

Request: Total particles (delete TPN and consider solid particles SPN10). Length of the PN (and PM) sampling line need to be discussed.

Response. See the comment above regarding the necessity and feasibility of defining a measurement procedure for TPN10. The high variability needs to be reflected in any relevant emission limits.

Dimensions of the PN and PM lines have been extensively discussed during the TF2 meetings and the proposals have been elaborated using the ILS data. Multiple feedback loops followed and the final specifications reflect the instrument manufacturer's state-of-the-art experience. If there are particular points in the definition of the lengths or any other dimensions that are not clear please define them.

[04.07.2022] OICA-16. **General comment:** The validation and calibration methods need to be elaborated and included in the GTR.

Response. The entire Paragraph 14 is dedicated to calibration and quality control procedures. In particular, for the PN and PM systems, the proposed procedures follow GTR 15.

[04.07.2022] OICA-17. **To do:** Check sampling nozzle size for PM for isokinetic sampling at different dilution flows. Should be added to test report.

Response. Agreed. The check has been added to the Table (lines 195, 197, 299, 301).

[04.07.2022] OICA-18. **To do:** Proper mounting of spreader springs.

Response. Agreed. Please submit a proposal for the proper mounting of the spreader springs.

[05.07.2022] AIP-1. 7.2.2.2.3. Perform a zero verification of the PN measurement device. Apply a filter of appropriate performance at the PN measurement device inlet and record the PN concentration. The reading shall not exceed 0.2 #/cm³. Upon removal of the filter, the PN measurement device shall show an increase in measured concentration and a return to ≤ 0.2 #/cm³ on the replacement of the filter. The PN measurement device shall not report any errors.

Proposal: The sequence must be: First: Performance-check of the PN measurement device; second: Background-check.

Response. Agreed. Sequence modified.

[05.07.2022] AIP-2. 7.2.3. A system leak check covering the ductwork and the enclosure shall take place before testing. Set the cooling airflow at 50 per cent of the test setup’s maximum capacity. If the average measured flow in the sampling tunnel is within ±5 per cent of the set value proceed with the testing. If the flow fluctuates beyond ±5 per cent of the set value cease testing activities, verify the flow measurement device, identify possible sources of the leak(s), take corrective action to resolve the issue, and resume testing by first performing a successful leak check.

Comment: In combination with a slight systemic negative pressure (see paragraph 7.2) the leak check procedure is not significant; the procedure does only detect leaks from the flow measurement plane to the flow fan.

Response. Negative pressure is not mandatory; therefore, a leak check is required. The flow measurement device is installed downstream of the sampling plane and close to the "end" of the layout. A possible leak before the flow measurement device is crucial and shall be detected. A possible leak after is not crucial since i. the measurement is not affected, ii. particles have been filtered by the flow measurement device's filter. If the testing facility would like to apply an additional leak check downstream of the flow measurement device it is allowed to do so.

[05.07.2022] AIP-3. 7.4.3. Design the brake enclosure symmetrically to plane A1. The length of plane A1 (I_{A1}) represents the most extended length of the enclosure along the flow direction. The overall length of plane A1 (I_{A1}) shall be between 1200 mm and 1400 mm (1200 mm $\leq I_{A1} \leq$ 1400 mm);

Comment: The horizontal dimensions in figure 7.5 and in the marked paragraph are labelled with a big "I". If I compare with paragraph (e) it should be a little "l".

Response. Agreed. Symbols have been aligned.

[05.07.2022] AIP-4. 7.5. The provisions for the ducts described in points (a), (b), (c), and (d) of this paragraph shall apply to the overall test layout (including the ducts connecting to and from the climatic conditioning unit, fans, flow restrictors, and filter boxes).

Comment: Mentioning (b) in this context is a little confusing, because it is not the intention to design the overall test layout with an electropolished finish (or equivalent).

Response. Agreed. The requirement for electropolished ducts has been removed for parts other than those that are in contact with the aerosol. The text has been amended accordingly to clarify that (a), (c), and (d) shall apply from two diameters before the enclosure's inlet to two diameters downstream of the flow measurement device.

[05.07.2022] AIP-5. 12.1.1.2. If a bend is applied to the probe, the bending radius r_p shall be at least four times the probe's inner diameter ($4 \cdot d_p$);

Comment: From my point of view it doesn't make sense to permit a bending radius of at least $4d_p$ in terms of the sampling probes, on the other hand there is a restriction to design the bending radius of the sampling line (12.1.2.2 (g)) with at least $25d_s$; in terms of particle losses this seems contradicting for me.

Response. Allowing the design of a bend on sampling probes was requested by several TF2 participants to allow for some flexibility in the design. Based on the restrictions imposed by the tunnel inner diameter and the minimum distancing, $4 \cdot d_p$ is the maximum curvature we can request for. If there are similar concerns from other members (not the case so far) we could discuss again the possibility of not allowing bends at least for the PM10 sampling before the submission of the final proposal in October.

[05.07.2022] AIP-6. 12.1.2.1. The cyclones shall fulfill the specifications for the separation efficiency described in Tables 12.1 and 12.2;

Comment: I guess not all commercially cyclone manufacturers provide the size-depending efficiency; more popular is the flow-rate – cutpoint diagram.

Response. The GTR proposal follows the example of ISO 25597:2013 where the cyclone separation efficiency is applied. This was also applied during the ILS. The testing facilities shall request from cyclone manufacturers this information. Alternatively, labs can test the penetration themselves if they have the appropriate equipment.

[05.07.2022] AIP-7. 12.1.2.2. The overall length of the sampling line from the cyclonic separator to the tip of the filter holder shall be as short as possible. In any case, do not use sampling lines longer than the maximum allowed length of 1 m;

Comment: In combination with an inner diameter of 15 mm (see paragraph (c) and (g) it is impossible to design a 180° bending with a max. length of 1 m; 180° are necessary to connect cyclone (outlet upwards) with the filter holder (inlet downwards).

Response. The specifications in this clause do not restrict the setup to the use of cyclones with 180° (outlet upwards – inlet downwards). A cyclone with a 90° angle between outlet and inlet may be applied. When 180° cyclones are applied; indeed, the maximum inner diameter for the sampling line can be up to 13 mm. This is in line with the recommendation in the text “A sampling line with a constant inner diameter close to 15 mm is recommended”.

[05.07.2022] AIP-8. 12.1.2.3. The PM sampling device shall operate continuously during the brake emissions measurement section. This includes also the cooling sections between the individual trips of the WLTP-Brake cycle where the PM sampling flow shall not be paused or bypass the main sampling line;

Comment: In my point of view the idea is to restrict a pausing or bypassing the main sampling line while testing. A device-internal bypass should be permitted to adjust the correct flow before starting sampling.

Response. This provision has been added for harmonisation purposes (i.e. all testing facilities apply the same method). During the ILS, there were only two laboratories that applied such devices whereas the rest 14 did not. In any case, we don’t expect any difference in emission levels.

[05.07.2022] AIP-9. 12.1.4. Weigh the reference filters at the beginning and the end of a weighing session;

Comment: How is the weighing session defined? Weighing a reference filter with each sample filter or just once a day/week etc.?

Response. The weighing session is defined by the brake emissions test. This means that reference filters shall be weighed before the pre-sampling and after the post-sampling weighing. A clarification has been added to the text.

[05.07.2022] AIP-10. 12.2.1.1. When applying a flow splitting device, demonstrate that the penetration with and without the splitter remains within ±5 per cent at all operating conditions. Perform the comparison by measuring the particle penetration at 15 nm and 1.5 µm with and without the flow splitter using at least one brake system;

Comment: Determining a particle penetration at the test stand is not practicable in my eyes and should be done, if necessary, in the laboratory: The brake itself for particle generation at 15 nm and 1.5 µm seems questionable for me. Except of this a DMA is necessary to produce the monodisperse aerosol, so the effort is very high at this point.

Response. We don’t believe that flow-splitters are an ideal solution for PN measurement; however, we understand that it facilitates the design and simplifies the overall layout. However, we need to make sure that whenever they are used they have been adequately validated. Additionally, data from the CARB project show that the PN distribution shows one peak at 1.0-2.0 µm; therefore, the validation of the effective penetration of both very small (i.e. 15 nm) and bigger (i.e. 1.5 µm) particles is necessary for a correct measurement. Indeed, a DMA is required but this is a one-off exercise that the testing facility will need to carry out upon the installation of the system. Indeed, the reference to a brake system is misleading and has been removed since the verification will need to take place not at the test stand.

[05.07.2022] AIP-11. 12.2.3.2. The method of measuring the volumetric flow of the sampling and measurement system shall have a maximum permissible error of ±5 per cent of the reading under all operating conditions;

Comment: Against the background of the wide isokinetic ratio 0.6 – 1.5, see below: Is it reasonable to measure the PN sampling flow? Adjusting the flow by a critical orifice and periodical checking the flow would be also proper from my point of view.

Response. This is to verify that everything was smoothly executed during the test. This is a rather long test and it might be the case that problems are encountered. Periodical checking could be a solution; however, it has not been precisely defined and does not ensure harmonisation among the testing facilities.