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Working Program for GRPE Working Group on Non-Road Mobile Machinery (NRMM)

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At the Ann Arbor NRMM WG meeting of 12th of September 2003, the working program for 2003 to 2005 was jointly agreed upon and it is presented in this informal document. This working program is based on a proposal by European Commission (EC), US Environmental Protection Agency (EPA) and Japanese Ministry of the Environment (MoE) concerning an efficient and fast working strategy of the NRMM WG:

Aim: The development of a world harmonised non-road test protocol (resulting in GTR) is based on the innovative approach of the comparison of the different legislations at world level. This will be done in an efficient way, deriving a test procedure which is as simple[1] as possible but still covers all aspects concerning the tests of the NRMM engines and meeting the overall requirements of a good methodology such as repeatability, etc. Consequently, due to this approach, the work can be used for other test protocols under GRPE and not only for NRMM.

Steps:

1. A reference test procedure, defined as "base-procedure", is selected: such a base-procedure should be the most complete one for number of topics and advanced methodology necessary to account very stringent emission standards. The test procedure, able to fulfil these requirements, is the on-highway US EPA 2007 that should be integrated for the specific parts, e.g.: the steady-state and transient cycles of NRMM engines, by the ad-hoc test procedure as quoted in the US EPA NPRM of April 15, 2003[2].

2. A table is prepared for each main topic of the base-procedure. Topics are, for example, CVS, exhaust gas flow measurement, particulate sampling system, etc. Each main topic is split in sub-topics such as, in case of the topic particulate sampling system: measurement system, probe, particulate sample transfer tube (from exhaust pipe or primary dilution tunnel to secondary dilution tunnel), etc. The characteristic of each sub-topic is examined like, in case of the sub-topic measurement system: method, type of dilution, ratio variations between sample flow rate and primary tunnel flow rate, etc.

3. The base-procedure has to be compared, sub-topic by sub-topic, with other three procedures: European, Japanese and relevant ISO ones. In this way, a cross-comparison of how the different sub-topics are dealt with by the various test procedures can be carried out.

[1] The adjective "simple" indicates not only the intended avoidance of any undue complexity of the test procedure (are certain measurements or limitations really necessary?) but also the optimisation of cost for equipment and work.

[2] ENVIRONMENTAL PROTECTION AGENCY: 40 CFR Parts 69, 80, 89, 1039, 1065, and 1068; 68 Federal Register pp.28327 – 28603.

4. A point that is approached in the same way by the various test procedures has to be in principle accepted provided that verifies the general frame of the GTR and its simplicity, repeatability and cost effectiveness requirements. It has to be avoided to join all together all the most complex things of each of the test procedures.

5. The controversial points existing among the various procedures will be clarified, where possible, by a theoretical approach (via mathematics or statistics) and by ad hoc testing, where needed.

6. Proposed responsibility for each line of activity will be with: Cle Jackson (assisted by Shirish Shimpi) for the US EPA test procedure (i.e. the base-procedure), Giorgio Cornetti for the test procedure of the European Directives, Kenji Kamita (assisted by Mitsuo Shikata) for the Japanese test procedure, Juergen Stein for the ISO standards.

7. Examination and cross correlation among the different test procedures will be carried out by a team (Giorgio Cornetti and other available experts).

8. Theoretical and/or testing definition of the controversial points will be carried out by governmental representatives (JRC, US EPA, Japanese MoE).

The following pages are an enclosure added to this informal document. They contain a good example for the comparison work: Comparison between ISO and EPA Part 89 carried out by Shirish Shimpi (Engine Manufacturer Association) in 2002.

ISO DIS 8178-1 2002 revisions, how they differ from 1996 Edition and EPA Part 89 and comments on the impact of these changes

Note: The emphasis is on changes in the ISO DIS 8178-1 2002 revision compared to previous edition. Comments in the other columns are provided as needed for clarification or to emphasize impact on those accustomed to performing to both US EPA and ISO procedures. EMA has requested EPA and CARB to allow EPA's 2007 on-highway procedures and technical amendments to apply to non-road engines to eliminate duplication of test equipment and methods. Comments are provided on the difference between the new ISO and the 2007 EPA procedures.

Shirish A. Shimpi
August 23, 2002

No	Sec No	DIS 8178-1 2002 (Edition 2)	8178-1 1996 (Edition 1)	EPA Part 89 Subpart D & E	Additional Comments
1	5.1.	References to volumes and volumetric flow rates as units of measure have been removed.	All volumes and volumetric flow rates were related to 273 K (0 ^{o}C) and 101.3 kPa	All volumes and volumetric flow rates were related to 273 K (0 ^{o}C) and 101.3 kPa. However, CVS computations that were based upon Part 86, Subpart N had reference conditions of 68 ^{o}F and 29.92 in. of Hg.	The objective was to convert volume and volumetric flow rates to mass and mass flow rates as a more robust unit of measure. This avoids the problems encountered when different procedures call for differing reference conditions of pressure and temperature. For example EPA's Part 86 Subpart N has reference conditions of 68 ^{o}F and 29.92 in. of Hg. The conversion of volumetric flow rate to mass flow rate requires that the density of the fluid be appropriately accounted for. This is not clearly laid out in 8178-1 Edition 2.
2	5.1.1	"compression ignition" has been removed from engine description			
3	5.1.1	The parameter α_a for naturally aspirated and pressure charged spark ignition engines has been removed		No impact – the parameter was not used in Part 89	
4	5.1.2	f_a has been widened to	Valid f_a is	Valid f_a is	f_a range has been widened to enable testing in laboratories

		$0{,}93 \leq f_a \leq 1{,}07$	$0{,}98 \leq f_a \leq 1{,}02$	$0{,}98 \leq f_a \leq 1{,}02$	where the original validity range was very difficult to meet. This change has permeated to other ISO test procedures.
5	5.2	Engines with charge air cooling – set at speed of declared maximum power and full load and within ± 5 K of the maximum charge air temperature specified by the manufacturer. Temp. of cooling media shall be at least 293 K (20 °C). CAC settings at full load and speed of the declared maximum power will not be changed for the whole test cycle. SAE J1937 may be optionally used.	Specifications of CAC air temperature and cooler pressure drop within ± 4K and ± 2 kPa of the manufacturers specs.	Section 89.327 follows SAE J1937	No major impact if SAE J1937 had been in use at the test site.
6	5.4.1	Engine intake restriction is within ±300 Pa (± 2.6 in H_2O) of the value specified by the manufacturer for a clean air cleaner.	Engine intake restriction is within ± 10% of the upper limit specified by the manufacturer for a clean air filter.	Engine intake restriction is within ± 5 % of the upper limit specified by the manufacturer for a clean air cleaner.	Actual impact will depend upon clean air cleaner value at maximum flow.
7	5.4.2	Engine exhaust back pressure set within ± 650 Pa (± 0.19 in Hg) of the value specified by the manufacturer in accordance with the respective regulation.	Engine exhaust back pressure set within ± 10% of the upper limit specified by the manufacturer at maximum declared power	Engine exhaust back pressure set within ± 5% upper limit at maximum declared power as specified by the manufacturer.	Actual impact will depend upon manufacturer's specification for upper limit.
8	5.4.5	For engines with limited adjustable carburetors, test of the engines shall be performed at both extremes of adjustment.	Not previously mentioned.	Not previously mentioned.	New requirement – unknown impact.
9	6	When a suitable reference fuel is not available, a fuel with properties very close to the reference fuel may be	Not previously mentioned.	EPA has specific fuel requirements.	No impact on certification testing since the fuel used has to be agreed to by the parties concerned.

ISO DIS 8178-1 2002 revisions, how they differ from 1996 Edition and EPA Part 89 and comments on the impact of these changes

		used. The characteristics of the fuel shall be declared.			
10	7.1	Equivalency of sample pair averages will be based upon T-test statistics	Equivalency of sample pair averages will be based upon ± 5% agreement of the sample pair average.	No EPA equivalency criteria in Part 89. In the 2007 regulations for Part 86, the T-test statistic is also used.	The EPA equivalency test for 2007 and the ISO test are similar but not the same. An F test has also been introduced.
11	7.3	Exhaust gas flow measurement has been expanded to allow tracer measurement method and air flow and air to fuel ratio measurement method. The air and fuel measurement method no longer allows flow based measurements (either wet or dry) – all measurements are to be converted to mass basis.	Exhaust gas flow measurement does not allow tracer measurement method and air flow and air to fuel ratio measurement method. The air and fuel measurement method allows flow based measurements (either wet or dry).	Exhaust gas flow measurement does not allow tracer measurement method and air flow and air to fuel ratio measurement method. The air and fuel measurement method allows flow based measurements (either wet or dry).	More options are provided for exhaust gas flow measurement but any flow based measurements need to be converted to mass based measurements.
	7.4	Accuracy			
	7.4	Power requirement deleted Engine speed (± 2 % of reading or ±1% of engine maximum value whichever is larger) Engine torque (± 2 % of reading or ±1% of engine maximum value whichever is larger) Air consumption (± 2 % of reading or ±1% of engine maximum value whichever is larger) Exhaust gas flow (± 2.5 % of reading or ±1.5% of engine maximum value whichever is larger) Calibration intervals are not specified and are left to	Power accuracy is specified. Engine speed (± 2% of engine maximum value) Engine torque (± 2% of engine maximum value) Air consumption (± 2% of engine maximum value) Exhaust gas flow (± 4% of engine maximum value) Calibration intervals are specified.	No power accuracy requirement. Engine speed (± 2 % of reading) Engine torque (± 2 % of reading or ±1% of engine maximum value whichever is larger) Air consumption (± 2% of engine maximum value) No specification for exhaust gas flow Calibration intervals specified.	No major impact except that the calibration intervals are now based upon specific regulatory agency requirements or quality system criteria.

		internal audit or quality procedures (ISO 9000). Accuracy for other instruments Temperatures ≤ 600K (±2K) Temperatures ≥ 600K (± 1% of reading) Exhaust gas pressure (±0.2 kPa absolute) Intake air depression (± 0.05 kPa absolute) Atmospheric Pressure (± 0.1 kPa absolute) Other Pressures (± 0.1 kPa absolute) Relative Humidity (± 3% absolute) Absolute Humidity (± 5% of reading) Dilution air flow (± 2% of reading) Diluted Exhaust Gas Flow (± 2% of reading) No calibration interval specified	Accuracy for other instruments Specific devices specified (Coolant and lube oil, fuel, combustion air, exhaust gas and dilution tunnel temperatures). Exhaust gas and dilution tunnel temperatures less stringent than in 2002. Pressures were specified as a % of engine max value or % of reading in 1996 but are now based on kPa units and the values are more stringent in 2002. Relative humidity accuracy specification unchanged in 2002 but additional absolute humidity specification introduced in 2002. No specification for dilution air flow accuracy in 1996. Calibration interval specified	Accuracy for other instruments Specific devices specified (Coolant and lube oil, fuel, combustion air, exhaust gas and dilution tunnel temperatures). Exhaust gas temperature (± 15 K) less stringent than in 2002. Pressures are specified as a % of engine max value or % of reading. Humidity specified in units of g of H_2O/Kg of dry air in CFR (± 0.5). Calibration interval is as required.	
	7.5	Determination of gaseous components			
	7.5.1.1	Accuracy: The analyzer cannot deviate from the nominal calibration point by more than ± 2% over the whole measurement range except zero, or ± 0.3% of full scale whichever is larger.	The term Measurement Error was used instead of Accuracy. The analyzer accuracy was ± 5% of reading or ± 3.5% of full scale whichever is smaller in 1996 Edition. The 2002 requirements are much more stringent.	The CFR requirements are essentially the same as the 2002 edition.	No impact if CFR requirements were followed.

			Specifications for concentrations less than 100 ppm in 1996 edition have been removed from 2002 edition.		
	7.5.1.2	Precision is the new word for Repeatability. Same as in 1996 except that specifications are based upon being above or below 100 ppm instead of 155 ppm.	Repeatability was the term used. Specifications were based upon being above or below 155 ppm.	Identical to 2002 edition	No or little impact.
	7.5.3.4	Hydrocarbon (HC) analysis. Additional item specifies the use of a non-heated FID for testing gas fuelled and dilute testing of spark ignited engines	Non-heated FID not an option in 1996 edition.	Non-heated FID not an option in EPA Part 89 rules.	Minor impact.
	7.5.3.6	Oxides of nitrogen (NOx) analysis. New item specifies that the sampling path be maintained at a wall temp of 328 K to 473 K (55 ^{o}C to 200 ^{o}C) for CLD or HCLD. Ice bath or other cooling device is optional for raw measurement as long as quench check is satisfied.	Only converter temperature spec. of 60 ^{o}C was specified.	EPA specifies 60 ^{o}C and above for wall temperature. EPA specifies ice bath or other cooling device for raw sampling.	Major difference between EPA and ISO regarding the use of ice bath or other cooling device for raw sampling. EPA requires cooling device and for ISO it is optional.
	7.5.3.7	Sulfur dioxide (SO_2) analysis. Equation for computation of SO_2 emissions is now specified.	No equation given.	No specification provided by EPA.	No impact.
	7.5.3.10	Formaldehyde (HCHO) analysis. FTIR is now specified as an optional measurement instrument.		Not specified in Part 89	No impact
	7.5.3.12	Air to fuel measurement is a new measurement allowed using a wide range air to fuel ratio sensor or lambda sensor of Zirconia type.		EPA doe not have this feature.	In appropriate to use this technique for certifying to EPA and ISO in one test.

ISO DIS 8178-1 2002 revisions, how they differ from 1996 Edition and EPA Part 89 and comments on the impact of these changes

	7.5.4	Sampling for gaseous emissions from dilution tunnel. For spark ignition engines and gas fuelled engines, direct measurement from the tunnel or by using bags for all gaseous emissions components is allowed.	Only specification for sampling from dilution tunnel for diesel engines is specified.	Dilute exhaust gas sampling is specified for petroleum-fueled non-road compression–ignition engines only.	No major impact.
	7.6.2.1	Filter Specification. Maximum filter face velocity is increased from 80cm/sec to 100 cm/s. Filter collection efficiency of at least 95% retained from earlier version of 8178-1. Not updated to match 2007 on-highway specification.	Max filter face velocity is 80 cm/sec.	EPA/CARB refer to 1992 version of ISO 8178-1 for PM. The 2007 on-highway regulations limit the maximum filter velocity to 100 cm/s. More requirements specified	Filter flow can now be increased to match maximum filter face velocity of 100 cm/s.
	7.6.2.3	Primary and backup filter pair required – same as in the past but does not match 2007 EPA on-highway requirements of one 47 mm filter	Primary and backup filter pair required	Non-road rules are expected to allow 2007 on-highway requirements of one 47 mm filter	If ISO does not allow single filter, then there will be a difference between ISO and EPA.
	7.6.2.4	Filter face velocity: See 7.6.2.1			
	7.6.2.5	Filter loading: changed from earlier version of 8178-1 to reflect lower emissions from engines. These are only recommendations.		No recommended filter loading specified. None specified in 2007 on-highway rules.	Since it is a recommendation – no impact.
	7.6.3.1	Weighing chamber conditions: Same as in earlier version of 8178-1. However, the specifications in the 2007 on-highway rules have been tightened. ISO: Room temp = 22°C ± 3 °C, Dew Pt = 9.5 °C ± 3 °C, Relative Humidity: 45% ± 8%.	ISO: Room temp = 22°C ± 3 °C, Dew Pt = 9.5 °C ± 3 °C, Relative Humidity: 45% ± 8%.	Same as ISO 8178-1 but 2007 on-highway rules require: Filter Stabilization environment: Room temp = 22°C ± 3 °C, Dew Pt = 9.5 °C ± 1 °C, Microbalance weigh station: Room temp = 22°C ± 1 °C, Dew Pt = 9.5 °C ± 1 °C,	As long as 2007 on-highway rules are followed, for weigh room set up, then we should not have a problem. Setting up per ISO may not allow 2007 based measurements.

ISO DIS 8178-1 2002 revisions, how they differ from 1996 Edition and EPA Part 89 and comments on the impact of these changes

	7.6.3.2	Reference filter weighing: Unchanged from earlier version of ISO 8178-1 – requires single filters or filter pairs. Reference filter weight change criteria has been modified: If deviation ≥ 40 μg max. or 10 μg +5% of PM loading then sample filter must be discarded.	If reference filter mass deviation is > ± 5% (± 7.5%) of recommended minimum filter loading then sample filter must be discarded.	Same as ISO 8178-1. 2007 on-highway requires single filters also if reference filter mass deviation is >10 μg then sample filter must be discarded.	No problem if single filters are used and 2007 on-highway procedure is followed.
	7.6.3.3	Analytical balance: Unchanged from earlier version of ISO 8178-1	For filters less than 70mm diameter – precision shall be 2μg and resolution shall be 1μg.	Same as ISO 8178-1. 2007 on-highway requires precision of better than ± 0.25 μg for repeated weights of a calibrated weight or better than ± 2.5 μg for repeated weights of a clean filter. Resolution of ≤ 0.1 μg.	No issue if 2007 on-highway specifications are followed.
	7.6.4	Additional specifications for particulate measurement – buoyancy correction is not required or specified as it is in 2007 on-highway rules		2007 on-highway requires buoyancy correction for PM.	No issue if 2007 on-highway specifications are followed.
	8.2.2	Calibration and span gases: Same as in earlier version of ISO 8178-1. Significant changes are in 2007 on-highway rules.			No issue if 2007 on-highway specifications are followed.
	8.2.3	Use of gas dividers – new section added – expanded the two sentences specified in previous version of ISO 8178-1. Primary gases used for blending must be known to an accuracy of at least ± 1%.			No issue
	8.2.4	Oxygen interference check gases: section added since it was left out of previous ISO			No issue

		8178-1 for raw measurements.			
	8.5.5	Establishment of the calibration curve – number of calibration points increased from 5 to 6; best fit linear or non-linear equation may be used instead of specifying the order of the curve fit polynomial; Zero specification was changed from ± 1% of full scale to ± 0.3% of fullscale. Once the calibration is done, the zero setting needs to be rechecked and the calibration repeated if necessary.			The calibration curve language is now more close to the language in Part 89. However, major changes are going to be in effect in the 2007 rules.
	8.6	Calibration of tracer gas: new section added. Calibration below 15% of full scale section is no longer specified except in this section – needs to be separated or clarified.			
	8.8.1	Optimization of the FID detector response: the following sentences were added – This is the initial flow rate setting which may need to be further optimized depending on the results of the hydrocarbon response factors and oxygen interference check according to 8.8.2 and 8.8.3. If the oxygen interference or the hydrocarbon response factors do not meet the following specifications, the air flow shall be incrementally			

		adjusted above and below the manufacturer's specification, 8.8.2 and 8.8.3 for each flow. The optimization may optionally be conducted using the procedures outlined in SAE paper 770141.			
	8.8.3	Oxygen interference check – this section has been modified to reflect specifications per EPA for raw emissions sampling.			No impact.
	8.8.4	New section on the efficiency of the Non-Methane Cutter (NMC) has been introduced with details on how to determine methane and ethane efficiencies. Portion of this was introduced in the earlier edition of ISO 8178-1 in Appendix C.			No impact.
	8.9.1	Interference effects with CO, CO2, NOx and O2 analysers – The frequency of performing these interference checks has been changed to include "but at least once per year".			EPA's frequency is once per year and hence no impact.
	8.9.3.2	NOx analyzer water quench check: the procedure has been changed to reflect changes in EPA's Part 89. However, the 2007 on-highway rules have made significant changes in the requirements.		ISO now matches Part 89.	However, changes in 2007 procedures makes EPA requirements more stringent.
	9.2.2	Exhaust gas analyzers used to check dilution ratio – the previous requirement of checking dilution ratio with		Not directly specified in Part 89 except through CARB rules to ISO 8178-1.	If the dilution ratio checks using CO2 or NOx measurements is deleted, the likely hood of errors in

		the use of either CO2 or NOx concentration measurements in the raw and dilute exhaust for each new engine installation has been deleted – it should be kept to ensure good DR measurements,			measuring dilution ratio can be high leading to errors in PM computation.
	9.4	The flow measurement calibration interval has been changed from every three months to at least once per year.		Matches Part 89.	More harmonization.
	11.7.1	Test sequence: Additional specifications have been inserted in this section. For engines with dyno controlling speed, the specifications are as the earlier version of ISO 8178-1. However, for dyno controlling load, new specifications are provided.		Specific control strategy not specified in Part 89.	EPA criteria is more stringent.
	12.1	Gaseous emissions – instead of "the last 60 seconds" – "at least the last 60 seconds" has been inserted.		Matches what was already in Part 89	More harmonization.
	13.1	Calculation of gaseous emissions - General: A table has been provided to help the reader navigate the various equations provided to determine gaseous emissions. This did not exist in earlier edition.			No issue
	13.3	Dry/wet correction: For the raw exhaust, a newer equation has been provided that takes into account fuel composition, molecular weights and molar volumes. Moisture after the			Results using the new equations may need to be restated in the case of EPA where no adjustment for the moisture content after the bath is made. The adjustment for the moisture

		ice bath is now accounted for when dry measurements are recorded. Previously this remaining moisture was ignored. One out was given for those that were not willing to measure this moisture. An estimate of the moisture content was made and a value prescribed. This concept is not in Part 89 or the 2007 rules.			content will have an impact on our emissions results causing them to be measured slightly higher – a penalty for the engine manufacturer compared to 1996 edition.
	13.4	NOx correction for humidity and temperature: A new equation is given based upon EPA/EMA study at SwRI. Although in the US 2007 rules, the corrections can only be applied based upon certain ambient conditions, ISO does not limit the application of this equation.			Corrections would need to be applied based upon the regulation. Although the equations are the same, their applicability differs.
	13.5	The "u" value is now provided in an equation form for those who want to use the more correct value. A tabulated value for "u" is also available based upon certain assumptions. This was the format in the earlier ISO version and in Part 89. However, here the table is more extensive. The treatment in 2007 as in previous EPA on-highway procedures, relies upon EPA specified densities for the various species.			Two separate computations need to be made for emissions computations although the differences would be minor.
	13.5.3	Determination of NMHC:			Minor issue since the

		This was in the annex in the previous edition. EPA's rules provide for a different computational scheme.			differences existed before.
	15.2	Main exhaust components: The cooling bath is retained as 'optional' in spite of ISO workgroup being informed that EPA insists on requiring a cooling bath for raw NOx measurements.			In order to satisfy both EPA and ISO, a cooling bath would be required.
	16	Determination of PM: No changes have been made to this section of ISO DIS 8178-1. This was not an issue in the past since EPA was aligned with ISO through CARB for PM. However, with the request for EPA and CARB to reference 2007 PM measurement techniques for non-road engines, there would be a difference in the way ISO and EPA measurements are taken. ISO needs to start adopting EPA's 2007 test techniques either by reference or by modifying the current DIS.			Could be an issue on harmonization.
	Annex A	The contents of the annex are better organized compared to the previous version. Neither Part 89 nor 2007 rules have anything like this in their texts.			Since this section is for clarifying/deriving equations, it does not have any impact on testing other than to help in the understanding where certain equations in the text were derived. One issue that is of concern is the fact that the molar volumes used in the derivation of equations do not

					follow the ideal gas law assumption of being equal and constant = 22.414 l/mole. This was also an issue with the 1996 edition. The worst example is for NO_2 that has been given a value of 21.809 l/mole, which is about 2.7% lower than the ideal gas value. I have provided corrections to the equations in my comments on the Annex. ISO may be reluctant to change the document and computations in the DIS – opting to do it in the future.
	Annex B	An example of an emissions computation is shown. This was not available in the earlier edition of 8178-1. It would be useful to make available a copy of the computational spreadsheet for those who need it. CFR does not have examples of calculations shown in Part 89, although some calculation examples are shown in Part 86.			No issue.
	Annex D	Determination of system equivalence is new and is more statistically rigorous than the criteria given in previous version of ISO 8178-1. EPA started with similar criteria to that in the DIS but after several iterations, has homed in on a criteria which includes a t-test and an F test.			Minor issue.

	Annex E	This section on Fuel Specific parameters is new and provides some convenient numerical values for users. No such item is available in Part 89 or in Part 86.			If care is given in the use of these parameters, there should only be a minor impact.