COMMISSION OF THE EUROPEAN COMMUNITIES

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Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery

(presented by the Commission)

EXPLANATORY MEMORANDUM

1. OBJECTIVE OF THE PROPOSAL

Requirements concerning emissions of air pollutants from compression ignition (CI) engines intended for use in non-road mobile machinery and with an engine power of 18-560 kW are covered by Directive 97/68/EC. The Directive includes two stages of emission standards. Stage I standards have already entered into force for all power bands and Stage II standards will enter into force between 31 December 2000 and 31 December 2003 depending on the power band. In December 2000, the Commission, in accordance with recital (5) of the said Directive, presented a proposal to include small (19 kW or below) spark-ignition (petrol) engines within its scope. This proposal was voted on by the European Parliament for second reading in July 2002 and the Council has accepted the result of that voting.

Furthermore, Article 19 of the Directive provides for a tightening of the emission standards for compression ignition engines. The Commission should submit a proposal for a further reduction in limit values based on the techniques generally available for controlling air-polluting emissions and the air quality situation.

2. BACKGROUND

2.1. Air quality situation

2.1.1. General

The Auto-oil Programme (COM (2000) 626 final) concluded that, although air quality within the Community has improved and would further improve as the result of action already decided upon, environmental air quality problems would still remain. It mentioned in particular the need to address ozone formation (the emission of nitrogen oxides, NOx, and volatile organic compounds, VOCs,) and particulate emissions. In addition, local air quality problems in the form of high NO_2 levels would remain in some cities.

2.1.2. Emissions from CI engines in non-road mobile machinery (NRMM)

In relation to the remaining air quality problems, as presented in the Auto-Oil II Programme, the pollutants of importance from CI engines are NOx and particulate matter (PM). Emissions of VOCs, the other precursor of ozone, are generally low from these engines.

With a few exemptions, non-road mobile machinery is not registered. Furthermore, the actual uses of the different types of NRMM vary considerably. It is therefore difficult to estimate the actual emissions from this equipment with any degree of accuracy.

At Community level a rather comprehensive inventory was made in 1994 as a basis for the implementation of Directive 97/68/EC. The study did of course include some uncertainties, and is now some years old, but it does nevertheless give a rough estimate of emissions from non-road mobile machinery – including tractors. According to this inventory, emissions before the introduction of Stage I of Directive 97/68/EC were as follows:

Engines	NOx (kt)	PM (kt)
All CI engines covered by Directive 97/68/EC and agricultural & forestry tractors	1,630	190

The implementation of Stages I and II of the current legislation has reduced and will further reduce those emissions. It is reasonable to assume that compared with a “non-regulated” engine, a Stage II engine emits around 40% less NOx and 60% less PM. To a certain extent this reduction has been counteracted by the increased number of engines. Based on that inventory, overall emissions from non-road mobile machinery with engines of 19 kW or above, including tractors, will be as shown in the table below once all current engines have been replaced by Stage II engines.

To give a rough idea of the overall level of emissions the data from the final Auto-Oil II report has been incorporated into the table below

Sources	NOx (kt)	PM (kt)
All CI engines covered by Directive 97/68/EC and agricultural & forestry tractors - estimate for 2020 (all engines meeting Stage II limit values)	1,000	80
Overall emissions 2020 (AO II report)	6,015	1,538
Emissions from road transport 2020. (AO II report)	985	83 (1)

(1) Tailpipe emissions only

2.1.3. Conclusions

It can be concluded that there is a need for further action to tackle air quality problems in the future. This was mentioned in Article 19 of the current Directive 97/68/EC as one of the prerequisites for Stage III. It can further be concluded that emissions from non-road mobile machinery, even allowing for the uncertainty of the emission inventories, will significantly add to those air quality problems.

2.2. Globally available technology

The number of engines produced for non-road mobile machinery is much lower than for on-road applications. A global market has therefore been developed for these products. This is the reason for mentioning the availability of abatement technology on a global basis in Article 19 of the current Directive 97/68/EC.

Primarily because of higher production volume, the development of advanced technology to reduce pollutant emissions from CI engines has generally taken place within the field of on-road applications. These technical solutions are then applied, with the necessary modifications, in the non-road sector some years later. So it makes sense when estimating future availability of advanced abatement technology to use legislation and technical development in the on-road sector as a starting point. When doing this it needs to be borne in mind that non-road equipment works in a different environment and that on-road technologies cannot always be directly transferred to all kinds of non-road applications.

2.2.1. On-road legislation in Europe

As a result of the Auto-Oil Programme, the emission standards for on-road vehicles are to be tightened in stages. In 2005 Euro IV standards will be implemented with very low limit values for particulate emissions. When deciding on this legislation, it was anticipated that manufacturers would need to use particulate traps or technology with corresponding performance to meet those limit values.

For heavy-duty vehicles, a further tightening of the NOx limit values will be introduced from 2008, although subject to a technical review clause. To meet these limit values manufacturers need to use some kind of after-treatment device.

2.2.2. On-road legislation in the US

In December 2000, the US administration decided on a next set of limit values for heavy-duty vehicles. Those limit values will enter into force starting in 2007. For particulate emissions the limit value is more or less the same as the European Euro IV/V value and for NOx emissions the limit value is in principle a sixth of the Euro V limit value. Thus - to meet those US-standards - manufacturers have to use after-treatment devices for both PM and NOx emissions.

2.2.3. On-road legislation in Japan

Emission legislation for CI engines on heavy-duty vehicles has traditionally been less stringent in Japan than the corresponding legislation in the US and the EU. However, because of the deterioration in air quality, Japan has decided to implement far-reaching legislation in stages to reduce the emission of NOx and PM. A first stage, which is in the same order of magnitude as the Euro IV standards, will be implemented in 2005 and a further stage is planned for the future.

2.2.4. Conclusions

It can be concluded that, in principle, technology to further limit the emissions of air pollution from CI engines is available or will be available on the global market within 3 to 5 years (prerequisite 2 in Article 19). However, since this technology has been developed for on-road applications, it will in many cases have to be modified for non-road applications. Indeed, for certain applications it might ultimately be technically impossible or very expensive to use. This issue will be discussed later in this explanatory memorandum.

3. ISSUES OF IMPORTANCE FOR THE IMPLEMENTATION OF STAGE III

3.1. Global alignment

As mentioned previously, engines for use in NRMM are to a large extent produced for a global market. Production volumes for different engine types are low and development costs would therefore be difficult to bear if different regional emission requirements were introduced.

Consequently, global alignment was a high priority when the current legislation was developed. It also succeeded to the extent that the current emission requirements of Directive 97/68/EC are similar to those in Japanese and US legislation, making it possible for engine manufacturers to offer one and the same concept on those markets.

Concerning future legislation, the USA has already decided to introduce Tier III standards for engines from 37 kW to 560 kW. Those standards, which cover only gaseous emissions, will be implemented between 2006 and 2008 depending on the power band of the engines. A future Tier IV is being discussed by the US administration and according to information from the EPA (the US Environmental Protection Agency) a notice of proposed rulemaking (NPRM) is expected at the beginning of 2003. The EPA has also indicated that it intends to base this proposal on what has already been decided for on-road vehicles, i.e. the use of after-treatment equipment.

Furthermore emission limit values for the power band 19-37 kW going beyond the current Stage II limits in Directive 97/68/EC are included in the current US legislation.

Japan has so far taken no decision on further tightening of the emission standards beyond the current EU Stage II standards, but it is participating in the international discussions now taking place between the authorities and the industry.

3.1.1. Conclusions

Global alignment is a high priority issue as regards future emission standards. Accordingly, the process of amending Directive 97/68/EC on Stage III limit values has been discussed very closely with industry and authorities in the USA and Japan. The aim has been to achieve a win-win situation where the industry can operate with one and the same set of concepts on a global market and by so doing save money that can be used in part to achieve a high level of environmental protection.

3.2. Scope of the Directive

3.2.1. Engine power band

The current Directive 97/68/EC covers CI engines of 18 kW to 560 kW. The corresponding US legislation covers the power band 19-560 kW. In practice it does not matter if the power band starts at 19 or 18 kW but for the sake of future alignment the Directive 97/68/EC should use 19 kW instead of 18 kW in any future requirements.

In the USA engines below 19 kW and above 560 kW are also covered by legislation and to achieve further alignment it could be argued that limit values for these engines should also be included in Directive 97/68/EC. However, the inventory referred to in point 1.1.2 above does not show that these engines notably contribute to the overall emissions in the EU. It is therefore currently difficult to justify devising legislation for this category of CI engines.

However, to further align the legislation, this should be studied further and be included as a part of the technical review discussed below in paragraph 3.9.

Moreover, under an amendment recently decided upon by the Council and the European Parliament, the Directive will cover small petrol engines (19 kW or below).

3.2.2. Exempted applications

In addition to limitations imposed by engine power, certain applications are currently exempted from the scope of the Directive, namely:

the propulsion of:

- vehicles (on-road vehicles) as defined by Directive 70/156/EEC, and by Directive 92/61/EEC,
- agricultural tractors as defined by Directive 74/150/EEC

and

applications in:

- ships
- railway locomotives
- aircrafts
- generating sets
- recreational vehicles.

For *on-road vehicles* existing standards, and those adopted for the future, are tighter than those for NRMM and there is no reason to include those within the scope of Directive 97/68.

Tractors are covered by another Directive - Directive 2000/25/EC – with requirements basically identical to those in Directive 97/68/EC (but with some differences as regards implementation dates). The tractor Directive states that as soon as the provisions referred to in Article 19 of Directive 97/68/EC are adopted, the limit values and implementation dates are to be aligned without delay. Consequently, as soon as a formal decision on the amendment to Directive 97/68/EC has been taken, the Commission will forward a proposal on the same limit values and entry into force dates to be implemented into Directive 2000/25/EC using the committee procedure.

The abovementioned amendment on spark ignition engines also included limit values for *generating sets* and *other constant speed engines* – CI engines as well as SI engines - thereby removing the exemption for generating sets.

Recreational vehicles are of interest chiefly as regards petrol engines only and will not be discussed in this proposed amendment on diesel engines.

Railway locomotives, defined as locomotives that are “not designed to carry any passengers or freight by themselves”, are covered by separate legislation in the USA. The engines they use normally are more powerful than 560 kW. Other railway applications, e.g. engines in rail-cars, are covered by the normal NRMM legislation.

The current Directive 97/68/EC contains no definition of “locomotives”. For better alignment, we should use the same definition as in US legislation. This would then cover “small” engines used for railway applications.

Furthermore, the Commission addressed this issue in its communication “Towards an integrated European railway area” (COM (2002) 18 final). Concerning air pollution, it declared its intention to include “light-duty diesel train engines ” into the revision of Directive 97/68/EC and to develop technical interoperability specifications for heavy-duty diesel engines.

It has been argued that emission standards for railway applications should be based on a separate test cycle, since of course the driving pattern of a railway vehicle is different from that of an excavator or an agricultural tractor. This is especially so for genuine locomotives. However, for reasons discussed under “test procedure” below, it is proposed not to include a separate test procedure in Directive 97/68/EC.

Ships have recently been shown to be a major contributor to overall emissions of NOx and particulates. This is true in particular of sea-going ships but also vessels on inland waterways are contributers.

In its White Paper on a common transport policy the Commission pointed out not only railways but also inland waterways as environmentally friendly modes of transport. To confirm this role vessels used on inland waterways have to improve their environmental performance.

On an international level the International Maritime Organisation (IMO) has developed regulations covering emissions of NOx from ships (MARPOL, Annex VI). However this Annex has still not entered into force due to the lack of necessary ratification. Furthermore it does not address the emissions of particulates, which is an issue of very high priority.

Engine manufacturers have expressed their favour of implementing the limit values (and ISO test procedure) used in the USA for this kind of engines. These limit values are ambitious from an environmental point of view and will meet the overall target of alignment and could therefore also be used in the EU legislation.

The strategy on how to address the emissions from sea-going ships will be addressed in a separate Communication from the Commission.

Recreational Craft are covered by another Directive – Directive 94/25/EC. The Commission proposed in October 2000 an amendment to this Directive to include exhaust and sound emission limits for engines to be used in recreational craft (COM(2000)639). The Council’s common position on this amendment, adopted on 22 April 2002, contains a review clause in its Article 2. This clause provides that the Commission shall submit by 31 December 2005 a report on the possibilities of further reducing emissions from recreational craft and personal watercraft and, in the light of this report, submit by 31 December 2006 appropriate proposals to the European Parliament and the Council on more stringent requirements and emission values. Therefore there is no reason to include recreational craft engines within the scope of Directive 97/68.

3.2.3. Conclusions

To achieve further alignment with US legislation, the current lowest power limit of 18 kW should be changed to 19 kW. Engines below 19 kW and above 560 kW should, for the moment being, remain outside the scope of the Directive.

For agricultural and forestry tractors, implementation dates and limit values are to be aligned through the Commission proposal on an amendment to Directive 2000/25/EC, which is being presented in parallel to this proposal.

A clarification of definitions should be inserted in order to cover emissions from railway applications, except for locomotives that "are not designed to carry any passengers or freight by themselves" to align it with US legislation.

Vessels used on inland waterways should be included within the scope of Directive 97/68/EC. Since they have so far been excluded and since they are of a different technical nature, separate emission limits and entry into force dates should apply.

3.3. Test procedure

The current procedure for measuring emissions in Directive 97/68/EC is based on a steady state test cycle, the ISO 8178-4 C1 8-mode cycle. Since NRMM covers a lot of different applications with different practical operations, it will be very difficult to cover all of those with one test cycle. Consequently, the current test cycle does not represent all the actual operating conditions for NRMM. Furthermore, it does not include some of the modes of operation which generate the most air pollution. However, with the new stringent emission levels it is considered a good compromise.

When tightening emission limits, it becomes more important to have a test procedure covering the most important modes of operation in order to avoid any discrepancy between real-life emissions and laboratory measurements. Particulate matter (PM) in particular is far more prevalent when operating under "transient conditions". This was confirmed when developing the current EU legislation on emissions from on-road vehicles, which resulted in the introduction of a transient test procedure.

Most non-road engines are used for applications that are largely transient in nature. Even equipment such as pumps and generators, which operate mostly at constant speeds, may depart from steady-state operation because of variations in engine load over time. Through broad co-operation between the authorities and industry in the USA, Japan and Europe efforts have therefore been made to develop a new test cycle which will better reflect this.

This co-operation has resulted in a new transient test cycle that will meet those requirements. The test cycle has been developed so that it can be run on eddy-current dynamometers with significant cost saving (between a third and a quarter of the usual cost) over conventional equipment (AC dyno or DC dyno) used for transient tests without compromising on environmental objectives.

Even higher cost saving (a fifth of usual cost or less) can be obtained if the transient test is carried out using the partial flow dilution systems already used for the steady-state procedure, instead of using the conventional CVS (Constant Volume Sampling) facility. The work, performed under ISO/FDIS 16183 "Heavy duty engines – Measurement of gaseous and particulate exhaust emissions under transient test conditions – Raw exhaust gas and partial flow dilution systems", has now been concluded and, according to the EC, the procedure can be transferred from on-road to non-road engines.

This new test procedure should be mandatory for measuring PM emissions as soon as the Stage III B values enter into force. For gaseous pollutants the manufacturer could use the current test procedure, but in order to avoid two tests, manufacturers will most likely use the transient test procedure for gaseous pollutants too, once the Stage III B values apply.

The attention has been drawn to the fact that locomotives have different patterns of operation compared to other NRMM applications, and thus a separate test procedure ought to be used. Indeed, a separate test procedure already exists - the ISO 8178-4 steady-state test cycle type F "Rail traction". This type F test cycle appears to accurately reflect the operational behaviour of the old power-train system used on the railways.

However it is important to bear in mind the purpose of the emission legislation – to reduce the environmental and health impact. In this respect it is rather the local emissions, which occur around railway stations in urban areas, than the contribution to the overall emissions that are of importance for railways. Those emissions occur during accelerations and under heavy load of the engines whereas emissions during constant speed, mostly in rural areas, are very low. Using a separate test procedure would allow an averaging of the emissions and thus not address the real environmental problems.

Nevertheless further studies should be carried out and if appropriate modify the test procedure before stringent particulate emission limit values enter into force. This can be covered in the technical review discussed below in paragraph 3.9.

It should also be noted that in the corresponding US legislation a separate test procedure is only used for genuine locomotives, which anyhow will not be covered by the scope of Directive 97/68/EC.

3.3.1. Conclusions

The future Stage IIIB standards on particulate matter should be based on a new dedicated transient test procedure to better reflect actual operating conditions, and especially to represent real emissions of particulates and to ensure that emissions reduction technology is developed to address those operating conditions.

For the measurement of gaseous emissions, manufacturers should have the option of using either the new transient test cycle or the current steady-state test procedure.

Different test procedures should be used for all variable speed engines except those for inland waterways, though specific consideration should be given to engines for constant speed applications and railway applications in the technical review discussed below in paragraph 3.9. For engines intended to be used for propulsion of inland waterway vessels, the internationally accepted test procedures according to ISO 8178-4, test cycles E2 and E3 should be applied.

The current possibility for manufacturers to choose between full flow systems or partial flow systems should remain.

3.4. Limit values and implementation dates for Stage III

3.4.1. Limit values

3.4.1.1. Limit values for power bands 37-560 kW

Although in theory a large number of possible limit values can be chosen for Stage III, these will in practice be limited by the number of technological steps that can be implemented.

In principle we are talking about two different levels of intervention: engine modifications only, and the use of after-treatment equipment. These "technical levels" must of course be converted into limit values, allowing manufacturers to choose the specific technical solutions necessary to meet the standards.

The possible scenarios for the Stage III level are basically the following:

Scenario	Environmental improvements (*)	Technology available today?	Technology available 2010?	Fuel requirements	Comments
1.	NOx: - 30-40% PM: - 0-10%	Yes	Yes	S: 1000 ppm	
2.	NOx: - 30-40% PM: - 30-40%	Yes	Yes	S: 350 ppm	
3.	NOx: - 30-40% PM: - 80-90%	No	Yes	S: 10-50 ppm	
4.	NOx: -70-80% PM: - 80-90%	No	Yes	S: 10-50 ppm	

(*) Environmental improvements as emission reductions [%] with respect to Stage II engines.

Scenario 1 corresponds to the Tier III already decided upon by the USA. It can be met by engine modifications, it could be implemented with a short lead time and it would meet the industry's wish for alignment. It would not however address the issue of emissions of PM, which was highlighted in the Auto-Oil II Communication as a high-priority form of pollution and which has been addressed as an important issue by several Member States. It is therefore questionable whether a proposal based on this scenario would adequately meet the identified environmental needs. In the long term this scenario cannot achieve global alignment since additional PM limit values will be implemented in the USA. Under this scenario there is no need for further restrictions on fuel sulphur level, beyond those already decided (1000 ppm).

Scenario 2 includes limit values for PM. These can be met by engine modifications (including the use of cooled EGR) in line with the on-road Euro 3 technology. It should be noted that, compared with Stage II emissions, the main reduction in PM is due to the lower sulphur content of the fuel even though engine modifications are expected to reduce emissions still further by another 10%. To meet the requirements of this scenario the use of fuels with a lower sulphur content (max. 350 ppm) must be made mandatory by amending Directive 98/70/EC. This scenario needs a longer lead time than Scenario 1 and will not achieve global alignment.

Scenario 3 is based on the assumption that after-treatment equipment is used to reduce emissions of particulates. This technology is already available in the road vehicle sector and, given a reasonable lead time, should be available for most applications in the non-road sector too. Reduction of NOx is in line with Scenario 2. A maximum sulphur content of 50 ppm is required. This scenario could lead to global alignment.

Scenario 4 differs from Scenario 3 to the extent that after-treatment equipment is also expected to reduce NOx. In the USA, the EPA has unofficially announced that in the future they would like to move towards something like Scenario 4. However, they do agree that uncertainty about the technology is greater for NOx after-treatment technology than for PM traps within the NRMM sector and therefore expect to introduce tighter limit values later for NOx than for PM. As for Scenario 3, a maximum sulphur content of 50 ppm is required. This scenario could lead to global alignment.

It is obvious that the availability and feasibility of after-treatment equipment will be of great importance when deciding on Stage 3 limit values. Auto-oil II considered particulates to be one remaining air quality problem for the future. Many reports have identified small (ultrafine) particles as perhaps the most important issue affecting health. As explained above, basic after-treatment technology (PM traps) is already available for the on-road sector and to a certain extent also for the non-road sector. Tests also show that technology developed for on-road vehicles can generally also be used for certain applications in the non-road sector, and given enough lead time possibly for most other applications.

It is of course true that the environment in which NRMM machinery operates tends to be different from the on-road sector. For instance, the exhaust temperature might be too low to use PM traps with passive regeneration. This could also apply to city buses, which are not exempt from the Euro IV standards. Nevertheless, it might ultimately prove that the use of PM traps or technology with similar performance is not possible for some applications even if industry is allowed a long lead time. To address this uncertainty, a technical review could be carried out before the entry into force dates to determine whether there will have to be certain exemptions from the standards. This solution was used when introducing Euro V standards for Heavy Duty Vehicles in Directive 1999/96/EC.

Bilateral discussions with the EPA have clearly indicated that its intention is to base the next stage of US legislation in this field on the use of after-treatment equipment originally developed for the road sector. It seems that the EPA plans to implement these stringent requirements for PMs first, and then for NOx some years later.

As regards, PMs there are no basic differences between the situation in the USA and the situation in the EU. There will be the same need for low-sulphur fuel, and the technology is global and can be applied in the same way. Thus a Stage III standard for particulate emissions equal to the corresponding Tier IV standard in the USA seems feasible.

For NOx emissions, however, the current situation is a bit more complicated. For the on-road sector, standards have been decided upon in the USA and in the EU that will require after-treatment equipment. The limit value in the EU legislation though is about eight times higher than the US limit value.The EPA has declared quite categorically that it is in favour of NOx absorbers as the technology to be used whilst manufacturers in Europe seem to favour the use of SCR (Selective Catalytic Reduction), which needs a separate ammonium/urea distribution system. For the on-road sector the choice of different strategies is somewhat less important since the market is not global as is the case for the non-road sector. For the non-road sector, however, the current strongly global approach could be jeopardised if Europe favours technological development of SCR and the US opts for NOx absorbers.

Furthermore, in the EU the Euro V standards for NOx are subject to a technical review by the Commission before the end of 2002. Even though this review will probably conclude that the necessary technology will be available for the on-road sector by 2008 (when Euro V enters into force), the Commission cannot be expected to present conclusions on the use of this technology in the non-road sector before that review is published. Neither can it be excluded that the Euro V limit values will be tightened as a result of the technical review.

In addition, the Commission is currently studying the future air quality situation and the need for action under the CAFE project (Clean Air For Europe). The result of this project will be available in 2004/2005 and should serve as input for a subsequent decision on a possible Stage IV limit value for NOx. This kind of consideration should be covered by the technical review discussed below in paragraph 3.9.

3.4.1.2. Limit values for power band 19-37 kW.

US legislation to be implemented in 2004 makes engines with a power output between 19 and 37 kW subject to Tier II emission limit values. The emission limits for these engines do not require the use of after-treatment equipment.

Engines within the 19-37 kW power band are already covered by Directive 97/68, but are subject to only one set of limit values. The Tier II limit values in US legislation are somewhat more stringent than the ones in Directive 97/68/EC, especially as regards particulate matter (see below). The inventory carried out in 1994 also indicates that the contribution to overall emissions by those engines is not negligible. In addition, discussions with the industry concerned indicate that they prefer to align by incorporating the US legislation into Directive 97/68/EC.

Regulation/Standard	HC+NOx (g/kWh)	HC (g/kWh)	NOx (g/kWh)	PM (g/kWh)
US Tier III 19-37 Kw	7.5	-	-	0.60
Directive 97/6818-37 kW	-	1.5	8.0	0.8

3.4.2. Implementation dates for Stage III

Whatever scenario is adopted will of course be closely linked to implementation dates. In this respect, for the *power band above 37 kW*, Scenario I could be implemented (in stages) as from 2006, since in any case manufacturers have to meet the requirements of the US market. Scenario 2 will need a longer lead time, at least as regards PM limit values, since additional requirements are imposed on engine manufacturers and the use of low-sulphur fuel has to be made mandatory in all Member States. For Scenario 3, a longer lead time is also needed for the PM requirements. To give manufacturers enough development time it is reasonable to assume that the PM standards can enter into force around 2009-2011. For Scenario 4, theuncertainty on the availability of NOx after-treatment equipment in the non-road sector and especially concerning the final decision for the on-road sector in EU is greater. Further clarifications therefore are needed before a decision can be made on the implementation of limit values based on the use of aftertreatment equipment for NOx.

For *power band 19-37 kW* the corresponding US legislation is to be implemented in 2004. However, for practical reasons, it is not possible to introduce it into the EU before 2006.

One specific issue is implementation dates for *constant-speed engines*. These are exempted under Directive 97/68/EC as it stands. However, under the amendment described above these engines will become subject to emission limit values, though not until 31 December 2006. To give manufacturers a reasonable lead time the entry into force date for these engines should therefore be some years later than for other types of engines.

For some types of equipment covered in Directive 97/68/EC new noise limit values will be implemented in 2006 (Directive 2000/14/EC). It would have been advantageous to co-ordinate the implementation dates. However it is not possible to have an enter into force date for stage IIIA by (next) 2006 for all kind of engines. At the revision of Directive 2000/14/EC on noise, foreseen by 2005, the need for future co-ordination of implementation dates will be taken into account.

3.4.3. Conclusions

To properly address environmental needs, Stage III limit values should be introduced for NOx as well as for PM. They should be based on the best available technology, they should be applicable to NRMM and they would have to be globally aligned.

In doing so the limit values for gaseous pollutants (Stage III A) would be equivalent to the US Tier III standards for power bands above 37 kW and to the Tier II standards for the 19-37 kW power band. They should be implemented in stages starting on 31 December 2006. The PM limit values (Stage III B) for the power bands above 37 kW should be based on the assumption that PM traps, or technology with a similar effect, will be available in the non-road sector. To allow the necessary lead time, those limit values should be implemented in the EU in stages starting on 31 December 2009. However the necessary fuel will not be available in the USA until a year later and to maintain the alignment and to offer the industry a global market the implementation should start a year later, 31 December 2010.

To ensure that the necessary technology is generally available, a review clause should be inserted to the effect that the Commission should review technical progress so as to confirm the PM limit values and propose any necessary exemptions not later that 2006. This review should also consider a Stage IV set of limit values for NOx based on the availability and feasibility of using after-treatment equipment and also consider a further tightening of the limit values for engines in the powerband 19-37 kW.

A Stage III set of limit values in Directive 97/68/EC should thus be implemented in two steps as follows:

Category: Net power (P) (kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates (PT) (g/kWh)
H: 130 kW ≤ P ≤ 560 kW	3.5	4.0	0.2
I: 75 kW ≤ P < 130 kW	5.0	4.0	0.3
J: 37 kW ≤ P <75 kW	5.0	4.7	0.4
K: 19 kW ≤ P <37 kW	5.5	7.5	0.6

Table: Stage III A limit values

Category: Net power (P) (kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates[1] (PT) (g/kWh)
L: 130 kW ≤ P ≤ 560 kW	3.5	4.0	0,025
M: 75 kW ≤ P < 130 kW	5.0	4.0	0,025
N: 37 kW ≤ P <75 kW	5.0	4.7	0,025

Table: Stage III B limit values

Category: Net power (P)	Entry into force dates
H: 130 kW ≤ P ≤ 560 kW	31 December 2005
I: 75 kW ≤ P < 130 kW	31 December 2006
J: 37 kW ≤ P <75 kW	31 December 2007
K: 19 kW ≤ P <37 kW	31 December 2005

Table: Stage III A. Entry into force dates (placing on the market dates.) For constant speed engines the implementation dates for Stage III B should also be used for gaseous pollutants.

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[1] PM standards subject to a technical review by the end of 2006. For applications where PM trap technology or similar is not possible the following limit values could tentatively apply: 0,15; 0.20; 0.25.

Category: Net power (P)	Entry into force dates
L: 130 kW ≤ P ≤ 560 kW	31 December 2010
M: 75 kW ≤ P < 130 kW	31 December 2010
N: 37 kW ≤ P <75 kW	31 December 2011

Table: Stage III B. Entry into force dates (placing on the market dates).

For inland waterway vessels the following limit values and implementation dates will be used:

Category: swept volume/net power (SV/P) (litres per cylinder/kW)	Carbon monoxid (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates (PT) (g/kWh)
V1:1 SV≤ 0,9 and P>37 kW	5.0	7.5	0.40
V1:2 0,9<SV≤1,2	5.0	7.2	0.30
V1:3 1,2<SV≤2,5	5.0	7.2	0.20
V1:4 2,5<SV≤5	5.0	7.2	0.20
V2:1 5<SV≤15	5.0	7.8	0.27
V2:2 15<SV≤20 and P ≤3300 kW	5.0	8.7	0.50
V2:3 15<SV≤20 and P>3300 kW	5.0	9.8	0.50
V2:4 20<SV≤25	5.0	9.8	0.50
V2:5 25<SV≤30	5.0	11.0	0.50

Table: Limit values for inland waterway vessels

Category:	Entry into force dates
V1:1	31 December 2006
V1:2	31 December 2006
V1:3	31 December 2006
V1:4	31 December 2008
V2	31 December 2008

Table: Entry into force dates for emission limits for inland waterway vessels (placing on the market dates).

3.5. The importance of fuel quality

3.5.1. General

The two stages of emission standards in the current Directive 97/68/EC can be met without any specific fuel quality requirements therefore some Member States also allow the use of heating oil for non-road mobile machinery. Other Member States require the same fuel quality to be used as for the on-road sector. One Member State – Spain - has introduced a separate fuel quality standard for the NRMM sector. The main reason for the choice of fuel quality is taxation and not the production cost of different fuel qualities. The tax on heating oil is normally low while the tax on motor fuel is high.

With more stringent emission standards and more sophisticated technology needed to meet those standards, fuel quality will become more important. The most important parameter in this respect is sulphur content. A high sulphur content will cause higher emissions of particulates and in addition, if after-treatment devices have to be used to meet emission limits, might damage or reduce the efficiency of after-treatment equipment. To prevent this, sulphur content has to be at least below 50 ppm.

Requirements concerning sulphur content in gas oils are laid down in Directive 98/70/EC (on petrol and diesel fuels for on-road and non-road vehicles) and Directive 1999/32/EC (on heating oil). According to the latter Directive, the maximum sulphur content of gas oil used for purposes other than on-road vehicles is 2000 ppm. From 2008 this limit will be lowered to 1000 ppm.

Directive 98/70/EC requires a maximum sulphur content of 50 ppm for diesel intended for use in on-road vehicles from 1 January 2005. A proposed amendment to this Directive, currently awaiting a final decision in the Council and the EP, would further tighten this maximum to 10 ppm. It would seem that the Council and the European Parliament will agree to make this mandatory from 2009.

In principle the quality of diesel fuel for use in non-road mobile machinery is also covered by Directive 98/70/EC. However, since there is no technical need for any specific fuel requirements to meet the Stage I and II emission standards it has been left to Member States to decide on sulphur content as long as it does not exceed the content specified in Directive

1999/32/EC and is not more stringent than for on-road applications. The Common position on the proposed amendment mentioned above states that the Commission should present more detailed requirements on diesel fuel for the non-road sector when proposing emission limit values for Stage III.

Today about 9% of gas oil consumption is for non-road purposes - if inland waterways are included. About 50% is used for the on-road sector and about 40% as heating oil. At European level, there is no separate non-road diesel quality, and with a market share of less than 10% this situation is unlikely to change in the future. At national level, special fuel qualities might well be made available.

As previously mentioned, for tax reasons, some Member States are allowing low-taxed heating oil to be used for non-road applications too. In this respect, there might be a need for specific action, especially in the agricultural sector. A marker is now added to low-tax oil to help enforce the legislation and check that low-tax fuel is not used for applications where on-road quality should be used. If a better fuel quality than heating oil is needed to meet the Stage III limit values, certain practical problems might arise in those Member States that still want to allow the use of low-tax fuel.

This might be solved in different ways, for instance by having one dyed grade gas oil for heating purposes, a second dyed grade diesel for NRMM, which could also be used as heating oil by farmers with one storage tank, and a third non-dyed (high-tax) diesel oil for on-road purposes.

It is up to Member States to decide on what tax policy they want to apply and also on how they want to implement the distribution systems. The example above is only to illustrate that there are solutions which can also be used in those Member States that want to continue to allow low-tax diesel oil to be used for NRMM purposes in the future.

Given the above conclusions on limit values, we will in the future have a situation where the Stage III A limit values for gaseous pollutants can be met by using heating oil. However, to meet the Stage III B PM limit values, a fuel with a maximum of 10-50 ppm sulphur must be used. Thus, it is necessary to ensure that low-sulphur fuel is used once the PM limit values enter into force or in Member States that want to encourage earlier implementation of those limit values.

3.5.2. Reference fuel

The reference fuel used for type-approval purposes should reflect the fuel quality used under real operational conditions. Since legislation in the Member States differs as regards the market fuel, the current reference fuel specification is a compromise. The most important parameter - sulphur content - must be between 1000 and 2000 ppm.

The proposed Stage III B limit values for particulate emissions will require the use of low-sulphur fuel (10-50 ppm). Accordingly, the reference fuel should be changed to reflect the proposal to make the use of low-sulphur fuel mandatory for all non-road mobile machinery applications. In addition, some Member States might want to offer incentives to encourage manufacturers to meet the more stringent PM standards before they become mandatory. In this case manufacturers should be allowed to use a low-sulphur reference fuel when type-approving engines.

3.5.3. Conclusions

The availability of appropriate fuels will not be a limiting factor in introducing Stage III emission limits for non-road mobile machinery.

Stage III A limit values can be met without any further fuel quality specifications. To meet the III B limit values the sulphur content of the fuel must be in the order of 10-50 ppm at the highest. The Commission will propose an amendment to Directive 98/70/EC to secure the European-wide introduction of the relevant fuel.

To reflect this a separate reference fuel should be brought into use once the Stage III B PM limit values enter into force, or when a manufacturer voluntarily type-approves engine families to meet those limit values.

3.6. Durability requirements

The corresponding US legislation includes definitions on the useful life during which limit values must be met, as well as provisions for recall schemes.

Europe has generally been later in implementing this kind of legislation. It was introduced for light vehicles by Directive 98/69/EC and there are ongoing efforts to introduce similar provisions for heavy duty vehicles, intended to enter into force in 2005.

In principle the same kind of legislation should also apply to non-road engines. However, since this kind of equipment is not registered, it is more difficult to implement in-use compliance programmes. However, a first step would be to define useful life for different categories of engines and to require that manufacturers establish deterioration factors to apply to type-approval.

A further stage – to include in-use compliance checks and recalls – could be addressed in the technical review mentioned above.

3.6.1. Conclusions

A definition of useful life should be included in the legislation - 3000 hours for engines below 37 kW and 5000 hours for engines at or above 37 kW.

The manufacturer has to establish a deterioration factor for each engine family. If the established factor is below 1.0, then 1.0 should be used.

3.7. Costs and cost-effectiveness

3.7.1. Costs

The main issues for the development of the stage III limit values have been to establish a world wide aligned legislation based on the environmental need and the availability of emission reducing technology. Even so it is important to examine the cost – effectiveness/benefit of the proposal and to see to that it is in the same order of magnitude as other introduced legislation addressing the same environmental issues, bearing in mind that the benefits for manufacturers of an alignment can not be included

As mentioned above there is a lack of precise information on the number of NRMM and the use of them. In addition existing emission models are normally developed for road transport and is not possible to use for NRMM emission calculations. To overcome this shortage of information the calculations have been made on an engine basis, taking into account the life time emissions and life time costs of the engines. Using the different power bands in the current directive the following life costs to meet the stage III limit values (stage IIIA + stage IIIB) have been used in a consultant study that the Commission has carried out. These costs include the cost for equipment and engineering. It should though be noted that the costs for the power band 18-37 kW includes a further tightening of the PM limit values compared to the one proposed in this amendment. In the absence of better estimates those costs have been used in the analyses.

Engine power (kW)	18-37	37-75	75-130	130-560
Cost for emission technology (€/engine)	1, 800	3, 775	5, 300	8, 400

Table: Additional cost (technology and engineering) for the implementation of stage III limit values.

Source: Consultant study by VTT Process.

In addition to those cost there will be additional costs for low sulphur fuel, which is required to meet the stage IIIB limit values on PM. Low sulphur fuel is not required for engines in the power band 18-37 kW since no after-treatment device is needed. However in practice it will be difficult to distribute fuel with higher sulphur content only for that category of engines. Therefore the additional cost for low sulphur fuel has been added also to this category of engines.

In a separate consultant study carried out by Beicip-Franlab the cost for going from a fuel with a sulphur content of 1000 ppm to one with a sulphur content of 10 ppm has been estimated to 1,5-1,9 Euro-cent per litre. Net value of 1.5 Euro-cent per litre has been used for the further analyses.

Engine power (kW)	18-37	37-75	75-130	130-560
Life time fuel consumption (litre)	19.938	47.150	95.120	333.500
Additional cost for low sulphur fuel (€)	299	707	1.426	5.002

Table: Additional costs for the use of low sulphur fuel.

Sources: Consultant studies by VTT Process and Beicip-Franlab.

Costs of this kind are difficult to estimate with sufficient accuracy since these are standards that are to be implemented a long time in the future. Experience in the on-road sector shows that these costs are normally overestimated when comparing real costs with the estimates made as the legislation was decided upon. In addition, since the market is almost 100% global, it could be argued that the costs of meeting the Stage III A standards are already there since the EPA has confirmed that it will be continuing with its Tier III standards. Furthermore the consultant has based its costs on the use of two sets of particulate filters for all engines which is not likely to happen. The corresponding cost calculations (preliminary) made by the US EPA indicates much lower costs.

3.7.2. Benefits

In a separate consultant study, "Estimates of the marginal external costs of air pollution in Europe", carried out by the company Netcen, the marginal external costs for different pollutants were estimated as follows:

Benefits of emission reductionsin rural areas

Country	NOx (€/tonne)	PM 2.5 (€/tonne)	SO_2 (€/tonne)
Austria	6,800	14,000	7,200
Belgium	4,700	22,000	7,900
Denmark	3,300	5,400	3,300
Finland	1,500	1,400	970
France	8,200	15,000	7,400
Germany	4,100	16,000	6,100
Greece	6,000	7,800	4,100
Ireland	2,800	4,100	2,600
Italy	7,100	12,000	5,000
Netherlands	4,000	18,000	7,000
Portugal	4,100	5,800	3,300
Spain	4,700	7,900	3,700
Sweden	2,600	1,700	1,700
UK	2,600	9,700	4,500
EU-15 Average	4,200	14,000	5,200

Benefits of emission reductions in urban areas

City size	NO_x (€/tonne)	PM 2,5 (€/tonne)	SO_2 (€/tonne)
100,000 people	Same as rural	33,000	6,000
500,000 people	Same as rural	165,000	30,000
1,000,000 people	Same as rural	247,500	45,000
Several million people	Same as rural	495,000	90,000

As can be seen in the tables, the marginal costs differ widely depending on where the emissions take place. In 1999 80% of the population in EU lived in urban areas. However, since a large share of the engines is used in the agricultural sector and thus the emissions taking place in rural areas the following assumptions are made concerning the use of and the emissions from NRMM: 50% of the emissions take place in rural areas, 30% in cities with 100.000 inhabitants, 8% in cities with 500.000 inhabitants and 2% in cities with more than 1 million inhabitants.

Under those assumptions the benefits will be the following:

NOx – 4200 €/tonne

PM – 36420 €/tonne

SO2 – 8220 €/tonne

3.7.3. Emission reductions

In the above study by VTT Process the life time "savings" (tonne/engine) of the emissions has been estimated to the following.

Engine power band (kW)	**19-37**	**37-75**	**75-130**	**130-560**
SN. Savings NOx (tonne)	0.1	0.4	0.7	2.9
SPM. Savings PM (tonne)	0.023	0.043	0.068	0.184
SS. Savings SO2 (30 % PM) (tonne)	0.034	0.057	0.114	0.399

3.7.4. Cost- efficiency (feasibility)

Based on the data above and on data given by equipment manufacturers on the distribution of different engine sizes in Europe the overall benefits of the package proposed for the NRMM engines shows that the benefits per engine are about 75 Euro higher than the costs. The same calculation indicates that the overall result is due to high benefits for larger engines.No separate calculation has been made for inland waterway vessels.

3.7.5. Conclusions

Cost estimates on technical measures that are supposed to be implemented rather far in the future will for natural reasons be uncertain. Experience shows that at the time of the development of the legislation those costs are overestimated compared to the real costs when they once have to be implemented.

Furthermore in this particular case it could be questionable whether the cost for stage IIIA should be fully included since the majority of manufacturers anyhow has to meet the corresponding US legislation which is already decided on. For the engines in the power band 19-37 kW the consultant's cost estimates are based on a stage IIIB limit value for PM of 0.3 g/kWh whilst the proposal only requires 0.6 g/kWh. The consultant has also assumed that every engine must use two sets of PM traps, which can be questioned since durability requirements are included in the proposal. Furthermore preliminary cost calculations made by the EPA indicate much lower values.

On the other hand no cost for increased fuel consumption has been inserted. The use of more advanced technology will open the possibility for manufacturers to improve the fuel economy and thereby compensate for the fuel penalty that will occur due to the use of particulate traps.

Furthermore great uncertainties are linked to the estimates of benefits. In this respect it should be noted that all particles emitted from NRMM are so called nano-particles, which seems to be more and more a concern from a health point of view..

Bearing those uncertainties, which can go in both directions, in mind it seems as if the stage III package as such is positive from a cost benefit point of view. It should however be noted that this overall outcome is due to the very positive effect on large engines and this underlines the importance of the technical review which is suggested as a part of the package.

3.8. Flexibilities

3.8.1. General

Non-road mobile machinery have a large number of different applications. Furthermore, although legislation in this field is basically geared towards engine manufacturers. it will still involve many manufacturers of equipment (OEMs), who may or may not produce engines as well. To cover these different aspects and yet not just aim at the lowest common denominator in legislation, or delay its introduction and consequently the use of advanced technology, certain so called flexibilities (exemptions) should be used. This is also a concept that has been used in the corresponding US legislation.

On the other hand, legislation should be as clear as possible so that it is given the same interpretation in all Member States. Consequently, there should be as few exemptions as possible. It is also difficult to copy US legislation completely due to the different administrative systems.

The following cases are covered by special arrangements in the legislation.

3.8.2. Engine manufacturers

3.8.2.1. Small volume manufacturers

Small volume manufacturers have fewer resources for developing new technology. They also have fewer products to cover the development costs. If they are not operating on the global market they are not forced to comply with US legislation.

3.8.2.2. Small volume engine families

Basically the development costs should be covered by the specific engine family. The smaller the engine family the more difficult to do so. It is especially difficult for small-volume manufacturers who cannot transfer costs to other engine families.

3.8.3. Equipment manufacturers

Directive 97/68/EC is an engine Directive, meaning that it is the engine manufacturer that has to meet the standards. Ultimately, however, engines are mounted into pieces of equipment, either by the engine manufacturers themselves or by separate equipment manufacturers. In the latter case especially it is necessary to allow the equipment manufacturer time to adapt his product to the design of the engine. One way of meeting this need would be to allow engines to be placed on the market over a certain period providing that the engines have been produced before the entry into force dates.

The current Directive allows for this, but makes it subject to decisions by individual Member States. In theory the whole market would be open even if only one Member State accepted the option. However, in practice this creates problems for manufacturers since they then have to place their engines on the market in that Member State (or States) and then transport the engine to the customer in another Member State. It could be argued that this option might encourage a manufacturer to produce and stockpile a large number of engines just before the new emission limits enter into force. However, in practice this is unlikely to happen as the economic uncertainty for the manufacturer would be too great. To simplify the legislation this option of designing equipment for engines already manufactured should not be left to the discretion of individual Member States.

3.8.4. Possible solutions

The corresponding US legislation allows a certain amount of flexibility. One essential element of this flexibility is the use of averaging, banking and trading of emissions. Basically this allows an engine manufacturer to place an engine that exceeds the emission limit values on the market providing that this is offset by placing on the market engines with emissions below the limit values and that the average emission of the total production is below the limit values. This is a way of allowing the necessary flexibility without losing environmental benefits.

The Commission proposal on emissions from spark ignition engines (COM(2000) 840 final) included this system. However, both the Council and the European Parliament rejected it as too complicated and unfair. This time the Commission is not proposing to include such a system.

Nevertheless, manufacturers will face similar problems in complying with EU legislation, so they have to be addressed properly. Any solution will involve deviation from the conventional type-approval system and it is therefore essential to implement flexibile arrangements that will be interpreted in the same way by different Member States and create a minimum of administrative burden.

A way of doing this is to basically use the same concept as is used in the US legislation when dealing with the difficulties for equipment manufacturers. In other words, a manufacturer is allowed to use a limited number of engines that only comply with the previous emission limit standards. He can then use this flexibility in the way that best helps him solve his specific problems. One manufacturer might need more time for technical development of his production while another might need a longer development time only for a small engine family. The benefit of this kind of flexibility is that approval authorities do not have to decide on the details, but that this framework ensures that the environmental consequences will be known in advance and will be the same whatever strategy the manufacturer is using.

3.8.5. Conclusions

To resolve the special difficulties which might occur for equipment manufacturers, including small volume manufacturers, and for small-volume products, a voluntary flexibility scheme should be introduced whereby an OEM is allowed, for a four-year period, to use engines that only comply with the previous stage of limit values. The number of engines in each engine power band should be limited to 20% of one year's production or a maximum of units depending on powerband (50, 100, 150 or 200).

3.9. Technical feasibility review

As mentioned above, it might ultimately prove difficult to apply trap technology (or similar solutions) to certain kinds of NRMM by the time Stage III B limit values enter into force. For this kind of equipment it might be necessary to delay the implementation dates or to allow exemptions from the Stage III B limits. In the latter case some other limit values should apply, probably based on those in the Scenario 2 described in point 3.4.1.1 above, meaning a PM limit value 40% lower than the current Stage II limits. A technical feasibility study should therefore be carried out on the applicability of PM trap technology in the non-road mobile machinery sector, and any exemptions necessary should be proposed. This study, and the decisions linked to it, have to be carried out early enough to allow manufacturers time they need. On the other hand, if it is done too early it will not leave enough time for technical development and might then result in exemptions even though the technology would have been available by the date of implementation. As a compromise solution between those two needs a proposal from the Commission should be presented not later than by the end of December 2006.

Some other issues of major interest might be included in the study and, if appropriate, in the proposals. One such topic is of course the need to further reduce NOx, which is closely linked to the availability of after-treatment equipment. By addressing this in the technical review in 2006, information from the on-going CAFE project will be available on the overall need for further reductions and on the cost-efficiency of measures in other sectors.

Other topics that could be included in the technical review are:

- the need to reconsider the scope of the Directive concerning railway applications according to the last developments and possibilities offered by the new railway legislative framework, in particular in the field of railway interoperabililty,

- the need for and feasibility of in-use compliance checks and specific test procedures for railway applications.

4. CONTENT OF THE PROPOSAL

4.1. Scope of the Directive (Annex I)

The current Directive 97/68/EC covers CI engines from 18 kW to 560 kW. The corresponding US legislation covers the power band 19-560 kW. To achieve alignment the lower limit of 19 kW will be used in Directive 97/68/EC from the dates when Stage III enters into force.

Railway locomotives are currently excluded from the scope of the Directive, but there is no specific definition. A definition of railway locomotives is now to be included in accordance with the corresponding US legislation. This means that small engines used in rail-cars for example will be covered. This is line with what the Commission stated in its White Paper on a Common Transport Policy (COM (2001) 370).

Engines used in inland waterway vessels will also be included within the scope of the Directive.

4.2. Test procedure (Annex III)

The current procedure for measuring emissions in Directive 97/68/EC is based on a steady-state test cycle - the ISO C1 8-mode cycle.

Most non-road engines are used for applications that are largely transient in nature. Even equipment such as pumps and generators, which operate mostly at constant speeds, may depart from steady-state operation due to variations in engine loads over time. Thanks to widespread co-operation between the authorities and industry in USA, Japan and Europe, efforts have been made to develop a new test cycle which will better reflect this. This co-operation has resulted in a new transient test cycle that can also be run on what are known as eddy-current dynamometers with a significant cost saving (between one third and one quarter) of the conventional equipment (AC dyno or DC dyno) used for transient tests.

The future Stage IIIB standards for particulate matter will be based on this new dedicated transient test procedure to better reflect actual operating conditions and in particular to represent real emissions of particulates and to ensure that emissions reduction technology is developed to take account of those driving conditions. For measurement of gaseous emissions it will be optional for the manufacturer to use either the new transient test cycle or the current steady-state test procedure.

A significant cost saving (one fifth or less) can be obtained if the transient test is carried out by means of the partial flow dilution systems instead of using the conventional CVS (Constant Volume Sampling) facility. In this respect, manufacturers will still be able to choose between full-flow systems or partial-flow systems as at present.

4.3. Limit values for Stage III (Annex I)

To properly address environmental needs, Stage III limit values are being introduced for NOx as well as for PM. They are based on the best available technology, and applied as feasible to NRMM, taking account of the need for global alignment.

Accordingly, the Stage III limit values for gaseous pollutants (Stage III A) are basically equivalent to the US Tier III standards for the power bands above 37 kW and to the Tier II standards for power band 19-37 kW. The PM limit values (Stage III B) for the power bands above 37 kW are based on the assumption that PM traps, or technology with similar effect, will be generally available in the non-road sector if enough time is allowed.

To ensure that the necessary technology is available a review clause is included to the effect that the Commission should review technical progress, confirm the PM limit values and propose necessary exemptions not later that 2006. This review could include an additional study into the possible use of after-treatment equipment to reduce gaseous pollutants (NOx) at a later stage.

4.4. Implementation dates for Stage III (Article 9)

For the *power band above 37 kW*, the Stage III A limit values can be implemented (in stages) from 2006, since by then manufacturers will be having to meet the requirements of the US market. For Stage III B limit values on particulates, a longer lead time is needed. To give manufacturers enough time for the necessary technical development work, those limit values will enter into force in stages between 2010 and 2012.

For *power band 19-37 kW,* the corresponding US legislation is to be implemented in 2004. However, for practical reasons, it is not possible to introduce it into the EU before 2006.

A specific issue is implementation dates for *constant-speed engines*. These are exempt in Directive 97/68/EC. However, following the amendment on spark-ignition engines recently decided upon by the Council and the European Parliament, they will be covered as of 31 December 2006, which is 3-6 years later than for other types of engine. To allow manufacturers reasonable time the entry into force dates for this kind of engines have been adjusted accordingly.

4.5. Fuel quality

4.5.1. General

The two stages of emission standards in the current Directive 97/68/EC can be met without any specific requirements as regards fuel quality. To meet the proposed Stage III B standards for particulates, however, a low-sulphur fuel (below 50 ppm) will have to be used. A separate amendment to Directive 98/70/EC will therefore be proposed by the Commission in good time before the entry into force dates of those limit values.

4.5.2. Reference fuel

The reference fuel used for type-approval purposes should reflect the fuel quality used under real operating conditions. Since legislation on market fuels in the Member States differs, the current reference fuel specification is a compromise. The most important parameter - sulphur content - must be between 1000 and 2000 ppm.

The proposed Stage III B limit values for particulate emissions will require the use of low-sulphur fuel. To reflect this, a reference fuel, equivalent to the one used for on-road vehicle, is included. The manufacturer may use this fuel quality when type-approving engines to meet the Stage III B limit values, whether mandatory or voluntary.

4.6. Durability requirements (Annex III – Appendix 5)

The corresponding US legislation includes definitions of the useful life during which the limit values must be complied with, as well as provisions on recall schemes.

Since this kind of equipment is not registered, it is more difficult to carry out in-use compliance programmes. Therefore, at this initial stage, useful life is defined only for the different categories of engines – 3000-5000 hours for engines below 37 kW and 8000 hours for engines of 37 kW or over - and the manufacturers are required to establish deterioration factors to be used at the type-approval stage.

A further stage – to include in-use compliance checks and recalls – could be addressed in the technical review mentioned above.

4.7. Flexibilities (Article 9 and Annex XIV)

Directive 97/68/EC is an engine Directive, meaning that it is the engine manufacturer that has to meet the standards. Ultimately, however, engines are mounted into pieces of equipment, either by the engine manufacturers themselves or by separate equipment manufacturers. In the latter case especially it is necessary to allow the equipment manufacturer time to adapt his product to the design of the engine. Specific problems in this respect will occur for small-volume manufacturers, or in the case of small-volume products.

To provide a flexible approach, two possibilities have been introduced.

The first is to allow equipment manufacturers to use “old” engines for a period of two years providing that those engines are produced before the date of entry into force of the new limit values. This option is already included in the current Directive, but subject to the decision of a Member State.

The second is a voluntary option allowing equipment manufacturers to use a limited number of engines that comply only with the previous limit values. The number of these engines is limited to 20% of one year’s production within each power band or a maximum of units depending on powerband (50, 100, 150 or 200) and they can be used for the period between two stages of limit values. This allows each manufacturer to adopt the solution which best suits his situation; one manufacturer might have problems with one engine family while another manufacturer might be suffering from a general delay with the development of his products. Under this option, the environmental consequences are known in advance and the main responsibility for dealing with the difficulties is transferred to the manufacturers. This is also the best way of solving potential discrepancies between small and big manufacturers.

A similar option is provided in the corresponding US legislation, which also includes a number of other flexibilities like averaging and banking. Some of these other options might be practical in the USA since the legislation there is implemented by one single administration. In Europe, theoretically 15 different approval authorities are involved and it is not therefore practical to introduce all of those different options.

The European engine and equipment manufacturer organisations (Euromot and CECE/CEMA respectively) have explained that they are satisfied with the solution proposed. In the Commission's opinion, these organisations represent the whole range of manufacturers.

4.8. Technical feasibility study

As mentioned above, a technical feasibility study should be carried out into whether PM trap technology can be applied in the non-road mobile machinery sector, if appropriate proposing which applications should meet only the less stringent PM standards. This study has to be carried out early enough to give manufacturers information on the appropriate limit values in good time. On the other hand, it must allow reasonable time for the necessary technical development be carried out. A compromise solution is for the Commission to present any proposals by December 2006 at the latest.

2002/0304 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission[1],

Having regard to the opinion of the European Economic and Social Committee[2],

Acting in accordance with the procedure laid down in Article 251 of the Treaty[3],

Whereas:

(1) Directive 97/68/EC of the European Parliament and of the Council of 16 December 1997 on the approximation of the laws of the Member States relating to measures against the emissions of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery[4] implements two stages of emission limit values for compression ignition engines and calls on the Commission to propose a further reduction in emission limits, taking into account the global availability of techniques for controlling air polluting emissions from compression engine and the air quality situation.

(2) The Auto-Oil programme[5] concluded that further measures are needed to improve the future air quality of theCommunity, especially as regards ozone formation and emissions of particulate matter.

(3) Advanced technology to reduce emissions from compression ignition engines on on-road vehicles is already available to a large extent and such technology should, to a large extent, be applicable to the non-road sector.

(4) There are still some uncertainties regarding the situation around 2010 as to the cost effectiveness of using after-treatment equipment for particulate matter (PM) emissions

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[1] OJ L […], [.. .. ..], p. […].

[2] OJ L […], [.. .. ..], p. […].

[3] OJ L […], [.. .. ..], p. […].

[4] OJ L 59, 27.2.1998, p. 1.

[5] COM(2000) final

on small engines and on the availability of after-treatment equipment to reduce oxides of nitrogen (Nox) emissions. A technical review should be carried out before 31 December 2006 and, where appropriate, exemptions or delayed enter into force dates for PM limit values and tighter limit values for gaseous pollutants should be considered.

(5) A transient test procedure is needed to cover the operational conditions used by this kind of machinery under real working conditions.

(6) The proposed package of Stage III limit values should be aligned as far as possible on developments in the United States so as to offer manufacturers a global market for their engine concepts.

(7) Emission standards should also be introduced for certain railway and marine applications to help promote them as environmentally friendly modes of transport.

(8) Because of the technology needed to meet the Stage III B limits for PM emissions, the sulphur content of the fuel must be reduced from today's levels in many Member States. A reference fuel that reflects the fuel market situation should be defined.

(9) Emission performance during the full useful life of the engines is of importance. Durability requirements should be introduced to avoid deterioration of emission performance.

(10) It is necessary to introduce special arrangements for equipment manufacturers to give them time to design their products and to handle small series production.

(11) Since the objectives of the action to be taken to improve the future air quality situation cannot be sufficiently achieved by the Member States since necessary emission regulations concerning products have to be regulated at Community level, the Community may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty. In accordance with the principle of proportionality, as set out in that Article, this Directive does not go beyond what is necessary in order to achieve those objectives.

(12) Directive 97/68/EC should therefore be amended accordingly,

HAVE ADOPTED THIS DIRECTIVE:

Article 1

Directive 97/68/EC is amended as follows:

(1) In Article 2 the following indent is added:

- "inland waterway vessel" shall mean a vessel having a length of 20 metres or more, having a volume of 100 m^3 or more according to the formula defined in Annex I, Section 2, point 2.8a, or tugs or pusher craft having been built to tow or to push or to move alongside vessels of 20 meters or more."

(2) In Article 2 the following subparagraph is added:

“The definition in the 16th indent of the first subparagraph does not include vessels intended for passenger transport carrying no more than 12 people in addition to the crew, ferries, recreational craft with a length of less than 24 metres (as defined in article 1 (2) of Directive 94/25/EC), service craft belonging to supervisory authorities and fire-service vessels, naval vessels and sea-going vessels, including sea-going tugs and pusher craft operating or based on tidal waters or temporarily on inland waterways, provided that they carry a valid navigation or safety certificates as defined in Annex I, Section 2, point 2.8b.”

(3) In Article 4 the following paragraph 6 is added:

"6. For engines placed on the market under a “flexible scheme”, the procedure in Annex XIII shall apply in addition to paragraph 1 to 5."

(4) In Article 6 the following paragraph 5 is added:

"5. Engines placed on the market under a “flexible scheme” should be labelled in accordance with Annex XIII.”

(5) Article 8 is amended as follows:

(a) The heading is replaced by “placing on the market”:

(b) In paragraph 1 the word “new” is deleted.

(6) Article 9 is amended as follows:

(a) In the introductory phrase of paragraph 3 the words “and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine is installed” is replaced by “and shall refuse to grant any other type-approval for non-road mobile machinery, not already placed on the market, in which an engine is installed”.

(b) The following paragraphs 3a, 3b and 3c are inserted

“3a. TYPE-APPROVAL of STAGE III A ENGINES (ENGINE CATEGORIES H, I, J and K)

Member States shall refuse to grant type-approval for the following engine types or families and to issue the document as described in Annex VI, and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine, not already placed on the market, is installed:

– H: after 30 June 2005 for engines – other than constant speed engines - of a power output: 130 kW ≤ P ≤ 560 kW,

– I: after 31 December 2005 for engines – other than constant speed engines - of a power output: 75 kW ≤ P < 130 kW,

- J: after 31 December 2006 for engines – other than constant speed engines - of a power output: 37 kW ≤ P <75 kW,

- K: after 31 December 2005 for engines – other than constant speed engines - of a power output: 19 kW ≤ P <37 kW,

where the engine fails to meet the requirements specified in this Directive and where the emissions of gaseous pollutants from the engine do not comply with the limit values as set out in the table in section 4.2.3~~,~~ of Annex I.

3b. TYPE-APPROVAL OF STAGE III B ENGINES (ENGINE CATEGORIES K, L, M and N)

Member States shall refuse to grant type-approval for engine types or families and to issue the document as described in Annex VI, and shall refuse to grant any other type-approval for non-road mobile machinery in which an engine, not already placed on the market, is installed:

- Constant speed K engines: after 31 December 2009 for engines of a power output: 19 kW ≤ P <37 kW,

- L and constant speed H engines: after 31 December 2009 for engines of a power output: 130 kW ≤ P ≤ 560 kW,

- M and constant speed I engines: after 31 December 2009 for engines of a power output: 75 kW ≤ P < 130 kW,

- N and constant speed J engines: after 31 December 2010 for engines of a power output: 37 kW ≤ P < 75 kW,

where the engine fails to meet the requirements specified in this Directive and where the emissions of particulate pollutants from the engine do not comply with the limit values set out in the table in Section 4.2.3. of Annex I."

“3c. TYPE-APPROVAL OF ENGINES USED IN INLAND WATERWAY VESSELS (ENGINE CATEGORIES V)

Member States shall refuse to grant type-approval for engine types or families and to issue the document as described in Annex VI:

- V1:1: after 31 December 2005 for engines of ~~a~~ power output above 37 kW and ~~a~~ swept volume below 0.9 litres per cylinder,

- V1:2: after 30 June 2005 for engines with swept volume at or above 0.9 but below 1.2 litres per cylinder,

- V1:3: after 30 June 2005 for engines with swept volume at or above 1.2 but below 2.5 litres per cylinder and a power output and an engine power output of :37 kW ≤ P < 75 kW,

- V1:4: after 31 December 2006 for engines with swept volume at or above 2.5 but below 5 litres per cylinder,
- V2: after 31 December 2007 for engines with a swept volume above 5 litres per cylinder,

where the engine fails to meet the requirements specified in this Directive and where the emissions of particulate pollutants from the engine do not comply with the limit values as set out in the table in section 4.1.2.4 of Annex I".

(c) Paragraph 4 is amended as follows

(i) In the heading the words "registration and" are deleted

(ii) In the first subparagraph the words "… Member States shall permit the registration, where applicable, and placing on the market of new engines,…" is replaced by "… Member States shall permit the placing on the market of new engines"

(iii) The second and third subparagraphs are replaced by the following:

"Stage III A

- category H: 31 December 2005
- category I: 31 December 2006
- category J: 31 December 2007
- category K: 31 December 2006
- category V1:1: 31 December 2006
- category V1:2: 31 December 2006
- category V1:3: 31 December 2006
- category V1:4: 31 December 2008
- categories V2: 31 December 2008

For constant speed engines of categories H, J, K and L respectively, the implementation dates are four years later than the dates mentioned above.

Stage III B

- category L: 31 December 2010
- category M: 31 December 2010
- category N: 31 December 2011

For each category, the above requirements shall be postponed by two years in respect of engines with a production date prior to the said date.

The permission granted for one stage of emission limit values shall be terminated with effect from the mandatory implementation of the next stage of limit values."

(7) In Article 10 the following paragraph 3 is added:

"3. Engines may be placed on the market under a “flexible scheme” in accordance with the provisions in Annex XIII."

(8) The Annexes are amended as follows:

(a) Annexes I, III, V, VII and XII are amended in accordance with Annex I to this Directive.

(b) Annex VI is replaced by the text in Annex II to this Directive.

(c) A new Annex XIII as set out in Annex III to this Directive is added.

Article 2

The Commission shall, not later than 31 December 2006

– consider the available technology with a view to confirming Stage III B limit values and evaluating the possible need for additional flexibilities, exemptions or later introduction dates for certain types of equipment or engines,

– evaluate the need to use a separate test procedure for railway applications,

– evaluate the need to amend the scope of the Directive according to the last developments in the railway transport and interoperability legislative framework in order to cover, in the most effective way, all railway applications.

– consider tightening the limit values for emissions of gaseous pollutants in the light of environmental needs and technological developments in after-treatment equipment for NOx reduction in the on-road sector,

– consider the need to introduce a further set of limit values for engines to be used in inland waterway vessels,

– consider the need to introduce emission limit values for engines below 19 kW and above 560 kW,

and submit, where appropriate proposals to the European Parliament and the Council.

Article 3

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive [within 12 months of its entry into force] [before 1 July 2005]. They shall forthwith inform the Commission thereof.

When Member States adopt those provisions, they shall contain a reference to this Directive or be accompanied by such a reference on the occasion of their official publication. Member States shall determine how such reference is to be made.

2. Member States shall communicate to the Commission the texts of the main provisions of the national law that they adopt in the field governed by this Directive.

Article 4

This Directive shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Communities*.

Article 5

This Directive is addressed to the Member States.

Done at Brussels,

For the European Parliament *The President*	*For the Council* *The President*

ANNEX I

1. ANNEX I TO DIRECTIVE 97/68 IS AMENDED AS FOLLOWS:

a) In point B of section 1, last subparagraph

the word "ships" is replaced by : "Ships, except vessels intended for use on inland waterwayss"

b) In pointC of section 1, last subparagraph the words "Railway locomotives" are replaced by: " Railway locomotives that are not designed to carry any passengers or freight by themselves."

c) Section 2 is amended as follows:

(i) The following points 2.8a and 2.8b are inserted:

"2.8a: "volume of 100^3 or more" with regard to a vessel intended for use on inland waterways means its volume calculated on the formula LxBxT, "L" being the maximum length of the hull, excluding rudder and bowsprit, "B" being the maximum breadth of the hull in metres, measured to the outer edge of the shell plating (excluding paddle wheels, rubbing strakes, etc.) and "T" being the vertical distance between the lowest moulded point of the hull or the keel and the maximum draught line.

2.8b: "valid navigation or safety certificated" means

(a) a certificate proving conformity with the 1974 International Convention for the Safety of Life at Sea (SOLAS), as amended, or equivalent or

(b) a certificate proving conformity with the 1966 International Convention on Load Lines, as amended, or equivalent, and an IOPP certificate proving conformity with the 1973 International Convention for the Prevention of Pollution from Ships (MARPOL), as amended." (ii) The follwing section 2.17 is inserted:

"*"test cycle*" means a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (NRSC test) or transient operating conditions (NRTC test);"

(iii) Section 2.17 is renumbered to 2.18 and replaced by the following:

2.18. Symbols and abbreviations

2.18.1. Symbols for test parameters

Symbol	**Unit**	**Term**
A/F_{st}	-	Stoichiometric air/fuel ratio
A_P	m^2	Cross sectional area of the isokinetic sampling probe
A_T	m^2	Cross sectional area of the exhaust pipe
Aver	 m^3/h kg/h	Weighted average values for: -volumeflow – mass flow
C1	-	Carbon 1 equivalent hydrocarbon
C_d	-	Discharge coefficient of the SSV
Conc	ppm Vol%	Concentration (with suffix of the component nominating)
$Conc_c$	ppm Vol%	Background corrected concentration
$Conc_d$	ppm Vol%	Concentration of the pollutant measured in the dilution air
$Conc_e$	ppm Vol%	Concentrtion of the pollutant measured in the diluted exhaust gas
d	m	Diameter
DF	-	Dilution factor
f_a	-	Laboratory atmospheric factor
G_{AIRD}	kg/h	Intake air mass flow rate on dry basis
G_{AIRW}	kg/h	Intake air mass flow rate on wet basis
G_{DILW}	kg/h	Dilution air mass flow rate on wet basis
G_{EDFW}	kg/h	Equivalent diluted exhaust gas mass flow rate on wet basis
G_{EXHW}	kg/h	Exhaust gas mass flow rate on wet basis
G_{FUEL}	kg/h	Fuel mass flow rate
G_{SE}	kg/h	Sampled exhaust mass flow rate
G_T	cm^3/min	Tracer gas flow rate
G_{TOTW}	kg/h	Diluted exhaust gas mass flow rate on wet basis
H_a	g/kg	Absolute humidity of the intake air
H_d	g/kg	Absolute humidity of the dilution air
H_{REF}	g/kg	Reference value of absolute humidity (10,71 g/kg)
i	-	Subscript denoting an individual mode (for NRSC test) or an instananeous value (for NRTC test)
K_H	-	Humidity correction factor for NO_x
K_p	-	Humidity correction factor for particulate
K_V	-	CFV calibration function
$K_{W,a}$	-	Dry to wet correction factor for the intake air
$K_{W,d}$	-	Dry to wet correction factor for the dilution air
$K_{W,e}$	-	Dry to wet correction factor for the diluted exhaust gas
$K_{W,r}$	-	Dry to wet correction factor for the raw exhaust gas
L	%	Percent torque related to the maximum torque for the test speed
M_d	mg	Particulate sample mass of the dilution air collected
M_{DIL}	kg	Mass of the dilution air sample passed through the particulate sampling filters
M_{EDFW}	kg	Mass of equivalent diluted exhaust gas over the cycle
M_{EXHW}	kg	Total exhaust mass flow over the cycle

M_f	mg	Particulate sample mass collected
$M_{f,p}$	mg	Particulate sample mass collected on primary filter
$M_{f,b}$	mg	Particulate sample mass collected on back-up filter
M_{gas}	g	Total mass of gaseous pollutant over the cycle
M_{PT}	g	Total mass of particulate over the cycle
M_{SAM}	kg	Mass of the diluted exhaust sample passed through the particulate sampling filters
M_{SE}	kg	Sampled exhaust mass over the cycle
M_{SEC}	kg	Mass of secondary dilution air
M_{TOT}	kg	Total mass of double diluted exhaust over the cycle
M_{TOTW}	kg	Total mass of diluted exhaust gas passing the dilution tunnel over the cycle on wet basis
$M_{TOTW,I}$	kg	Instantaneous mass of diluted exhaust gas passing the dilution tunnel on wet basis
mass	g/h	Subscript denoting emissions mass flow (rate)
N_P	-	Total revolutions of PDP over the cycle
n_{ref}	min^{-1}	Reference engine speed for NRTC test
$\dot{n}_{sp}$	s^{-2}	Derivative of the engine speed
P	kW	Power, brake uncorrected
p_1	kPa	Pressure depression at pump inlet of PDP
P_A	kPa	Absolute pressure
P_a	kPa	Saturation vapour pressure of the engine intake air (ISO 3046: ps_y=PSY test ambient)
P_{AE}	kW	Declared total power absorbed by auxiliaries fitted for the test which are not required by paragraph 2.4 of this Annex
P_B	kPa	Total atmospheric pressure (ISO 3046: P_x=PX Site ambient total pressure P_y=PY Test ambient total pressure)
p_d	kPa	Saturation vapour pressure of the dilution air
P_M	kW	Maximum power at the test speed under test conditions (see Annex VII, Appendix 1)
Pm	kW	Power measured on test bed
p_s	kPa	Dry atmospheric pressure
q	-	Dilution ratio
Q_s	m^3/s	CVS volume flow rate
r	-	Ratio of cross sectional areas of isokinetic probe and exhaust pipe
R_a	%	Relative humidity of the intake air
R_d	%	Relative humidity of the dilution air
Re	-	Reynolds number
R_f	-	FID response factor
T	K	Absolute temperature
t	s	Measuring time
T_a	K	Absolute temperature of the intake air
T_D	K	Absolute dew point temperature
T_{ref}	K	Reference temperature (of combustion air: 298 K)
T_{sp}	N·m	Demanded torque of the transient cycle
t_{10}	s	Time between step input and 10% of final reading
t_{50}	s	Time between step input and 50% of final reading
t_{90}	s	Time between step input and 90% of final reading

Δt_i	s	Time interval for instantaneous CFV flow
V_0	m³/rev	PDP volume flow rate at actual conditions
W_{act}	kWh	Actual cycle work of NRTC
WF	-	Weighting factor
WF_E	-	Effective weighting factor
X_0	m³/rev	Calibration function of PDP volume flow rate
Θ_D	kg·m^2	Rotational inertia of the eddy-current dynamometer
ß	-	Ratio of the SSV throat diameter, d, to the inlet pipe inner diameter
λ	-	Relative air/fuel ratio, actual A/F devided by stoichiometric A/F
ρ_{EXH}	kg/m³	Density of the exhaust gas

2.18.2. *Symbols for chemical components*

CH_4	Methane
C_3H_8	Propane
C_2H_6	Ethane
CO	Carbon monoxide
CO_2	Carbon dioxide
DOP	Di-octylphtalate
H_2O	Water
HC	Hydrocarbons
NOx	Oxides of nitrogen
NO	Nitric oxide
NO_2	Nitrogen dioxide
O_2	Oxygen
PT	Particulates
PTFE	Polytetrafluoroethylene

2.18.3. Abbreviations

CFV	Critical Flow Venturi
CLD	Chemiluminescent detector
CI	Compression Ignition
FID	Flame Ionisation Detector
FS	Full scale
HCLD	Heated Chemiluminescent Detector
HFID	Heated Flame Ionisation Detector
NDIR	Non-Dispersive Infrared Analyser
NG	Natural Gas
NRSC	Non-Road Steady Cycle
NRTC	Non-Road Transient Cycle
PDP	Positive _Displacement Pump
SI	Spark Ignition
SSV	Sub-Sonic Venturi

(d) Section 3 is amended as follows:

(i) The following section 3.1.4. is inserted

“3.1.4. "labels in accordance with annex XIV, ... if the engine is placed on the market under flexible scheme provisions.”

d) Section 4 is amended as follows:

- The following section 4.1.2.4 is added:

“4.1.2.4. The emissions of the carbon monoxide, the emissions of the sum of hydrocarbons and oxides of nitrogen and the emissions of particulates obtained shall for stage IIIA not exceed amounts shown in the table below:

Engines for use in other applications than inland waterway vessels:

Category: Net power (P) (kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates (PT) (g/kWh)
H: 130 kW ≤ P ≤ 560 kW	3,5	4,0	0,2
I: 75 kW ≤ P < 130 kW	5,0	4,0	0,3
J: 37 kW ≤ P <75 kW	5,0	4,7	0,4
K: 19 kW ≤ P <37 kW	5,5	7,5	0,6

Engines for use in inland waterway vessels

Category: swept volume/net power (SV/P) (litres per cylinder/kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates (PT) (g/kWh)
V1:1 SV≤ 0,9 and P>37 kW	5.0	7.5	0.40
V1:2 0,9<SV≤ 1,2	5.0	7.2	0.30
V1:3 1,2<SV≤ 2,5	5.0	7.2	0.20
V1:4 2,5<SV≤ 5	5.0	7.2	0.20
V2:1 5<SV≤ 15	5.0	7.8	0.27
V2:2 15<SV≤ 20 and P ≤3300 kW	5.0	8.7	0.50
V2:3 15<SV≤ 20 and P>3300 kW	5.0	9.8	0.50
V2:4 20<SV≤ 25	5.0	9.8	0.50
V2:5 25<SV≤ 30	5.0	11.0	0.50

- The following section 4.1.2.5 is inserted:

4.1.2.5. The emissions of the carbon monoxide, the emissions of the sum of hydrocarbons and oxides of nitrogen and the emissions of particulates obtained shall for stage IIIB not exceed amounts shown in the table below:

Category: Net power (P) (kW)	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC+NOx) (g/kWh)	Particulates (PT) (g/kWh)
L: 130 kW ≤ P ≤ 560 kW[1]	3,5	4,0	0,025
M: 75 kW ≤ P < 130 kW	5,0	4,0	0,025
N: 37 kW ≤ P <75 kW	5,0	4,7	0,025

- The following section 4.1.2.6 is inserted:

4.1.2.6. The limit values in sections 4.1.2.4 and 4.1.2.5 shall include deterioration calculated in accordance with Annex III, appendix 5.

- Section 4.1.2.4 is renumbered to 4.1.2.7

3. ANNEX III IS AMENDED AS FOLLOWS:

(a) Section 1 is amended as follows:

- In paragraph 1.1 the following paragraph is added:

“Two test cycles are described that shall be applied according to the provisions of Annex I, Section 1:

- the NRSC (Non-Road Steady Cycle) which shall be used for stages I, II and IIIA and for constant speed engines as well for stage IIIB,
- the NRTC (Non-Road Transient Cycle) which shall be used measurement of particulate emissions for stage IIIB for all engines but constant speed engines. By the choice of the manufacturer this test can be used also for stage IIA and for the gaseous pollutants in stage IIIB.

For engines intended to use in inland waterway vessels the ISO test procedure as specified by ISO 8178 and IMO MARPOL 73/78, Annex VI (NO_x Code) shall be used

- The following paragraph 1.3 is inserted:

1.3. Measurement principle:

The engine exhaust emissions to be measured include the gaseous components (carbon monoxide, total hydrocarbons and oxides of nitrogen), and the particulates. Additionally, carbon dioxide is often used as a tracer gas for determining the dilution ratio of partial and full flow dilution systems. Good engineering practice recommends the general measurement of carbon dioxide as an excellent tool for the detection of measurement problems during the test run.

1.3.1. NRSC Test:

During a prescribed sequence of operating conditions, with the engines warmed up, the amounts of the above exhaust emissions shall be examined continuously by taking a sample from the raw exhaust gas. The test cycle consists of a number of speed and torque (load) modes, which cover the typical operating range of diesel engines. During each mode the concentration of each gaseous pollutant, exhaust flow and power output shall be determined, and the measured values weighted. The particulate sample shall be diluted with conditioned ambient air. One sample over the complete test procedure shall be taken and collected on suitable filters.

Alternatively, a sample shall be taken on separate filters, one for each mode, and cycle-weighted results computed.

The grams of each pollutant emitted per kilowatt hour shall be calculated as described in Appendix 3 to this Annex.

1.3.2. NRTC Test:

During a prescribed transient cycle of operating conditions, with the engine warmed up, based closely on the operating conditions of diesel engines installed in nonroad machinery, the above pollutants shall be examined. Using the engine torque and speed feedback signals of the engine dynamometer, the power shall be integrated with respect to the time of the cycle, resulting in the work produced by the engine over the cycle. The concentrations of the gaseous components shall be determined over the cycle, either in the raw exhaust gas by integration of the analyzer signal in accordance with Appendix 3 to this Annex, or in the diluted exhaust gas of a CVS full-flow dilution system by integration or by bag sampling in accordance with Appendix 3 to this Annex. For particulates, a proportional sample shall be collected from the diluted exhaust gas on a specified filter by either partial flow dilution or full-flow dilution. Depending on the method used, the diluted or undiluted exhaust gas flow rate shall be determined over the cycle to calculate the mass emission values of the pollutants. The mass emission values shall be related to the engine work to give the grams of each pollutant emitted per kilowatt-hour.

(b) Section 2 is changed as follows:

- Paragraph 2.2.3 is replaced by the following:

2.2.3. Engines with charge air cooling

The charge air temperature shall be recorded and, at the declared rated speed and full load, shall be within ± 5 K of the maximum charge air temperature specified by the manufacturer. The temperature of the cooling medium shall be at least 293 K (20°C).

If a test shop system or external blower is used, the charge air temperature shall be set to within ± 5 K of the maximum charge air temperature specified by the manufacturer at the speed of the declared maximum power and full load. Coolant temperature and coolant flow rate of the charge air cooler at the above set point shall not be changed for the whole test cycle. The charge air cooler volume shall be based upon good engineering practice and typical vehicle/machinery applications.

Optionally, the setting of the charge air cooler may be done in accordance with SAE J 1937 as published in January 1995.

- The text under paragraph 2.3. Engine air inlet system is replaced by the following:

The test engine shall be equipped with an air inlet system presenting an air inlet restriction within ± 300 Pa of the value specified by the manufacturer for a clean air cleaner at the engine operating conditions as specified by the manufacturer, which result in maximum air flow. The restrictions are to be set at rated speed and full load A test shop system may be used, provided it duplicates actual engine operating conditions.

- The text under paragraph 2.4 Engine exhaust system is replaced by the following:

The test engine shall be equipped with an exhaust system with exhaust back pressure within ± 650 Pa of the value specified by the manufacturer as the engine operating conditions resulting in maximum declared power.

If the engine is equipped with an exhaust after-treatment device, the exhaust pipe shall have the same diameter as found in-use for at least 4 four diameters upstream to the inlet of the beginning of the expansion section containing the after-treatment device. The distance from the exhaust manifold flange or turbocharger outlet to the exhaust after-treatment device shall be the same as in the vehicle configuration or within the distance specifications of the manufacturer. The exhaust backpressure or restriction shall follow the same criteria as above, and may be set with a valve. The aftertreatment container may be removed during dummy tests and during engine mapping, and replaced with an equivalent container having an inactive catalyst support."

- Paragraph 2.8 is deleted.

(c) Section 3 is amended as follows:

- The title of section 3 is replaced by:

"3. TEST RUN (NRSC TEST)"

- The following paragraph 3.1 is inserted:

"3.1. Determination of dynamometer settings

The basis of specific emissions measurement is uncorrected brake power according to ISO 14396: 2002.

Certain auxiliaries, which are necessary only for the operation of the machine and may be mounted on the engine should be removed for the test. The following incomplete list is given as an example:

- air compressor for brakes
- power steering compressor
- air conditioning compressor
- pumps for hydraulic actuators

Where auxiliaries have not been removed, the power absorbed by them at the test speeds shall be determined in order to calculate the dynamometer settings, except for engines where such auxiliaries form an integral part of the engine (e.g. cooling fans for air cool engines).

The settings of inlet restriction and exhaust pipe backpressure shall be adjusted to the manufacturer's upper limits, in accordance with sections 2.3 and 2.4.

The maximum torque values at the specified test speeds shall be determined by experimentation in order to calculate the torque values for the specified test modes. For engines which are not designed to operate over a range on a full load torque curve, the maximum torque at the test speeds shall be declared by the manufacturer.

The engine setting for each test mode shall be calculated using the formula:

$$S = \left(\left(P_M + P_{AE} \right) x \frac{L}{100} \right) - P_{AE}$$

If the ratio,

$$\frac{P_{AE}}{P_M} \geq 0{,}03$$

the value of P_{AE} may be verified by the technical authority granting type approval.

- Current paragraphs 3.1 – 3.3 are renumbered to 3.2-3.4
- Current paragraph 3.4 is renumbered to paragraph 3.5 and the text replaced by the following:

3.5. Adjustment of the dilution ratio

The particulate sampling system shall be started and running on bypass for the single filter method (optional for the multiple filter method). The particulate background level of the dilution air may be determined by passing dilution air through the particulate filters. If filtered dilution air is used, one measurement may be done at any time prior to, during, or after the test. If the dilution air is not filtered, the measurement must be done on one sample taken for the duration of the test.

The dilution air shall be set to obtain a filter face temperature between 315 K (42 °C) and 325 K (52 °C) at each mode. The total dilution ratio shall not be less than four.

Note: For steady-state procedure, the filter temperature may be kept at or below the maximum temperature of 325 K (52 °C) instead of respecting the temperature range of 42 °C – 52 °C.

For the single and multiple filter methods, the sample mass flow rate through the filter shall be maintained at a constant proportion of the dilute exhaust mass flow rate for full flow systems for all modes. This mass ratio shall be within ± 5 % with respect to the averaged value of the mode, except for the first 10 seconds of each mode for systems without bypass capability. For partial flow dilution systems with single filter method, the mass flow rate through the filter shall be constant within ± 5 % with respect to the averaged value of the mode, except for the first 10 seconds of each mode for systems without bypass capability.

For CO_2 or NOx concentration controlled systems, the CO_2 or NOx content of the dilution air must be measured at the beginning and at the end of each test. The pre and post test background CO_2 or NOx concentration measurements of the dilution air must be within 100 ppm or 5 ppm of each other, respectively.

When using a dilute exhaust gas analysis system, the relevant background concentrations shall be determined by sampling dilution air into a sampling bag over the complete test sequence.

Continuous (non-bag) background concentration may be taken at the minimum of three points, at the beginning, at the end, and a point near the middle of the cycle and averaged. At the manufacturer's request background measurements may be omitted.

- Current paragraphs 3.5-3.6 are renumbered to 3.6-3.7
- Current paragraph 3.6.1 is replaced by the following:

3.7.1. Equipment specification according to Section 1A of Annex I:

3.7.1.1. Specification A.

For engines covered by Section 1A(i) of Annex I, the following 8-mode cycle[1] shall be followed in dynamometer operation on the test engine:

Mode Number	**Engine Speed**	**Load**	**Weighting Factor**
1	Rated	100	0,15
2	Rated	75	0,15
3	Rated	50	0,15
4	Rated	10	0,10
5	Intermediate	100	0,10
6	Intermediate	75	0,10
7	Intermediate	50	0,10
8	Idle	---	0,15

---

[1] Note 1 shall be amended as follows: Identical with C1 cycle as described in Paragraph 8.3.1.1 of the ISO8178-4: 2002(E) standard.

3.7.1.2. Specification B.

For engines covered by Section 1A(ii) of Annex I, the following 5-mode cycle[2] shall be followed in dynamometer operation on the test engine:

Mode Number	Engine Speed	Load	Weighting Factor
1	Rated	100	0,05
2	Rated	75	0,25
3	Rated	50	0,30
4	Rated	25	0,30
5	Rated	10	0,10

3.7.1.3 Specification C.

For engines intended to use in inland waterway vessels the ISO test procedure as specified by ISO 8178 and IMO MARPOL 73/78, Annex VI (NO_x Code) shall be used

The load figures are percentage values of the torque corresponding to the prime power rating defined as the maximum power available during a variable power sequence, which may be run for an unlimited number of hours per year, between stated maintenance intervals and under the stated ambient conditions, the maintenance being carried out as prescribed by the manufacturer.[1]"

- The current subparagraph 3.6.3 is changed as follows:

(i) In the first section the word “cycle” is replaced by the word “cycles”

(ii) In the second section the first sentence will start “During each mode of the given test cycle (the rest remains unchanged)”

- The current paragraph 3.7 is renumbered to 3.8

- The following section 4 is inserted:

4. TEST RUN (NRTC TEST)

4.1. Introduction

The non-road transient cycle (NRTC) is listed in Annex III, Appendix 4 as a second-by-second sequence of normalized speed and torque values applicable to all diesel engines covered by this Directive. In order to perform the test on an engine test cell, the normalised values shall be converted to the actual values for the individual engine under test, based on

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[2] Note 2 shall be amended as follows: Identical with D2 cycle as described in Paragraph 8.4.1 of the ISO8178-4: 2002(E) standard.

[1] For a better illustration of the prime power definition, see Figure 2 of ISO 8528-1: 1993(E) standard.

the engine mapping curve. This conversion is referred to as denormalisation, and the test cycle developed is referred to as the reference cycle of the engine to be tested. With these reference speed and torque values, the cycle shall be run on the test cell, and the feedback speed and torque values recorded. In order to validate the test run, a regression analysis between reference and feedback speed and torque values shall be conducted upon completion of the test.

4.2. Engine mapping procedure

When generating the NRTC on the test cell, the engine shall be mapped before running the test cycle to determine the speed vs torque curve.

4.2.1. Determination of the mapping speed range

The minimum and maximum mapping speeds are defined as follows:

Minimum mapping speed = idle speed

Maximum mapping speed = n_{hi} x 1,02 or speed where full load torque drops off to zero, whichever is lower (where n_{hi} is the high speed, defined as the highest engine speed where 70% of the rated power is delivered).

4.2.2. Engine mapping curve

The engine shall be warmed up at maximum power in order to stabilise the engine parameters according to the recommendation of the manufacturer and good engineering practice. When the engine is stabilised, the engine mapping shall be performed according to the following procedures.

4.2.2.1. Transient map

(a) The engine shall be unloaded and operated at idle speed.

(b) The engine shall be operated at full load setting of the injection pump at minimum mapping speed.

(c) The engine speed shall be increased at an average rate of 8 ± 1 min-1 /s from minimum to maximum mapping speed. Engine speed and torque points shall be recorded at a sample rate of at least one point per second.

4.2.2.2. Step map

(a) The engine shall be unloaded and operated at idle speed.

(b) The engine shall be operated at full load setting of the injection pump at minimum mapping speed.

(c) While maintaining full load, the minimum mapping speed shall be maintained for at least 15 s, and the average torque during the last 5 s shall be recorded. The maximum torque curve from minimum to maximum mapping speed shall be determined in no greater than 100 ± 20 /min speed increments. Each test point shall be held for at least 15 s, and the average torque during the last 5 s shall be recorded.

4.2.3. Mapping curve generation

All data points recorded under clause 4.2.2 shall be connected using linear interpolation between points. The resulting torque curve is the mapping curve and shall be used to convert the normalized torque values of the engine dynamometer schedule of Annex IV into actual torque values for the test cycle, as described in clause 4.3.3.

4.2.4. Alternate mapping

If a manufacturer believes that the above mapping techniques are unsafe or unrepresentative for any given engine, alternate mapping techniques may be used. These alternate techniques must satisfy the intent of the specified mapping procedures to determine the maximum available torque at all engine speeds achieved during the test cycles. Deviations from the mapping techniques specified in this section for reasons of safety or representativeness shall be approved by the parties involved along with the justification for their use. In no case, however, shall the torque curve be run by descending engine speeds for governed or turbocharged engines.

4.2.5. Replicate tests

An engine need not be mapped before each and every test cycle. An engine must be remapped prior to a test cycle if:

- an unreasonable amount of time has transpired since the last map, as determined by engineering judgement,

or,

- physical changes or recalibrations have been made to the engine, which may potentially affect engine performance.

4.3. Generation of the reference test cycle

4.3.1. Reference speed

The reference speed (n_{ref}) corresponds to the 100 % normalized speed values specified in the engine dynamometer schedule of Annex III, Appendix 4. It is obvious that the actual engine cycle resulting from denormalization to the reference speed largely depends on selection of the proper reference speed. The reference speed shall be determined by the following definition:

n_{ref} = *low speed + 0,95 * (high speed – low speed)*

(the high speed is the highest engine speed where 70% of the rated power is delivered, while the low speed is the lowest engine speed where 50% of the rated power is delivered).

4.3.2. Denormalization of engine speed

The speed shall be denormalized using the following equation:

$$\text{Actual speed} = \frac{\%\text{speed} \times (\text{reference speed} - \text{idle speed})}{100} + \text{idle speed}$$

4.3.3. Denormalization of engine torque

The torque values in the engine dynamometer schedule of Annex III, Appendix 4 are normalized to the maximum torque at the respective speed. The torque values of the reference cycle shall be denormalized, using the mapping curve determined according to clause 4.2.2, as follows:

$$\text{Actual torque} = \frac{\%\ \text{torque} \times \text{max. torque}}{100} \quad (5)$$

for the respective actual speed as determined in Section 4.3.2

4.3.4. Example of denormalization procedure

As an example, the following test point shall be denormalized:

% speed = 43 %

% torque = 82 %

Given the following values:

reference speed = 2200 /min

idle speed = 600 /min

results in

$$\textit{actual speed} = \frac{43 \times (2200 - 600)}{100} + 600 = 1288\ /\text{min}$$

With the maximum torque of 700 Nm observed from the mapping curve at 1288 /min

$$\textit{actual torque} = \frac{82 \times 700}{100} = 574\ \text{N·m}$$

4.4. Dynamometer

4.4.1. When using a load cell, the torque signal shall be transferred to the engine axis and the inertia of the dyno shall be considered. The actual engine torque is the torque read on the load cell plus the moment of inertia of the brake multiplied by the angular acceleration. The control system has to perform this calculation in real time.

4.4.2. If the engine is tested with an eddy-current dynamometer, it is recommended that the number of points, where the difference $T_{sp} - 2 \cdot \pi \cdot \dot{n}_{sp} \cdot \Theta_D$ is smaller than - 5% of the peak torque, does not exceed 30 (where T_{sp} is the demanded torque, $\dot{n}_{sp}$ is the derivative of the engine speed and· Θ_D is the rotational inertia of the eddy-current dynamometer).

4.5. Emissions test run

The following flow chart outlines the test sequence.

Engine Preparation, Pre-test Measurements, Performance Checks and Calibrations

↓

Generate Engine Map (Maximum Torque Curve)

↓

Run one or more Practice Cycles as necessary to check engine/test cell/emissions systems

↓

START

↓

Run prescribed Preconditioning Cycle for a minimum of 20 minutes to condition engine and particulate system including tunnel system (partial flow or full flow).

Particulates are collected on a dummy filter.

↓

With engine running, set PM system in by-pass mode and change PM filter to stabilized and weighed sampling filter. Ready all other systems for sampling and data collection.

↓

Run Hot Cycle exhaust emissions test within 5 minutes either from engine shut down or from running engine that has been brought down to idle conditions.

One or more Practice Cycles may be run as necessary to check engine, test cell and emissions systems before the measurement cycle.

4.5.1. Preparation of the sampling filters

At least one hour before the test, each filter shall be placed in a petri dish, which is protected against dust contamination and allows air exchange, and placed in a weighing chamber for stabilization. At the end of the stabilization period, each filter shall be weighed and the weight shall be recorded. The filter shall then be stored in a closed petri dish or sealed filter holder until needed for testing. The filter shall be used within eight hours of its removal from the weighing chamber. The tare weight shall be recorded.

4.5.2. Installation of the measuring equipment

The instrumentation and sample probes shall be installed as required. The tailpipe shall be connected to the full flow dilution system, if used.

4.5.3. Starting and preconditioning the dilution system and the engine

The dilution system and the engine shall be started and warmed up. The sampling system preconditioning shall be conducted by operating the engine at a condition of rated-speed, 100 percent torque for a minimum of 20 minutes while simultaneously operating either the Partial flow Sampling System or the Full flow CVS with secondary dilution system. Dummy particulate matter emissions samples are then collected. Particulate sample filters need not be stabilized or weighed, and may be discarded. Filter media may be changed during conditioning as long as the total sampled time through the filters and sampling system exceeds 20 minutes. Flow rates shall be set at the approximate flow rates selected for transient testing. Torque shall be reduced from 100 percent torque while maintaining the rated speed condition as necessary so as not to exceed the 191 ^{o} C maximum sample zone temperature specifications.

4.5.4. Starting the particulate sampling system

The particulate sampling system shall be started and run on by-pass. The particulate background level of the dilution air may be determined by sampling the dilution air prior to entrance of the exhaust into the dilution tunnel. It is preferred that background particulate sample be collected during the transient cycle if another PM sampling system is available. Otherwise, the PM sampling system used to collect transient cycle PM can be used. If filtered dilution air is used, one measurement may be done prior to or after the test. If the dilution air is not filtered, measurements should be carried out prior to the beginning and after the end of the cycle and the values averaged.

4.5.5. Adjustment of the dilution system

The total diluted exhaust gas flow of a full flow dilution system or the diluted exhaust gas flow through a partial flow dilution system shall be set to eliminate water condensation in the system, and to obtain a filter face temperature between 315 K (42°C) and 325 K (52°C).

4.5.6. Checking the analyzers

The emission analyzers shall be set at zero and spanned. If sample bags are used, they shall be evacuated.

4.5.7. Engine starting procedure

The stabilized engine shall be started within 5 min after completion of warm-up according to the starting procedure recommended by the manufacturer in the owner's manual, using either a production starter motor or the dynamometer. Optionally, the test may start within 5 min of the engine preconditioning phase without shutting the engine off, when the engine has been brought to an idle condition.

4.5.8. Cycle run

4.5.8.1. Test sequence

The test sequence shall commence when the engine is started from shut down after the preconditioning phase or from idle conditions when starting directly from the preconditioning phase with the engine running. The test shall be performed according to the reference cycle as set out in Annex III, Appendix 4. Engine speed and torque command set points shall be issued at 5 Hz (10 Hz recommended) or greater. The set points shall be calculated by linear interpolation between the 1 Hz set points of the reference cycle. Feedback engine speed and torque shall be recorded at least once every second during the test cycle, and the signals may be electronically filtered.

4.5.8.2. Analyzer response

At the start of the engine or test sequence, if the cycle is started directly from preconditioning, the measuring equipment shall be started, simultaneously:

- start collecting or analyzing dilution air, if a full flow dilution system is used;
- start collecting or analyzing raw or diluted exhaust gas, depending on the method used;
- start measuring the amount of diluted exhaust gas and the required temperatures and pressures;
- start recording the exhaust gas mass flow rate, if raw exhaust gas analysis is used;

start recording the feedback data of speed and torque of the dynamometer.

If raw exhaust measurement is used, the emission concentrations (HC, CO and NOx) and the exhaust gas mass flow rate shall be measured continuously and stored with at least 2 Hz on a computer system. All other data may be recorded with a sample rate of at least 1 Hz. For analogue analyzers the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.

If a full flow dilution system is used, HC and NOx shall be measured continuously in the dilution tunnel with a frequency of at least 2 Hz. The average concentrations shall be determined by integrating the analyzer signals over the test cycle. The system response time shall be no greater than 20 s, and shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary. CO and CO_2 shall be determined by integration or by analyzing the concentrations in the sample bag, collected over the cycle. The concentrations of the gaseous pollutants in the dilution air shall be determined by integration or by collection in the background bag. All other parameters that need to be measured shall be recorded with a minimum of one measurement per second (1 Hz).

4.5.8.3. Particulate sampling

At the start of the engine or test sequence, if the cycle is started directly from preconditioning, the particulate sampling system shall be switched from by-pass to collecting particulates.

If a partial flow dilution system is used, the sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe or transfer tube is maintained proportional to the exhaust mass flow rate.

If a full flow dilution system is used, the sample pump(s) shall be adjusted so that the flow rate through the particulate sample probe or transfer tube is maintained at a value within ± 5 % of the set flow rate. If flow compensation (i.e., proportional control of sample flow) is used, it must be demonstrated that the ratio of main tunnel flow to particulate sample flow does not change by more than ± 5 % of its set value (except for the first 10 seconds of sampling).

Note: For double dilution operation, sample flow is the net difference between the flow rate through the sample filters and the secondary dilution airflow rate.

The average temperature and pressure at the gas meter(s) or flow instrumentation inlet shall be recorded. If the set flow rate cannot be maintained over the complete cycle (within ± 5 %) because of high particulate loading on the filter, the test shall be voided. The test shall be rerun using a lower flow rate and/or a larger diameter filter.

4.5.8.4. Engine stalling

If the engine stalls anywhere during the test cycle, the engine shall be preconditioned and restarted, and the test repeated. If a malfunction occurs in any of the required test equipment during the test cycle, the test shall be voided.

4.5.8.5. Operations after test

At the completion of the test, the measurement of the exhaust gas mass flow rate, the diluted exhaust gas volume, the gas flow into the collecting bags and the particulate sample pump shall be stopped. For an integrating analyzer system, sampling shall continue until system response times have elapsed.

The concentrations of the collecting bags, if used, shall be analyzed as soon as possible and in any case not later than 20 minutes after the end of the test cycle.

After the emission test, a zero gas and the same span gas shall be used for re-checking the analyzers. The test will be considered acceptable if the difference between the pre-test and post-test results is less than 2 % of the span gas value.

The particulate filters shall be returned to the weighing chamber no later than one hour after completion of the test. They shall be conditioned in a petri dish, which is protected against dust contamination and allows air exchange, for at least one hour, and then weighed. The gross weight of the filters shall be recorded.

4.6. Verification of the test run

4.6.1. Data Shift

To minimise the biasing effect of the time lag between the feedback and reference cycle values, the entire engine speed and torque feedback signal sequence may be advanced or delayed in time with respect to the reference speed and torque sequence. If the feedback signals are shifted, both speed and torque must be shifted the same amount in the same direction.

4.6.2. Calculation of the Cycle Work

The actual cycle work Wact (kWh) shall be calculated using each pair of engine feedback speed and torque values recorded. The actual cycle work Wact is used for comparison to the reference cycle work Wref and for calculating the brake specific emissions. The same methodology shall be used for integrating both reference and actual engine power. If values are to be determined between adjacent reference or adjacent measured values, linear interpolation shall be used.

In integrating the reference and actual cycle work, all negative torque values shall be set equal to zero and included. If integration is performed at a frequency of less than 5 Hertz, and if, during a given time segment, the torque value changes from positive to negative or negative to positive, the negative portion shall be computed and set equal to zero. The positive portion shall be included in the integrated value.

Wact shall be between -15 % and + 5 % of Wref.

4.6.3. Validation Statistics of the Test Cycle

Linear regressions of the feedback values on the reference values shall be performed for speed, torque and power. This shall be done after any feedback data shift has occurred, if this option is selected. The method of least squares shall be used, with the best fit equation having the form:

$y = mx + b$

where:

y = feedback (actual) value of speed (min^{-1}) , torque (N·m), or power (kW)

m = slope of the regression line

x = reference value of speed (min^{-1}) , torque (N·m), or power (kW)

b = y intercept of the regression line

The standard error of estimate (SE) of y on x and the coefficient of determination (r^2) shall be calculated for each regression line.

It is recommended that this analysis be performed at 1 Hertz. For a test to be considered valid, the criteria of Table 1 must be met.

Table 1: Regression Line Tolerances

	Speed	Torque	Power
Standard error of estimate (SE) of Y on X	max 100 min^{-1}	max 13 % of power map maximum engine torque	max 8% of power map maximum engine power
Slope of the regression line, m	0,95 to 1,03	0,83 – 1,03	0,89 – 1,03
Coefficient of determination, r^2	min 0,9700	min 0,8800	min 0,9100
Y intercept of the regression line, b	± 50 min^{-1}	± 20 N·m or ± 2 % of max torque, whichever is greater	± 4 kW or ± 2 % of max power, whichever is greater

For regression purposes only, point deletions are permitted where noted in Table 2 before doing the regression calculation. However, those points must not be deleted for the calculation of cycle work and emissions. An idle point is defined as a point having a normalized reference torque of 0 % and a normalized reference speed of 0 %. Point deletion may be applied to the whole or to any part of the cycle.

Table 2. Permitted Point Deletions From Regression Analysis (points to which the point deletion is applied have to be specified)

CONDITION	**SPEED AND/OR TORQUE AND/OR POWER POINTS WHICH MAY BE DELETED WITH REFERENCE TO THE CONDITIONS LISTED IN THE LEFT COLUMN**
First 24 (±1) s and last 25 s	Speed, torque and power
Wide open throttle, and torque feedback < 95% torque reference	Torque and/or power
Wide open throttle, and speed feedback < 95% speed reference	Speed and/or power
Closed throttle, speed feedback > idle speed + 50 min^{-1}, and torque feedback > 105% torque reference	Torque and/or power
Closed throttle, speed feedback ≤ idle speed + 50 min^{-1}, and torque feedback = Manufacturer defined/measured idle torque ± 2% of max torque	Speed and/or power
Closed throttle and speed feedback > 105% speed reference	Speed and/or power

(e) Appendix 1 to Annex III is replaced by the following:

APPENDIX 1

MEASUREMENT AND SAMPLING PROCEDURES

1. MEASUREMENT AND SAMPLING PROCEDURES (NRSC TEST)

Gaseous and particulate components emitted by the engine submitted for testing shall be measured by the

methods described in Annex VI. The methods of Annex VI describe the recommended analytical systems for the gaseous emissions (Section 1.1) and the recommended particulate dilution and sampling systems (Section 1.2).

1.1. Dynamometer specification

An engine dynamometer with adequate characteristics to perform the test cycle described in Annex III, Section 3.7.1 shall be used. The instrumentation for torque and speed measurement shall allow the measurement of the power within the given limits. Additional calculations may be necessary. The accuracy of the measuring equipment must be such that the maximum tolerances of the figures given in point 1.3 are not exceeded.

1.2. Exhaust gas flow

The exhaust gas flow shall be determined by one of the methods mentioned in sections 1.2.1 to 1.2.4.

1.2.1. Direct measurement method

Direct measurement of the exhaust flow by flow nozzle or equivalent metering system (for detail see ISO 5167:2000).

Note: Direct gaseous flow measurement is a difficult task. Precautions must be taken to avoid measurement errors that will impact emission value errors.

1.2.2. Air and fuel measurement method

Measurement of the airflow and the fuel flow.

Air flow-meters and fuel flow-meters with the accuracy defined in Section 1.3 shall be used.

The calculation of the exhaust gas flow is as follows:

$G_{EXHW} = G_{AIRW} + G_{FUEL}$ *(for wet exhaust mass)*

1.2.3. Carbon balance method

Exhaust mass calculation from fuel consumption and exhaust gas concentrations using the carbon balance method (see Annex III, Appendix 3).

1.2.4. Tracer measurement method

The method involves measurement of the concentration of a tracer gas in the exhaust.

A known amount of an inert gas (e.g. pure helium) shall be injected into the exhaust gas flow as a tracer. The gas is mixed and diluted by the exhaust gas, but must not react in the exhaust pipe. The concentration of the gas shall then be measured in the exhaust gas sample.

In order to ensure complete mixing of the tracer gas, the exhaust gas sampling probe shall be located at least 1 m or 30 times the diameter of the exhaust pipe, whichever is larger, downstream of the tracer gas injection point. The sampling probe may be located closer to the injection point if complete mixing is verified by comparing the tracer gas concentration with the reference concentration when the tracer gas is injected upstream of the engine.

The tracer gas flow rate shall be set so that the tracer gas concentration at engine idle speed after mixing becomes lower than the full scale of the trace gas analyzer.

The calculation of the exhaust gas flow is as follows:

$$G_{EXHW} = \frac{G_{\mathrm{T}} \times \rho_{\mathrm{EXH}}}{60 \times \left(conc_{\mathrm{mix}} - conc_{a}\right)}$$

where

G_{EXHW} = instantaneous exhaust mass flow, kg/s

G_{T} = tracer gas flow, cm^3/min

$conc_{mix}$ = instantaneous concentration of the tracer gas after mixing, ppm

ρ_{EXH} = density of the exhaust gas, kg/m^3

$conc_{a}$ = background concentration of the tracer gas in the intake air, ppm

The background concentration of the tracer gas ($conc_{\mathrm{a}}$) may be determined by averaging the background concentration measured immediately before the test run and after the test run.

When the background concentration is less than 1% of the concentration of the tracer gas after mixing ($conc_{\mathrm{mix.}}$) at maximum exhaust flow, the background concentration may be neglected.

The total system shall meet the accuracy specifications for the exhaust gas flow, and shall be calibrated according to Appendix 2, Section 1.11.2

1.2.5. Air flow and air to fuel ratio measurement method

This involves exhaust mass calculation from the air flow and the air to fuel ratio. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$G_{EXHW} = G_{AIRW} \times \left(1 + \frac{1}{A/F_{\mathrm{st}} \times \lambda}\right) \text{with}$$

$$A/F_{\mathrm{st}} = 14{,}5$$

$$\lambda = \frac{\left(100 - \frac{conc_{\mathrm{CO}} \times 10^{-4}}{2} - conc_{\mathrm{HC}} \times 10^{-4}\right) + \left(0{,}45 \cdot \frac{1 - \frac{2 \times conc_{\mathrm{CO}} \times 10^{-4}}{3{,}5 \times conc_{\mathrm{CO2}}}}{1 + \frac{conc_{\mathrm{CO}} \times 10^{-4}}{3{,}5 \times conc_{\mathrm{CO2}}}}\right) \times \left(conc_{\mathrm{CO2}} + conc_{\mathrm{CO}} \times 10^{-4}\right)}{6{,}9078 \times \left(conc_{\mathrm{CO2}} + conc_{\mathrm{CO}} \times 10^{-4} + conc_{\mathrm{HC}} \times 10^{-4}\right)}$$

where A/Fst = stoichiometric air/fuel ratio, kg/kg

λ = relative air / fuel ratio

$conc_{CO2}$ = dry CO2 concentration, %

$conc_{CO}$ = dry CO concentration, ppm

$conc_{HC}$ = HC concentration, ppm

NOTE: The calculation refers to a diesel fuel with a H/C ratio equal to 1.8

The air flowmeter shall meet the accuracy specifications in Table 3, the CO_2 analyzer used shall meet the specifications of clause 1.4.1, and the total system shall meet the accuracy specifications for the exhaust gas flow.

Optionally, air to fuel ratio measurement equipment such as a zirconia type sensor may be used for the measurement of the relative air/fuel ratio in accordance with the specifications of clause 1.4.4.

1.2.6. Total dilute exhaust gas flow

When using a full flow dilution system, the total flow of the dilute exhaust (G_{TOTW}) shall be measured with a PD or CFI or SST - Annex VI, point 1.2.1.2. The accuracy shall conform to the provisions of Annex III, Appendix 2, Section 2.2.

1.3. Accuracy

The calibration of all measurement instruments shall be traceable to national (international) standards and comply with the requirements listed in Table 3.

Table 3. Accuracy of Measuring Instruments

No.	Measuring Instrument	Accuracy
1	Engine speed	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
2	Torque	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
3	Fuel consumption	± 2 % of engine's max. value
4	Air consumption	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
5	Exhaust gas flow	± 2,5 % of reading or ± 1,5 % of engine's max. value whichever is larger
6	Temperatures ≤ 600 K	± 2 K absolute
7	Temperatures > 600 K	± 1 % of reading
8	Exhaust gas pressure	± 0,2 kPa absolute
9	Intake air depression	± 0,05 kPa absolute
10	Atmospheric pressure	± 0,1 kPa absolute
11	Other pressures	± 0,1 kPa absolute
12	Absolute humidity	± 5 % of reading
13	Dilution air flow	± 2 % of reading
14	Diluted exhaust gas flow	± 2 % of reading

1.4. Determination of the gaseous components

1.4.1. General analyser specifications

The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (point 1.4.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If the full scale value is 155 ppm (or ppm C) or less or if read-out systems (computers, data loggers) that provide sufficient accuracy and resolution below 15 % of full scale are used concentrations below 15 % of full scale are also acceptable. In this case, additional calibrations are to be made to ensure the accuracy of the calibration curves - Annex III, Appendix 2, point 1.5.5.2.

The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimize additional errors.

1.4.1.1. Measurement error

The analyzer shall not deviate from the nominal calibration point by more than ± 2 % of the reading or ± 0.3 % of full scale whichever is larger.

NOTE: For the purpose of this standard, accuracy is defined as the deviation of the analyzer reading from the nominal calibration values using a calibration gas (≡ true value)

1.4.1.2. Repeatability

The repeatability, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, must be no greater than ± 1 % of full scale concentration for each range used above 155 ppm (or ppm C) or ± 2 % of each range used below 155 ppm (or ppm C).

1.4.1.3. Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10-second period shall not exceed 2 % of full scale on all ranges used.

1.4.1.4. Zero drift

The zero drift during a one-hour period shall be less than 2 % of full scale on the lowest range used. The zero response is defined as the mean response, including noise, to a zero gas during a 30-second time interval.

1.4.1.5. Span drift

The span drift during a one-hour period shall be less than 2 % of full scale on the lowest range used. Span is defined as the difference between the span response and the zero response. The span response is defined as the mean response, including noise, to a span gas during a 30-second time interval.

1.4.2. Gas drying

The optional gas drying device must have a minimal effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

1.4.3. Analysers

Sections 1.4.3.1. to 1.4.3.5 of this Appendix describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex VI.

The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearizing circuits is permitted.

1.4.3.1. Carbon monoxide (CO) analysis

The carbon monoxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

1.4.3.2. Carbon dioxide (CO_2) analysis

The carbon dioxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

1.4.3.3. Hydrocarbon (HC) analysis

The hydrocarbon analyser shall be of the heated flame ionization detector (HFID) type with detector, valves, pipework, etc, heated so as to maintain a gas temperature of 463 K (190 °C) ± 10 K.

1.4.3.4. Oxides of nitrogen (NOx) analysis

The oxides of nitrogen analyser shall be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO2/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with converter maintained above 328 K (55 °C) shall be used, provided the water quench check (Annex III, Appendix 2, point 1.9.2.2) is satisfied.

For both CLD and HCLD, the sampling path shall be maintained at a wall temperature of 328 K to 473 K (55 °C to 200 °C) up to the converter for dry measurement, and up to the analyzer for wet measurement.

1.4.4. Air to fuel measurement

The air to fuel measurement equipment used to determine the exhaust gas flow as specified in clause 1.2.5 shall be a wide range air to fuel ratio sensor or lambda sensor of Zirconia type.

The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.

The accuracy of the sensor with incorporated electronics shall be within:

± 3 % of reading $\lambda < 2$

± 5 % of reading $2 \leq \lambda < 5$

± 10 % of reading $5 \leq \lambda$

To fulfil the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.

1.4.5. Sampling for gaseous emissions

The gaseous emissions sampling probes must be fitted at least 0,5 m or three times the diameter of the exhaust pipe - whichever is the larger - upstream of the exit of the exhaust gas system as far as applicable and sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70 °C) at the probe.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a 'V`-engine configuration, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emissions calculation the total exhaust mass flow of the engine must be used.

If the composition of the exhaust gas is influenced by any exhaust after-treatment system, the exhaust sample must be taken upstream of this device in the tests of stage I and downstream of this device in the tests of stage II. When a full flow dilution system is used for the determination of the particulates, the gaseous emissions may also be determined in the diluted exhaust gas. The sampling probes shall be close to the particulate sampling probe in the dilution tunnel (Annex VI, point 1.2.1.2, DT and Section 1.2.2, PSP). CO and CO_2 may optionally be determined by sampling into a bag and subsequent measurement of the concentration in the sampling bag.

1.5. Determination of the particulates

The determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system or a full flow dilution system. The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas between 315 K (42°C) and 325 K (52°C) immediately upstream of the filter holders. De-humidifying the dilution air before entering the dilution system is permitted, if the air humidity is high. Dilution air pre-heating above the temperature limit of 303 K (30 °C) is recommended, if the ambient temperature is below 293 K (20 °C). However, the diluted air temperature must not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel.

Note: For steady-state procedure, the filter temperature may be kept at or below the maximum temperature of 325 K (52 °C) instead of respecting the temperature range of 42 °C – 52 °C.

For a partial flow dilution system, the particulate sampling probe must be fitted close to and upstream of the gaseous probe as defined in Section 4.4 and in accordance with Annex VI, point 1.2.1.1, figure 4-12 EP and SP.

The partial flow dilution system has to be designed to split the exhaust stream into two fractions, the smaller one being diluted with air and subsequently used for particulate measurement. From that it is essential that the dilution ratio be determined very accurately. Different splitting methods can be applied, whereby the type of splitting used dictates to a significant degree the sampling hardware and procedures to be used (Annex VI, point 1.2.1.1).

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, a microgram balance and a temperature and humidity controlled weighing chamber are required.

For particulate sampling, two methods may be applied:

- the single filter method uses one pair of filters (see point 1.5.1.3. of this Appendix) for all modes of the test cycle. Considerable attention must be paid to sampling times and flows during the sampling phase of the test. However, only one pair of filters will be required for the test cycle,

- the multiple filter method dictates that one pair of filters (see point 1.5.1.3. of this Appendix) is used for each of the individual modes of the test cycle. This method allows more lenient sample procedures but uses more filters.

1.5.1. Particulate sampling filters

1.5.1.1. Filter specification

Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required for certification tests. For special applications different filter materials may be used. All filter types shall have a 0,3 µm DOP (di-octylphthalate) collection efficiency of at least 99% at a gas face velocity between 35 and 100 cm/s. When performing correlation tests between laboratories or between a manufacturer and an approval authority, filters of identical quality must be used.

1.5.1.2. Filter size

Particulate filters must have a minimum diameter of 47 mm (37 mm stain diameter). Larger diameter filters are acceptable (point 1.5.1.5.).

1.5.1.3. Primary and back-up filters

The diluted exhaust shall be sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter shall be located no more than 100 mm downstream of, and shall not be in contact with the primary filter. The filters may be weighed separately or as a pair with the filters placed stain side to stain side.

1.5.1.4. Filter face velocity

A gas face velocity through the filter of 35 to 100 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

1.5.1.5. Filter loading

The recommended minimum filter loadings for the most common filter sizes are shown in the folowing table. For larger filter sizes, the minimum filter loading shall be 0,065 mg/1000 mm^2 filter area.

Filter Diameter (mm)	Recommended stain diameter (mm)	Recommended minimum loading (mg)
47	37	0,11
70	60	0,25
90	80	0,41
110	100	0,62

For the multiple filter method, the recommended minimum filter loading for the sum of all filters shall be the product of the appropriate value above and the square root of the total number of modes.

1.5.2. Weighing chamber and analytical balance specifications

1.5.2.1. Weighing chamber conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295 K (22 °C) ± 3 K during all filter conditioning and weighing. The humidity shall be maintained to a dew point of 282,5 (9,5 °C) ± 3 K and a relative humidity of 45 ± 8 %.

1.5.2.2. Reference filter weighing

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in point 1.5.2.1. will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personnel entrance into the weighing room. At least two unused reference filters or reference filter pairs shall be weighed within four hours of, but preferably at the same time as the sample filter (pair) weighing. They shall be the same size and material as the sample filters.

If the average weight of the reference filters (reference filter pairs) changes between sample filter weighing by more than 10µg, then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in point 1.5.2.1 is not met, but the reference filter (pair) weighing meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

1.5.2.3. Analytical balance

The analytical balance used to determine the weights of all filters shall have a precision (standard deviation) of 2 µg and a resolution of 1 µg (1 digit = 1 µg) specified by the balance manufacturer.

1.5.2.4. Elimination of static electricity effects

To eliminate the effects of static electricity, the filters shall be neutralized prior to weighing, for example, by a Polonium neutralizer or a device of similar effect.

1.5.3. Additional specifications for particulate measurement

All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, must be designed to minimize deposition or alteration of the particulates. All parts must be made of electrically conductive materials that do not react with exhaust gas components, and must be electrically grounded to prevent electrostatic effects.

2. MEASUREMENT AND SAMPLING PROCEDURES (NRTC TEST)

2.1. Introduction

Gaseous and particulate components emitted by the engine submitted for testing shall be measured by the methods described in Annex VI. The methods of Annex VI describe the recommended analytical systems for the gaseous emissions (Section 1.1) and the recommended particulate dilution and sampling systems (Section 1.2).

2.2. Dynamometer and test cell equipment

The following equipment shall be used for emission tests of engines on engine dynamometers.

2.2.1. Engine Dynamometer

An engine dynamometer shall be used with adequate characteristics to perform the test cycle described in Appendix 4 to this Annex. The instrumentation for torque and speed measurement shall allow the measurement of the power within the given limits. Additional calculations may be necessary. The accuracy of the measuring equipment must be such that the maximum tolerances of the figures given in Table 3 are not exceeded.

2.2.2. Other Instruments

Measuring instruments for fuel consumption, air consumption, temperature of coolant and lubricant, exhaust gas pressure and intake manifold depression, exhaust gas temperature, air intake temperature, atmospheric pressure, humidity and fuel temperature shall be used, as required. These instruments shall satisfy the requirements given in Table 3:

Table 3. Accuracy of Measuring Instruments

No.	Measuring Instrument	Accuracy
1	Engine speed	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
2	Torque	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
3	Fuel consumption	± 2 % of engine's max. value
4	Air consumption	± 2 % of reading or ± 1 % of engine's max. value whichever is larger
5	Exhaust gas flow	± 2,5 % of reading or ± 1,5 % of engine's max. value whichever is larger
6	Temperatures ≤ 600 K	± 2 K absolute
7	Temperatures > 600 K	± 1 % of reading
8	Exhaust gas pressure	± 0,2 kPa absolute
9	Intake air depression	± 0,05 kPa absolute
10	Atmospheric pressure	± 0,1 kPa absolute
11	Other pressures	± 0,1 kPa absolute
12	Absolute humidity	± 5 % of reading
13	Dilution air flow	± 2 % of reading
14	Diluted exhaust gas flow	± 2 % of reading

2.2.3. Raw Exhaust Gas Flow

For calculating the emissions in the raw exhaust gas and for controlling a partial flow dilution system, it is necessary to know the exhaust gas mass flow rate. For determinating the exhaust mass flow rate, either of the methods described in the following clauses may be used.

For the purpose of emissions calculation, the response time of either method described below shall be equal to or less than the requirement for the analyzer response time, as defined in Appendix 2, Section 1.11.1.

For the purpose of controlling a partial flow dilution system, a faster response is required. For partial flow dilution systems with online control, a response time of ≤ 0,3 s is required. For partial flow dilution systems with look ahead control based on a pre-recorded test run, a response time of the exhaust flow measurement system of ≤ 5 s with a rise time of ≤ 1 s is required. The system response time shall be specified by the instrument manufacturer. The combined response time requirements for exhaust gas flow and partial flow dilution system are indicated in Section 2.4.

Direct measurement method

Direct measurement of the instantaneous exhaust flow may be done by systems, such as:

- pressure differential devices, like flow nozzle, (details see ISO 5167: 2000)
- ultrasonic flowmeter
- vortex flowmeter

Precautions shall be taken to avoid measurement errors, which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Especially, engine performance and emissions must not be affected by the installation of the device.

The flowmeters shall meet the accuracy specifications of Table 3.

Air and fuel measurement method

This involves measurement of the airflow and the fuel flow with suitable flowmeters. The calculation of the instantaneous exhaust gas flow is as follows:

$G_{EXHW} = G_{AIRW} + G_{FUEL}$ (for wet exhaust mass)

The flowmeters shall meet the accuracy specifications of Table 3, but shall also be accurate enough to also meet the accuracy specifications for the exhaust gas flow.

Tracer measurement method

This involves measurement of the concentration of a tracer gas in the exhaust.

A known amount of an inert gas (e.g. pure helium) shall be injected into the exhaust gas flow as a tracer. The gas is mixed and diluted by the exhaust gas, but must not react in the exhaust pipe. The concentration of the gas shall then be measured in the exhaust gas sample.

In order to ensure complete mixing of the tracer gas, the exhaust gas sampling probe shall be located at least 1 m or 30 times the diameter of the exhaust pipe, whichever is larger, downstream of the tracer gas injection point. The sampling probe may be located closer to the injection point if complete mixing is verified by comparing the tracer gas concentration with the reference concentration when the tracer gas is injected upstream of the engine.

The tracer gas flow rate shall be set so that the tracer gas concentration at engine idle speed after mixing becomes lower than the full scale of the trace gas analyzer.

The calculation of the exhaust gas flow is as follows:

$$G_{EXHW} = \frac{G_{\mathrm{T}} \times \rho_{\mathrm{EXH}}}{60 \times \left(conc_{\mathrm{mix}} - conc_{a}\right)}$$

where

G_{EXHW} = instantaneous exhaust mass flow, kg/s

G_T = tracer gas flow, cm³/min

$conc_{\mathrm{mix}}$= instantaneous concentration of the tracer gas after mixing, ppm

ρ_{EXH} = density of the exhaust gas, kg/m³

$conc_{\mathrm{a}}$ = background concentration of the tracer gas in the intake air, ppm

The background concentration of the tracer gas ($conc_{\mathrm{a}}$) may be determined by averaging the background concentration measured immediately before the test run and after the test run.

When the background concentration is less than 1% of the concentration of the tracer gas after mixing ($conc_{\mathrm{mix.}}$) at maximum exhaust flow, the background concentration may be neglected.

The total system shall meet the accuracy specifications for the exhaust gas flow, and shall be calibrated according to Appendix 2, paragraph 1.11.2

Air flow and air to fuel ratio measurement method

This involves exhaust mass calculation from the airflow and the air to fuel ratio. The calculation of the instantaneous exhaust gas mass flow is as follows:

$$G_{EXHW} = G_{AIRW} \times \left(1 + \frac{1}{A/F_{\mathrm{st}} \times \lambda}\right) \text{with}$$

$$A/F_{\mathrm{st}} = 14{,}5$$

$$\lambda = \frac{\left(100 - \frac{conc_{\mathrm{CO}} \times 10^{-4}}{2} - conc_{\mathrm{HC}} \times 10^{-4}\right) + \left(0{,}45 \cdot \frac{1 - \frac{2 \times conc_{\mathrm{CO}} \times 10^{-4}}{3{,}5 \times conc_{\mathrm{CO2}}}}{1 + \frac{conc_{\mathrm{CO}} \times 10^{-4}}{3{,}5 \times conc_{\mathrm{CO2}}}}\right) \times \left(conc_{\mathrm{CO2}} + conc_{\mathrm{CO}} \times 10^{-4}\right)}{6{,}9078 \times \left(conc_{\mathrm{CO2}} + conc_{\mathrm{CO}} \times 10^{-4} + conc_{\mathrm{HC}} \times 10^{-4}\right)}$$

where *A/Fst =* *stoichiometric air/fuel ratio, kg/kg*

λ = relative air / fuel ratio

$conc_{CO2}$ = dry CO2 concentration, %

$conc_{CO}$ = dry CO concentration, ppm

$conc_{HC}$ = HC concentration, ppm

NOTE: The calculation refers to a diesel fuel with a H/C ratio equal to 1.8

The air flowmeter shall meet the accuracy specifications in Table 3, the CO_2 analyzer used shall meet the specifications of clause 2.3.1, and the total system shall meet the accuracy specifications for the exhaust gas flow.

Optionally, air to fuel ratio measurement equipment such as a zirconia type sensor may be used for the measurement of the excess air ratio in accordance with the specifications of clause 2.3.4.

2.2.4. Diluted Exhaust Gas Flow

For calculation of the emissions in the diluted exhaust gas, it is necessary to know the diluted exhaust gas mass flow rate. The total diluted exhaust gas flow over the cycle (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device (V_0 for PDV, K_V for CFV, C_d for SSV) the corresponding methods described in Appendix 3, clause 2.2.1 shall be used. If the total sample mass of particulates and gaseous pollutants exceeds 0,5 % of the total CVS flow, the CVS flow shall be corrected or the particulate sample flow shall be returned to the CVS prior to the flow measuring device.

2.3. Determination of the gaseous components

2.3.1. General Analyser Specifications

The analysers shall have a measuring range appropriate for the accuracy required to measure the concentrations of the exhaust gas components (point 1.4.1.1). It is recommended that the analysers be operated such that the measured concentration falls between 15 % and 100 % of full scale.

If the full scale value is 155 ppm (or ppm C) or less or if read-out systems (computers, data loggers) that provide sufficient accuracy and resolution below 15 % of full scale are used concentrations below 15 % of full scale are also acceptable. In this case, additional calibrations are to be made to ensure the accuracy of the calibration curves - Annex III, Appendix 2, point 1.5.5.2.

The electromagnetic compatibility (EMC) of the equipment shall be of a level such as to minimize additional errors.

2.3.1.1. Measurement error

The analyzer shall not deviate from the nominal calibration point by more than ± 2 % of the reading or ± 0.3 % of full scale whichever is larger.

NOTE: For the purpose of this standard, accuracy is defined as the deviation of the analyzer reading from the nominal calibration values using a calibration gas (≡ true value).

2.3.1.2. Repeatability

The repeatability, defined as 2,5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, must be no greater than ± 1 % of full scale concentration for each range used above 155 ppm (or ppm C) or ± 2 % of each range used below 155 ppm (or ppm C).

2.3.1.3. Noise

The analyser peak-to-peak response to zero and calibration or span gases over any 10-second period shall not exceed 2 % of full scale on all ranges used.

2.3.1.4. Zero drift

The zero drift during a one-hour period shall be less than 2 % of full scale on the lowest range used. The zero response is defined as the mean response, including noise, to a zero gas during a 30-second time interval.

2.3.1.5. Span drift

The span drift during a one-hour period shall be less than 2 % of full scale on the lowest range used. Span is defined as the difference between the span response and the zero response. The span response is defined as the mean response, including noise, to a span gas during a 30-second time interval.

2.3.1.6. Rise Time

For raw exhaust gas analysis, the rise time of the analyzer installed in the measurement system shall not exceed 2,5 s.

NOTE: Only evaluating the response time of the analyzer alone will not clearly define the suitability of the total system for transient testing. Volumes and especially dead volumes through out the system will not only affect the transportation time from the probe to the analyzer, but also affect the rise time. Also transport times inside of an analyzer would be defined as analyzer response time, like the converter or water traps inside of a NOx analyzers. The determination of the total system response time is described in Appendix 2, Section 1.11.1.

2.3.2. Gas Drying

Same specifications as for NRSC test cycle apply (see previous Section 1.4.2) as described here below.

The optional gas drying device must have a minimal effect on the concentration of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.

2.3.3. Analysers

Same specifications as for NRSC test cycle apply (see previous Section 1.4.3) as described here below.

The gases to be measured shall be analysed with the following instruments. For non-linear analysers, the use of linearizing circuits is permitted.

2.3.3.1. Carbon monoxide (CO) analysis

The carbon monoxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

2.3.3.2. Carbon dioxide (CO_2) analysis

The carbon dioxide analyser shall be of the non-dispersive infra-red (NDIR) absorption type.

2.3.3.3. Hydrocarbon (HC) analysis

The hydrocarbon analyser shall be of the heated flame ionization detector (HFID) type with detector, valves, pipework, etc, heated so as to maintain a gas temperature of 463 K (190 °C) ± 10 K.

2.3.3.4. Oxides of nitrogen (NOx) analysis

The oxides of nitrogen analyser shall be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO2/NO converter, if measured on a dry basis. If measured on a wet basis, a HCLD with converter maintained above 328 K (55 °C shall be used, provided the water quench check (Annex III, Appendix 2, point 1.9.2.2) is satisfied.

For both CLD and HCLD, the sampling path shall be maintained at a wall temperature of 328 K to 473 K (55°C to 200°C) up to the converter for dry measurement, and up to the analyzer for wet measurement.

2.3.4. Air to fuel measurement

The air to fuel measurement equipment used to determine the exhaust gas flow as specified in clause 2.2.3 shall be a wide range air to fuel ratio sensor or lambda sensor of Zirconia type.

The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.

The accuracy of the sensor with incorporated electronics shall be within:

± 3 % of reading $\lambda < 2$

± 5 % of reading $2 \leq \lambda < 5$

± 10 % of reading $5 \leq \lambda$

To fulfil the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.

2.3.5. Sampling of Gaseous Emissions

2.3.5.1. Raw exhaust gas flow

For calculation of the emissions in the raw exhaust gas the same specifications as for NRSC test cycle apply (see previous Section 1.4.4), as described here below.

The gaseous emissions sampling probes must be fitted at least 0,5 m or three times the diameter of the exhaust pipe - whichever is the larger - upstream of the exit of the exhaust gas system as far as applicable and sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70 °C) at the probe.

In the case of a multicylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multicylinder engines having distinct groups of manifolds, such as in a 'V`-engine configuration, it is permissible to acquire a sample from each group individually and calculate an average exhaust emission. Other methods which have been shown to correlate with the above methods may be used. For exhaust emissions calculation the total exhaust mass flow of the engine must be used.

If the composition of the exhaust gas is influenced by any exhaust after-treatment system, the exhaust sample must be taken upstream of this device in the tests of stage I and downstream of this device in the tests of stage II.

2.3.5.2. Diluted exhaust gas flow

If a full flow dilution system is used, the following specifications apply.

The exhaust pipe between the engine and the full flow dilution system shall conform to the requirements of Annex VI.

The gaseous emissions sample probe(s) shall be installed in the dilution tunnel at a point where the dilution air and exhaust gas are well mixed, and in close proximity to the particulates sampling probe.

Sampling can generally be done in two ways:

- the pollutants are sampled into a sampling bag over the cycle and measured after completion of the test;
- the pollutants are sampled continuously and integrated over the cycle; this method is mandatory for HC and NO_x.

The background concentrations shall be sampled upstream of the dilution tunnel into a sampling bag, and shall be subtracted from the emissions concentration according to Appendix 3, Section 2.2.3.

2.4. Determination of the particulates

Determination of the particulates requires a dilution system. Dilution may be accomplished by a partial flow dilution system or a full flow dilution system. The flow capacity of the dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas between 315 K (42 °C) and 325 K (52 °C) immediately upstream of the filter holders. De-humidifying the dilution air before entering the dilution system is permitted, if the air humidity is high. Dilution air pre-heating above the temperature limit of 303 K (30 °C) is recommended if the ambient temperature is below 293 K (20 °C). However, the diluted air temperature must not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel.

The particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, and the installation shall comply with the provisions of Section 2.3.5.

To determine the mass of the particulates, a particulate sampling system, particulate sampling filters, microgram balance, and a temperature and humidity controlled weighing chamber, are required.

Partial flow dilution system specifications

The partial flow dilution system has to be designed to split the exhaust stream into two fractions, the smaller one being diluted with air and subsequently used for particulate measurement. For this it is essential that the dilution ratio be determined very accurately. Different splitting methods can be applied, whereby the type of splitting used dictates to a significant degree the sampling hardware and procedures to be used (Annex VI, point 1.2.1.1).

For the control of a partial flow dilution system, a fast system response is required. The transformation time for the system shall be determined by the procedure described in Appendix 2, Section 1.11.1.

If the combined transformation time of the exhaust flow measurement (see previous Section) and the partial flow system is less than 0,3 s, online control may be used. If the transformation time exceeds 0,3 s, look ahead control based on a pre-recorded test run must be used. In this case, the rise time shall be ≤ 1 s and the delay time of the combination ≤ 10 s.

The total system response shall be designed as to ensure a representative sample of the particulates, G_{SE}, proportional to the exhaust mass flow. To determine the proportionality, a regression analysis of G_{SE} versus G_{EXHW} shall be conducted on a minimum 5 Hz data acquisition rate, and the following criteria shall be met:

- The correlation coefficient r^2 of the linear regression between G_{SE} and G_{EXHW} shall be not less than 0,95.
- The standard error of estimate of G_{SE} on G_{EXHW} shall not exceed 5 % of G_{SE} maximum.
- G_{SE} intercept of the regression line shall not exceed ± 2 % of G_{SE} maximum.

Optionally, a pre-test may be run, and the exhaust mass flow signal of the pre-test be used for controlling the sample flow into the particulate system ("look-ahead control"). Such a procedure is required if the transformation time of the particulate system, $t_{50,\mathrm{P}}$ or/and the transformation time of the exhaust mass flow signal, $t_{50,\mathrm{F}}$ are > 0,3 s. A correct control of the partial dilution system is obtained, if the time trace of $G_{EXHW,\mathrm{pre}}$ of the pre-test, which controls G_{SE}, is shifted by a "look-ahead" time of $t_{50,\mathrm{P}} + t_{50,\mathrm{F}}$.

For establishing the correlation between G_{SE} and G_{EXHW} the data taken during the actual test shall be used, with G_{EXHW} time aligned by $\mathrm{t}_{50,\mathrm{F}}$ relative to G_{SE} (no contribution from $t_{50,\mathrm{P}}$ to the time alignment). That is, the time shift between G_{EXHW} and G_{SE} is the difference in their transformation times that were determined in Appendix 2, Section 2.6.

For partial flow dilution systems, the accuracy of the sample flow G_{SE} is of special concern, if not measured directly, but determined by differential flow measurement:

$G_{SE} = G_{TOTW} - G_{DILW}$

In this case an accuracy of ± 2 % for G_{TOTW} and G_{DILW} is not sufficient to guarantee acceptable accuracies of $G_{SE.}$ If the gas flow is determined by differential flow measurement, the maximum error of the difference shall be such that the accuracy of G_{SE} is within ± 5 % when the dilution ratio is less than 15. It can be calculated by taking root-mean-square of the errors of each instrument.

Acceptable accuracies of G_{SE} can be obtained by either of the following methods:

a) The absolute accuracies of G_{TOTW} and G_{DILW} are ± 0,2 % which guarantees an accuracy of G_{SE} of ≤ 5 % at a dilution ratio of 15. However, greater errors will occur at higher dilution ratios.

b) Calibration of G_{DILW} relative to G_{TOTW} is carried out such that the same accuracies for G_{SE} as in a) are obtained. For the details of such a calibration see clause Appendix 2, Section 2.6.

c) The accuracy of G_{SE} is determined indirectly from the accuracy of the dilution ratio as determined by a tracer gas, e.g. CO_2. Again, accuracies equivalent to method a) for G_{SE} are required.

d) The absolute accuracy of G_{TOTW} and G_{DILW} is within ± 2 % of full scale, the maximum error of the difference between G_{TOTW} and G_{DILW} is within 0.2 %, and the linearity error is within ± 0.2 % of the highest G_{TOTW} observed during the test.

2.4.1. Particulate Sampling Filters

2.4.1.1. Filter specification

Fluorocarbon coated glass fibre filters or fluorocarbon based membrane filters are required for certification tests. For special applications different filter materials may be used. All filter types shall have a 0,3 µm DOP (di-octylphthalate) collection efficiency of at least 99% at a gas face velocity between 35 and 100 cm/s. When performing correlation tests between laboratories or between a manufacturer and an approval authority, filters of identical quality must be used.

2.4.1.2. Filter size

Particulate filters must have a minimum diameter of 47 mm (37 mm stain diameter). Larger diameter filters are acceptable (point 2.4.1.5.).

2.4.1.3. Primary and back-up filters

The diluted exhaust shall be sampled by a pair of filters placed in series (one primary and one back-up filter) during the test sequence. The back-up filter shall be located no more than 100 mm downstream of, and shall not be in contact with, the primary filter. The filters may be weighed separately or as a pair with the filters placed stain side to stain side.

2.4.1.4. Filter face velocity

A gas face velocity through the filter of 35 to 100 cm/s shall be achieved. The pressure drop increase between the beginning and the end of the test shall be no more than 25 kPa.

2.4.1.5. Filter loading

The recommended minimum filter loadings for the most common filter sizes are shown in the following table. For larger filter sizes, the minimum filter loading shall be 0,065 mg/1000 mm² filter area.

Filter Diameter (mm)	Recommended stain diameter (mm)	Recommended minimum loading (mg)
47	37	0,11
70	60	0,25
90	80	0,41
110	100	0,62

2.4.2. Weighing Chamber and Analytical Balance Specifications

2.4.2.1. Weighing chamber conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within 295 K (22 °C) ± 3 K during all filter conditioning and weighing. The humidity shall be maintained to a dewpoint of 282,5 (9,5 °C) ± 3 K and a relative humidity of 45 ± 8 %.

2.4.2.2. Reference filter weighing

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilisation. Disturbances to weighing room specifications as outlined in point 2.4.2.1. will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room should meet the required specifications prior to personnel entrance into the weighing room. At least two unused reference filters or reference filter pairs shall be weighed within four hours of, but preferably at the same time as the sample filter (pair) weighing. They shall be the same size and material as the sample filters.

If the average weight of the reference filters (reference filter pairs) changes between sample filter weighing by more than 10µg, then all sample filters shall be discarded and the emissions test repeated.

If the weighing room stability criteria outlined in point 2.4.2.1 are not met, but the reference filter (pair) weighing meet the above criteria, the engine manufacturer has the option of accepting the sample filter weights or voiding the tests, fixing the weighing room control system and re-running the test.

2.4.2.3. Analytical balance

The analytical balance used to determine the weights of all filters shall have a precision (standard deviation) of 2 µg and a resolution of 1 µg (1 digit = 1 µg) specified by the balance manufacturer.

2.4.2.4. Elimination of static electricity effects

To eliminate the effects of static electricity, the filters shall be neutralized prior to weighing, for example, by a Polonium neutralizer or a device having similar effect.

2.4.3. Additional Specifications for Particulate Measurement

All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, must be designed to minimize deposition or alteration of the particulates. All parts must be made of electrically conductive materials that do not react with exhaust gas components, and must be electrically grounded to prevent electrostatic effects.

(f) Appendix 2 to Annex III is amended as follows:

- A new title is inserted as follows:

APPENDIX 2

CALIBRATION PROCEDURE (NRSC, NRTC[1])

- Paragraph 1.2.2 is amended as follows:

After the current text the following is inserted “This accuracy implies that primary gases used for blending shall be known to have an accuracy of at least ± 1 %, traceable to national or international gas standards. The verification shall be performed at between 15 and 50 % of full scale for each calibration incorporating a blending device. An additional verification may be performed using another calibration gas, if the first verification has failed.

Optionally, the blending device may be checked with an instrument which by nature is linear, e.g. using NO gas with a CLD. The span value of the instrument shall be adjusted with the

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[1] The calibration procedure is common for both NRSC and NRTC tests, with the exception of the requirements specified in Paragraphs 1.11 and 2.6.

span gas directly connected to the instrument. The blending device shall be checked at the used settings and the nominal value shall be compared to the measured concentration of the instrument. This difference shall in each point be within ± 1% of the nominal value.

Other methods may be used based on good engineering practice and with the prior agreement of the parties involved.

NOTE: A precision gas divider of accuracy is within ± 1 %, is recommended for establishing the accurate analyzer calibration curve. The gas divider shall be calibrated by the instrument manufacturer."

- in paragraph 1.5.5.1, first sentence, the word five is changed to six and in the third indent the figure 1% is changed to 0,3%
- in paragraph 1.5.5.2, last indent, the figure 1% is changed to 0,3%
- the text under paragraph 1.8.3 is replaced by the following:

The oxygen interference check shall be determined when introducing an analyser into service and after major service intervals.

A range shall be chosen where the oxygen interference check gases will fall within the upper 50 %. The test shall be conducted with the oven temperature set as required.

1.8.3.1. Oxygen interference gases

Oxygen interference check gases shall contain propane with 350 ppmC ÷ 75 ppmC hydrocarbon. The concentration value shall be determined to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. Nitrogen shall be the predominant diluent with the balance oxygen. Blends required for Diesel engine testing are:

O_2 concentration	**Balance**
21 (20 to 22)	Nitrogen
10 (9 to 11	Nitrogen
5 (4 to 6)	Nitrogen

1.8.3.2. Procedure

a. The analyzer shall be zeroed.

b. The analyzer shall be spanned with the 21 % oxygen blend.

c. The zero response shall be rechecked. If it has changed more than 0,5 % of full scale clauses (a) and (b) of this section shall be repeated.

d. The 5 % and 10 % oxygen interference check gases shall be introduced.

e. The zero response shall be rechecked. If it has changed more than ± 1 % of full scale, the test shall be repeated.

f. The oxygen interference (%O_2I) shall be calculated for each mixture in step d) as follows:

$$O_2 I = \frac{(B - C)}{B} \cdot 100$$

A = hydrocarbon concentration (ppmC) of the span gas used in b) of this subclause

B = hydrocarbon concentration (ppmC) of the oxygen interference check gases used in d) of this subclause

C = analyzer response

$$(ppmC) = \frac{A}{D}$$

D = percent of full scale analyzer response due to A

g. The % of oxygen interference (%O2I) shall be less than ± 3,0 % for all required oxygen interference check gases prior to testing.

h. If the oxygen interference is greater than ± 3,0 %, the air flow above and below the manufacturer's specifications shall be incrementally adjusted, repeating clause 1.8.1 for each flow.

i. If the oxygen interference is greater than ± 3,0 % after adjusting the air flow, the fuel flow and thereafter the sample flow shall be varied, repeating clause 1.8.1 for each new setting.

j. If the oxygen interference is still greater than ± 3,0 %, the analyzer, FID fuel, or burner air shall be repaired or replaced prior to testing. This clause shall then be repeated with the repaired or replaced equipment or gases.

- Current paragraph 1.9.2.2 is changed as follows:

(i) Sentence 5 in the first indent is replaced by the following:

The water temperature shall be determined and recorded as F.

(ii) The third indent is replaced by the following:

and recorded as De. For diesel exhaust, the maximum exhaust water vapour concentration (in %) expected during testing shall be estimated, under the assumption of a fuel atom H/C ratio of 1,8 to 1, from the maximum CO_2 concentration in the exhaust gas or from the undiluted CO_2 span gas concentration (A, as measured in section 1.9.2.1) as follows:

- a new paragraph 1.11. is inserted as follows:

1.11. Additional calibration requirements for raw exhaust measurements over NRTC test

1.11.1. Response time check of the analytical system

The system settings for the response time evaluation shall be exactly the same as during measurement of the test run (i.e. pressure, flow rates, filter settings on the analyzers and all other response time influences). The response time determination shall be done with gas switching directly at the inlet of the sample probe. The gas switching shall be done in less than 0.1 second. The gases used for the test shall cause a concentration change of at least 60% FS.

The concentration trace of each single gas component shall be recorded. The response time is defined as the difference in time between the gas switching and the appropriate change of the recorded concentration. The system response time (t_{90}) consists of the delay time to the measuring detector and the rise time of the detector. The delay time is defined as the time from the change (t_0) until the response is 10% of the final reading (t_{10}). The rise time is defined as the time between 10% and 90% response of the final reading ($t_{90} – t_{10}$).

For time alignment of the analyzer and exhaust flow signals in the case of raw measurement, the transformation time is defined as the time from the change (t_0) until the response is 50% of the final reading (t_{50}).

The system response time shall be ≤ 10 seconds with a rise time ≤ 2,5 seconds for all limited components (CO, NOx, HC) and all ranges used.

1.11.2. Calibration of tracer gas analyzer for exhaust flow measurement

The analyzer for measurement of the tracer gas concentration, if used, shall be calibrated using the standard gas.

The calibration curve shall be established by at least 10 calibration points (excluding zero) spaced so that a half of the calibration points are placed between 4% to 20% of analyzer's full scale and the rest are in between 20% to 100% of the full scale. The calibration curve is calculated by the method of least squares.

The calibration curve shall not differ by more than ± 1% of the full scale from the nominal value of each calibration point, in the range from 20% to 100% of the full scale. It shall also not differ by more than ± 2% from the nominal value in the range from 4% to 20% of the full scale.

The analyzer shall be set at zero and spanned prior to the test run using a zero gas and a span gas whose nominal value is more than 80% of the analyzer full scale.

- the text under paragraph 2.2 is replaced by the following:

The calibration of gas flow-meters or flow measurement instrumentation shall be traceable to national and/or international standards.

The maximum error of the measured value shall be within ± 2 % of reading.

For partial flow dilution systems, the accuracy of the sample flow G_{SE} is of special concern, if not measured directly, but determined by differential flow measurement:

$G_{SE} = G_{TOTW} - G_{DILW}$

In this case an accuracy of ± 2 % for G_{TOTW} and G_{DILW} is not sufficient to guarantee acceptable accuracies of $G_{SE.}$ If the gas flow is determined by differential flow measurement, the maximum error of the difference shall be such that the accuracy of G_{SE} is within ± 5 % when the dilution ratio is less than 15. It can be calculated by taking root-mean-square of the errors of each instrument.

- a new section 2.6 is inserted as follows:

2.6. Additional calibration requirements for partial flow dilution systems

2.6.1. Periodical calibration

If the sample gas flow is determined by differential flow measurement the flow meter or the flow measurement instrumentation shall be calibrated by one of the following procedures, such that the probe flow G_{SE} into the tunnel fulfils the accuracy requirements of Appendix I section 2.4:

The flow meter for G_{DILW} is connected in series to the flow meter for G_{TOTW}, the difference between the two flow meters is calibrated for at least 5 set points with flow values equally spaced between the lowest G_{DILW} value used during the test and the value of G_{TOTW} used during the test The dilution tunnel may be bypassed.

A calibrated mass flow device is connected in series to the flowmeter for G_{TOTW} and the accuracy is checked for the value used for the test. Then the calibrated mass flow device is connected in series to the flow meter for G_{DILW}, and the accuracy is checked for at least 5 settings corresponding to the dilution ratio between 3 and 50, relative to G_{TOTW} used during the test.

The transfer tube TT is disconnected from the exhaust, and a calibrated flow measuring device with a suitable range to measure G_{SE} is connected to the transfer tube. Then G_{TOTW} is set to the value used during the test, and G_{DILW} is sequentially set to at least 5 values corresponding to dilution ratios q between 3 and 50. Alternatively, a special calibration flow path, may be provided, in which the tunnel is bypassed, but the total and dilution air flow through the corresponding meters as in the actual test.

A tracer gas, is fed into the transfer tube TT. This tracer gas may be a component of the exhaust gas, like CO_2 or NOx. After dilution in the tunnel the tracer gas component is measured. This shall be carried out for 5 dilution ratios between 3 and 50. The accuracy of the sample flow is determined from the dilution ration *q*:

$G_{SE} = G_{TOTW} / q$

The accuracies of the gas analyzers shall be taken into account to guarantee the accuracy of G_{SE}

2.6.2. Carbon flow check

A carbon flow check using actual exhaust is strongly recommended for detecting measurement and control problems and verifying the proper operation of the partial flow dilution system. The carbon flow check should be run at least each time a new engine is installed, or something significant is changed in the test cell configuration.

The engine shall be operated at peak torque load and speed or any other steady-state mode that produces 5% or more of CO_2. The partial flow sampling system shall be operated with a dilution factor of about 15 to 1.

2.6.3. Pre-test check

A pre-test check shall be performed within 2 hours before the test run in the following way:

The accuracy of the flow meters shall be checked by the same method as used for calibration for at least two points, including flow values of G_{DILW} that correspond to dilution ratios between 5 and 15 for the G_{TOTW} value used during the test.

If it can be demonstrated by records of the calibration procedure described above that the flow meter calibration is stable over a longer period of time, the pre-test check may be omitted.

2.6.4. Determination of the transformation time

The system settings for the transformation time evaluation shall be exactly the same as during measrement of the test run. The transformation time shall be determined by the following method:

An independent reference flowmeter with a measurement range appropriate for the probe flow shall be put in series with and closely coupled to the probe. This flowmeter shall have a transformation time of less than 100 ms for the flow step size used in the response time measurement, with flow restriction sufficiently low not to affect the dynamic performance of the partial flow dilution system, and consistent with good engineering practice.

A step change shall be introduced to the exhaust flow (or air flow if exhaust flow is calculated) input of the partial flow dilution system, from a low flow to at least 90% of full scale. The trigger for the step change should be the same one as that used to start the look-ahead control in actual testing. The exhaust flow step stimulus and the flowmeter response shall be recorded at a sample rate of at least 10 Hz.

From this data, the transformation time shall be determined for the partial flow dilution system, which is the time from the initiation of the step stimulus to the 50% point of the flowmeter response. In a similar manner, the transformation times of the G_{SE} signal of the partial flow dilution system and of the G_{EXHW} signal of the exhaust flow meter shall be determined. These signals are used in the regression checks performed after each test (see Appendix I section 2.4).

The calculation shall be repeated for at least 5 rise and fall stimuli, and the results shall be averaged. The internal transformation time (<100 ms) of the reference flowmeter shall be subtracted from this value. This is the “look-ahead” value of the partial flow dilution system, which shall be applied in accordance with Appendix I section 2.4.

- a new section 3 is inserted as follows:

3. CALIBRATION OF THE CVS SYSTEM

3.1. General

The CVS system shall be calibrated by using an accurate flowmeter and means to change operating conditions.

The flow through the system shall be measured at different flow operating settings, and the control parameters of the system shall be measured and related to the flow.

Various type of flowmeters may be used, e.g. calibrated venturi, calibrated laminar flowmeter, calibrated turbinemeter.

3.2. Calibration of the Positive Displacement Pump (PD)

All the parameters related to the pump shall be simultaneously measured along with the parameters related to a calibration venturi which is connected in series with the pump. The calculated flow rate (in m^3/min at pump inlet, absolute pressure and temperature) shall be plotted against a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function shall be determined. If a CVS has a multiple speed drive, the calibration shall be performed for each range used.

Temperature stability shall be maintained during calibration.

Leaks in all the connections and ducting between the calibration venturi and the CVS pump shall be maintained lower than 0.3% of the lowest flow point (highest restriction and lowest PD speed point).

3.2.1. Data Analysis

The air flowrate (Q_s) at each restriction setting (minimum 6 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The air flow rate shall then be converted to pump flow (V_0) in m^3/rev at absolute pump inlet temperature and pressure as follows:

$$V_0 = \frac{Q_s}{n} * \frac{T}{273} * \frac{101.3}{p_A}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at pump inlet, K

p_A = absolute pressure at pump inlet (p_B- p_1), kPa

n = pump speed, rev/s

To account for the interaction of pressure variations at the pump and the pump slip rate, the correlation function (X_0) between pump speed, pressure differential from pump inlet to pump outlet and absolute pump outlet pressure shall be calculated as follows:

$$X_0 = \frac{1}{n} * \sqrt{\frac{\Delta p_p}{p_A}}$$

where,

Δp_p = pressure differential from pump inlet to pump outlet, kPa

p_A = absolute outlet pressure at pump outlet, kPa

A linear least-square fit shall be performed to generate the calibration equation as follows:

$$V_0 = D_0 - m * (X_0)$$

D_0 and m are the intercept and slope constants, respectively, describing the regression lines.

For a CVS system with multiple speeds, the calibration curves generated for the different pump flow ranges shall be approximately parallel, and the intercept values (D_0) shall increase as the pump flow range decreases.

The values calculated by the equation shall be within ± 0,5 % of the measured value of V_0. Values of m will vary from one pump to another. Particulate influx over time will cause the pump slip to decrease, as reflected by lower values for m. Therefore, calibration shall be performed at pump start-up, after major maintenance, and if the total system verification (section 3.5) indicates a change in the slip rate.

3.3. Calibration of the Critical Flow Venturi (CFI)

Calibration of the CFI is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature, as shown below

$$Q_s = \frac{K_v * p_A}{\sqrt{T}}$$

where,

K_v = calibration coefficient

p_A = absolute pressure at venturi inlet, kPa

T = temperature at venturi inlet, K

3.3.1. *Data Analysis*

The air flow rate (Q_s) at each restriction setting (minimum 8 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The calibration coefficient shall be calculated from the calibration data for each setting as follows:

$$K_v = \frac{Q_S * \sqrt{T}}{p_A}$$

where,

Q_s = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at the venturi inlet, K

p_A = absolute pressure at venturi inlet, kPa

To determine the range of critical flow, K_v shall be plotted as a function of venturi inlet pressure. For critical (choked) flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases, which indicates that the CFI is operated outside the permissible range.

For a minimum of eight points in the region of critical flow, the average K_V and the standard deviation shall be calculated. The standard deviation shall not exceed ± 0,3 % of the average K_V

3.4. Calibration of the Subsonic Venturi (SST)

Calibration of the SST is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, pressure drop between the SST inlet and throat, as shown below:

$$Q_{SSV} = A_0 d^2 C_d P_A \sqrt{\left[\frac{1}{T}\left(r^{1.4286} - r^{1.7143}\right)\left(\frac{1}{1-\beta^4 r^{1.4286}}\right)\right]}$$

where,

A_0 = collection of constants and units conversions

= 0,006111 in SI units of $\left(\frac{m^3}{\min}\right)\left(\frac{K^{\frac{1}{2}}}{kPa}\right)\left(\frac{1}{mm^2}\right)$

d = diameter of the SST throat, m

C_d = discharge coefficient of the SST

P_A = absolute pressure at venturi inlet, kPa

T = temperature at the venturi inlet, K

r = ratio of the SST throat to inlet absolute, static pressure = $1-\frac{\Delta P}{P_A}$

ß = ratio of the SST throat diameter, d, to the inlet pipe inner diameter = $\frac{d}{D}$

3.4.1. Data Analysis

The air flow rate (Q_{SSV}) at each flow setting (minimum 16 settings) shall be calculated in standard m^3/min from the flowmeter data using the manufacturer's prescribed method. The discharge coefficient shall be calculated from the calibration data for each setting as follows:

$$C_d = \frac{Q_{SSV}}{A_0 d^2 P_A \sqrt{\left[\frac{1}{T}\left(r^{1.4286} - r^{1.7143}\right)\left(\frac{1}{1-\beta^4 r^{1.4286}}\right)\right]}}$$

where,

Q_{SSV} = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

T = temperature at the venturi inlet, K

d = diameter of the SST throat, m

r = ratio of the SSV throat to inlet absolute, static pressure = $1-\frac{\Delta P}{P_A}$

ß = ratio of the SSV throat diameter, d, to the inlet pipe inner diameter = $\frac{d}{D}$

To determine the range of subsonic flow, C_d shall be plotted as a function of Reynolds number, at the SSV throat. The Re at the SSV throat is calculated with the following formula:

$$\text{Re} = A_1 \frac{Q_{SSV}}{d\mu}$$

where,

A_1 = a collection of constants and units conversions

$$= 25{,}55152 \left(\frac{1}{m^3}\right)\left(\frac{\min}{s}\right)\left(\frac{mm}{m}\right)$$

Q_{SSV} = air flow rate at standard conditions (101,3 kPa, 273 K), m^3/s

d = diameter of the SSV throat, m

μ = absolute or dynamic viscosity of the gas, calculated with the following formula:

$$\mu = \frac{bT^{3/2}}{S+T} = \frac{bT^{1/2}}{1+\frac{S}{T}} \quad \text{kg/m-s}$$

where:

b = empirical constant =. $1{,}458 \cdot 10^{6} \frac{kg}{msK^{\frac{1}{2}}}$

S = empirical constant = $110{,}4\,K$

Because Q_{SSV} is an input to the Re formula, the calculations must be started with an initial guess for Q_{SSV} or C_d of the calibration venturi, and repeated until Q_{SSV} converges. The convergence method must be accurate to 0.1% or better.

For a minimum of sixteen points in the subsonic flow region, the calculated values of C_d from the resulting calibration curve fit equation must be within ± 0.5% of the measured C_d for each calibration point.

3.5. Total System Verification

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analysed, and the mass calculated according to Annex III, Appendix 3, section 2.4.1 except in the case of propane where a factor of 0,000472 is used in place of 0,000479 for HC. Either of the following two techniques shall be used.

3.5.1. Metering with a Critical Flow Orifice

A known quantity of pure gas (propane) shall be fed into the CVS system through a calibrated critical orifice. If the inlet pressure is high enough, the flow rate, which is adjusted by means of the critical flow orifice, is independent of the orifice outlet pressure (critical flow). The CVS system shall be operated as in a normal exhaust emission test for about 5 to 10 minutes. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within ± 3% of the known mass of the gas injected.

3.5.2. Metering by Means of a Gravimetric Technique

The weight of a small cylinder filled with propane shall be determined with a precision of ± 0,01 g. For about 5 to 10 minutes, the CVS system shall be operated as in a normal exhaust emission test, while carbon monoxide or propane is injected into the system. The quantity of pure gas discharged shall be determined by means of differential weighing. A gas sample shall be analysed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within ± 3% of the known mass of the gas injected.

(g) Appendix 3 is amended as follows:

- The following title is inserted “DATA EVALUATION AND CALCULATIONS”
- the title of section 1 shall read “DATA EVALUATION AND CALCULATIONS – NRSC TEST
- in paragraph 1.2, first sentence, the words “or volumes ($V_{SAM,I}$)” are deleted and in the last indent the words “or volume (V_{DIL})” and the words “or M_d./V_{dil}” are deleted
- in paragraph 1.3.1, first indent the words “V_{EXHW} or V_{EXHD}0 are deleted and in the second indent the word $V_{TOTW)}$ are deleted
- paragraphs 1.3.2 -1.4.6 are replaced by the following:

1.3.2. Dry/wet correction

When applying G_{EXHW} the measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis:

conc (wet) = k_w × conc (dry)

For the raw exhaust gas:

$$K_{W,r,1} = \left(\frac{1}{1 + 1{,}88 \times 0{,}005 \times \left(\%CO[dry] + \%CO_2\,[dry]\right) + K_{w2}} \right)$$

For the diluted gas:

$$K_{W,e,1} = \left(1 - \frac{1{,}88 \times CO_2\,\%(wet)}{200} \right) - K_{W1}$$

or:

$$K_{W,e,1} = \left(\frac{1 - K_{W1}}{1 + \dfrac{1{,}88 \times CO_2\,\%(dry)}{200}} \right)$$

For the dilution air:

$$k_{W,d} = 1 - k_{W1}$$

$$k_{W1} = \frac{1{,}608 \times \left[H_d \times \left(1 - 1/DF\right) + H_a \times \left(1/DF\right)\right]}{1000 + 1{,}608 \times \left[H_d \times \left(1 - 1/DF\right) + H_a \times \left(1/DF\right)\right]}$$

$$H_d = \frac{6{,}22 \times R_d \times p_d}{p_B - p_d \times R_d \times 10^{-2}}$$

For the intake air (if different from the dilution air):

$$k_{W,a} = 1 - k_{W2}$$

$$k_{W2} = \frac{1{,}608 \times H_a}{1000 + (1{,}608 \times H_a)}$$

$$H_a = \frac{6{,}22 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

where:

H_a: absolute humidity of the intake air, g water per kg dry air

H_d: absolute humidity of the dilution air, g water per kg dry air

R_d: relative humidity of the dilution air, %

R_a: relative humidity of the intake air, %

p_d: saturation vapour pressure of the dilution air, kPa

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa.

Note: H_a and H_d may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

1.3.3. Humidity correction for NOx

As the NOx emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air temperature and humidity by the factors K_H given in the following formula:

$$k_H = \frac{1}{1 - 0{,}0182 \times (H_a - 10{,}71) + 0{,}0045 \times (T_a - 298)}$$

where:

T_a: temperatures of the air in K

H_a: humidity of the intake air, g water per kg dry air:

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air, %

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa.

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

1.3.4. Calculation of emission mass flow rates

The emission mass flow rates for each mode shall be calculated as follows:

(a) For the raw exhaust gas[1]*:*

$$Gas_{mass} = u \times conc \times G_{EXHW}$$

(b) For the dilute exhaust gas[1]*:*

$$Gas_{mass} = u \times conc_c \times G_{TOTW}$$

where:

$conc_c$ is the background corrected concentration

$$conc_c = conc - conc_d \times (1 - (1/DF))$$
$$DF = 13{,}4/(conc_{CO_2} + (conc_{CO} + conc_{HC}) \times 10^{-4})$$

or:

$$DF = 13{,}4/conc_{CO2}$$

The coefficients u - wet shall be used according to the following Table 4:

Table 4. Values of the coefficients u - wet for various exhaust components

Gas	u	conc
NO_x	0,001587	ppm
CO	0,000966	ppm
HC	0,000479	ppm
CO_2	15,19	percent

The density of HC is based upon an average carbon to hydrogen ratio of 1:1,85.

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[1] In the case of NO_x, the NO_x concentration ($NO_x conc$ or $NO_x conc_c$) has to be multiplied by K_{HNOx} (humidity correction factor for NO_x quoted in the previous section 1.3.3) as follows: K_{HNOx} x conc or K_{HNOx} x $conc_c$

1.3.5. Calculation of the specific emissions

The specific emission (g/kWh) shall be calculated for all individual components in the following way:

$$Individual\ gas = \frac{\sum_{i=1}^{n} Gas_{mass_i} \times WF_i}{\sum_{i=1}^{n} P_i \times WF_i}$$

where $P_i = P_{m,i} + P_{AE,i}$.

The weighting factors and the number of modes (n) used in the above calculation are according to Annex III, section 3.7.1.

1.4. Calculation of the particulate emission

The particulate emission shall be calculated in the following way:

1.4.1. Humidity correction factor for particulates

As the particulate emission of diesel engines depends on ambient air conditions, the particulate mass flow rate shall be corrected for ambient air humidity with the factor K_p given in the following formula:

$$K_P = 1/(1 + 0{,}0133 \times (H_a - 10{,}71))$$

H_a: humidity of the intake air, gram of water per kg dry air

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air,%

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae

1.4.2. Partial flow dilution system

The final reported test results of the particulate emission shall be derived through the following steps. Since various types of dilution rate control may be used, different calculation methods for equivalent diluted exhaust gas mass flow rate G_{EDF} apply. All calculations shall be based upon the average values of the individual modes (i) during the sampling period.

1.4.2.1. Isokinetic systems

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{G_{DILW,i} + (G_{EXHW,i} \times r)}{(G_{EXHW,i} \times r)}$$

where r corresponds to the ratio of the cross sectional areas of the isokinetic probe A_p and exhaust pipe A_T:

$$r = \frac{A_P}{A_T}$$

1.4.2.2. Systems with measurement of CO_2 or NO_x concentration

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{Conc_{E,i} - Conc_{A,i}}{Conc_{D,i} - Conc_{A,i}}$$

where:

$Conc_E$ = wet concentration of the tracer gas in raw exhaust

$Conc_D$ = wet concentration of the tracer gas in the diluted exhaust

$Conc_A$ = wet concentration of the tracer gas in the dilution air

Concentrations measured on a dry basis shall be converted to a wet basis according to section 1.3.2. of this Appendix.

1.4.2.3. Systems with CO2 measurement and carbon balance method

$$G_{EDFW,i} = \frac{206{,}6 \times G_{FUEL,i}}{CO_{2D,i} - CO_{2A,i}}$$

where:

CO_{2D} = CO_2 concentration of the diluted exhaust

CO_{2A} = CO_2 concentration of the dilution air

(concentrations in volume % on wet basis)

This equation is based upon the carbon balance assumption (carbon atoms supplied to the engine are emitted as CO_2) and derived through the following steps:

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

and:

$$q_i = \frac{206{,}6 \times G_{FUEL,i}}{G_{EXHW,i} \times \left(CO_{2D,i} - CO_{2A,i}\right)}$$

1.4.2.4. Systems with flow measurement

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{G_{TOTW,i}}{\left(G_{TOTW,i} - G_{DILW,i}\right)}$$

1.4.3. Full flow dilution system

The final reported test results of the particulate emission shall be derived through the following steps.

All calculations shall be based upon the average values of the individual modes (i) during the sampling period.

$$G_{EDFW,i} = G_{TOTW,i}$$

1.4.4. Calculation of the particulate mass flow rate

The particulate mass flow rate shall be calculated as follows:

For the single filter method:

$$PT_{mass} = \frac{M_f}{M_{SAM}} \times \frac{\left(G_{EDFW}\right)_{aver}}{1000}$$

where:

$(G_{EDFW})_{aver}$ over the test cycle shall be determined by summation of the average values of the individual modes during the sampling period:

$$\left(G_{EDFW}\right)_{aver} = \sum_{i=1}^{n} G_{EDFW,i} \times WF_i$$

$$M_{SAM} = \sum_{i=1}^{n} M_{SAM,i}$$

where i = 1, . . . n

For the multiple filter method:

$$PT_{mass} = \frac{M_{f,i}}{M_{SAM,i}} \times \frac{\left(G_{EDFW,i}\right)_{aver}}{1000}$$

where i = 1, . . . n

The particulate mass flow rate may be background corrected as follows:

For single filter method:

$$PT_{mass} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} \times \left(\sum_{i=1}^{i=n} \left(1 - \frac{1}{DF_i} \right) \times WF_i \right) \right) \right] \times \frac{(G_{EDFW})_{aver}}{1000}$$

If more than one measurement is made, (M_d/M_{DIL}) shall be replaced with $(M_d/M_{DIL})_{aver}$

$$DF = 13{,}4 / \left(concCO_2 + (concCO + concHC) \times 10^{-4} \right)$$

or:

$$DF=13{,}4/concCO_2$$

For multiple filter method:

$$PT_{mass,\, i} = \left[\frac{M_{f,\, i}}{M_{SAM,\, i}} - \left(\frac{M_d}{M_{DIL}} \times \left(1 - \frac{1}{DF_i} \right) \right) \right] \times \left[\frac{G_{EDFW,\, i}}{1000} \right]$$

If more than one measurement is made, (M_d/M_{DIL}) shall be replaced with $(M_d/M_{DIL})_{aver}$

$$DF = 13{,}4 / \left(concCO_2 + (concCO + concHC) \times 10^{-4} \right)$$

or:

$$DF=13{,}4/concCO_2$$

1.4.5. Calculation of the specific emissions

The specific emission of particulates PT (g/kWh) shall be calculated in the following way[1]:

For the single filter method:

$$PT = \frac{PT_{mass}}{\sum_{i=1}^{n} P_i \times WF_i}$$

For the multiple filter method:

$$PT = \frac{\sum_{i=1}^{n} PT_{mass,i} \times WF_i}{\sum_{i=1}^{n} P_i \times WF_i}$$

---

[1] The particulate mass flow rate PT_{mass} has to be multiplied by Kp (humidity correction factor for particulates quoted in section 1.4.1).

1.4.6. Effective weighting factor

For the single filter method, the effective weighting factor $WF_{E,i}$ for each mode shall be calculated in the following way:

$$WF_{E,i} = \frac{M_{SAM,i} \times (G_{EDFW})_{aver}}{M_{SAM} \times (G_{EDFW,i})}$$

where i = l, . . . n.

The value of the effective weighting factors shall be within ± 0,005 (absolute value) of the weighting factors listed in Annex III, section 3.7.1.

- A new section 2 is inserted as follows

2. DATA EVALUATION AND CALCULATIONS (NRTC TEST)

The two following measurement principles that can be used for the evaluation of pollutant emissions over the NRTC cycle are described in this section:

the gaseous components are measured in the raw exhaust gas on a real time basis, and the particulates are determined using a partial flow dilution system;

the gaseous components and the particulates are determined using a full flow dilution system (CVS system).

2.1. Calculation of gaseous emissions in the raw exhaust gas and of the particulate emissions with a partial flow dilution system

2.1.1. Introduction

The instantaneous concentration signals of the gaseous components are used for the calculation of the mass emissions by multiplication with the instantaneous exhaust mass flow rate. The exhaust mass flow rate may be measured directly, or calculated using the methods described in Annex III, Appendix 1, section 2.2.3 (intake air and fuel flow measurement, tracer method, intake air and air/fuel ratio measurement). Special attention shall be paid to the response times of the different instruments. These differences shall be accounted for by time aligning the signals.

For particulates, the exhaust mass flow rate signals are used for controlling the partial flow dilution system to take a sample proportional to the exhaust mass flow rate. The quality of proportionality is checked by applying a regression analysis between sample and exhaust flow as described in Annex III, Appendix 1, section 2.4.

2.1.2. Determination of the gaseous components

2.1.2.1. Calculation of mass emission

The mass of the pollutants M_{gas} (g/test) shall be determined by calculating the instantaneous mass emissions from the raw concentrations of the pollutants, the u values from Table 4 (see also previous paragraph 1.3.4.) and the exhaust mass flow, aligned for the transformation time and integrating the instantaneous values over the cycle. Preferably, the concentrations should be measured on a wet basis. If measured on a dry basis, the dry/wet correction as described here below shall be applied to the instantaneous concentration values before any further calculation is done.

Table 4. Values of the coefficients u – wet-for various exhaust components

Gas	u	conc
NO_x	0,001587	ppm
CO	0,000966	ppm
HC	0,000479	ppm
CO_2	15,19	percent

The density of HC is based upon an average carbon to hydrogen ratio of 1:1,85.

The following formula shall be applied:

$$M_{gas} = \sum_{i=1}^{i=n} u \times conc_{\mathrm{i}} \times G_{EXHW,i} \times \frac{1}{f} \quad \text{(in g/test)}$$

where

u = ratio between density of exhaust component and density of exhaust gas

conc$_i$ = *instantaneous concentration of the respective component in the raw exhaust gas, ppm*

$G_{EXHW,i}$= instantaneous exhaust mass flow, kg/s

f = data sampling rate, Hz

n = number of measurements

For the calculation of NO_x, the humidity correction factor k_H, as described here below, shall be used.

The instantaneously measured concentration shall be converted to a wet basis as described here below, if not already measured on a wet basis

2.1.2.2. Dry/wet correction

If the instantaneously measured concentration is measured on a dry basis, it shall be converted to a wet basis according to the following formulae.

$conc_{\mathrm{wet}} = k_{\mathrm{W}}$ x $conc_{\mathrm{dry}}$

where

$$K_{W,r,1} = \left(\frac{1}{1 + 1{,}88 \times 0{,}005 \times \left(conc_{CO} + conc_{CO_2} \right) + K_{W2}} \right)$$

with

$$k_{W2} = \frac{1{,}608 \times H_a}{1000 + \left(1{,}608 * H_a \right)}$$

where

$conc_{CO2}$ = dry CO_2 concentration, %

$conc_{CO}$ = dry CO concentration, %

H_a = intake air humidity, g water per kg dry air

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air,%

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.1.2.3. NOx correction for humidity and temperature

As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for humidity and ambient air temperature with the factors given in the following formula.

$$k_H = \frac{1}{1 - 0{,}0182 \times \left(H_a - 10{,}71 \right) + 0{,}0045 \times \left(T_a - 298 \right)}$$

with:

T_a = temperature of the intake air, K

H_a = humidity of the intake air,g water per kg dry air

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air,%

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.1.2.4. Calculation of the specific emissions

The specific emissions (g/kWh) shall be calculated for each individual component in the following way:

$$Individual\ gas = M_{gas}/W_{act}$$

Where

W_{act} = actual cycle work as determined in Annex III Section 4.6.2, kWh

2.1.3. Particulate determination

2.1.3.1. Calculation of mass emission

The mass of particulates M_{PT} (g/test) shall be calculated by either of the following methods.

a)

$$M_{PT} = \frac{M_f}{M_{SAM}} \times \frac{M_{EDFW}}{1000}$$

where

M_f = particulate mass sampled over the cycle, mg

M_{SAM} = mass of diluted exhaust gas passing the particulate collection filters, kg

M_{EDFW} = mass of equivalent diluted exhaust gas over the cycle, kg

The total mass of equivalent diluted exhaust gas mass over the cycle shall be determined as follows:

$$M_{EDFW} = \sum_{i=1}^{i=n} G_{EDFW,\mathrm{i}} \times \frac{1}{f}$$

$$G_{EDFW,i} = G_{EXHW,i} \times q_i$$

$$q_i = \frac{G_{TOTW,i}}{\left(G_{TOTW,i} - G_{DILW,i}\right)}$$

where

$G_{EDFW,\mathrm{i}}$= instantaneous equivalent diluted exhaust mass flow rate, kg/s

$G_{EXHW,\mathrm{i}}$= instantaneous exhaust mass flow rate, kg/s

q_i = instantaneous dilution ratio

$G_{TOTW,\mathrm{I}}$= instantaneous diluted exhaust mass flow rate through dilution tunnel, kg/s

$G_{DILW,\mathrm{i}}$ = instantaneous dilution air mass flow rate, kg/s

f = data sampling rate, Hz

n = number of measurements

b)

$$M_{PT} = \frac{M_f}{r_s * 1000}$$

where

M_f = particulate mass sampled over the cycle, mg

r_s = average sample ratio over the test cycle

with

where

$$r_s = \frac{M_{SE}}{M_{EXHW}} \times \frac{M_{SAM}}{M_{TOTW}}$$

M_{SE} = sampled exhaust mass over the cycle, kg

M_{EXHW} = total exhaust mass flow over the cycle, kg

M_{SAM} = mass of diluted exhaust gas passing the particulate collection filters, kg

M_{TOTW} = mass of diluted exhaust gas passing the dilution tunnel, kg

NOTE: In case of the total sampling type system, M_{SAM} and M_{TOTW} are identical.

2.1.3.2. Particulate correction factor for humidity

As the particulate emission of diesel engines depends on ambient air conditions, the particulate concentration shall be corrected for ambient air humidity with the factor Kp given in the following formula.

$$k_p = \frac{1}{\left[1 + 0{,}0133 \times \left(H_a - 10{,}71\right)\right]}$$

where

H_a = humidity of the intake air in g water per kg dry air

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air, %

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.1.3.3. Calculation of the specific emissions

The particulate emission (g/kWh) shall be calculated in the following way:

$$PT = M_{PT} \times K_p / W_{act}$$

Where

W_{act} = actual cycle work as determined in Annex III Section 4.6.2, kWh

2.2. Determination of gaseous and particulate components with a full flow dilution system

For calculation of the emissions in the diluted exhaust gas, it is necessary to know the diluted exhaust gas mass flow rate. The total diluted exhaust gas flow over the cycle M_{TOTW} (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device (V_0 for PD, K_V for CFI, C_d for SST) by either of the methods described in the following section 2.2.1 may be used. If the total sample mass of particulates (M_{SAM}) and gaseous pollutants exceeds 0,5 % of the total CVS flow (M_{TOTW}), the CVS flow shall be corrected for M_{SAM} or the particulate sample flow shall be returned to the CVS prior to the flow measuring device.

2.2.1. Determination of the Diluted Exhaust Gas Flow

PD-CVS system

The calculation of the mass flow over the cycle is as follows, if the temperature of the diluted exhaust is kept within ± 6 K over the cycle by using a heat exchanger

M_{TOTW} = $1{,}293 * V_0 * N_P * (p_B - p_1) * 273 / (101{,}3 * T)$

where

M_{TOTW} = mass of the diluted gas on wet basis over the cycle

V_0 = volume of gas pumped per revolution under test conditions, m^3/rev

N_P = total revolutions of pump per test

p_B = atmospheric pressure in the test cell, kPa

p_1 = pressure depression below atmospheric at pump inlet, kPa

T = *average temperature of the diluted exhaust gas at pump inlet over thecycle, K*

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$M_{TOTW,i}$= $1{,}293 * V_0 * N_{P,i} * (p_B - p_1) * 273 / (101{,}3 \cdot T)$

where

$N_{P,i}$ = total revolutions of pump per time interval

CFI-CVS system

The calculation of the mass flow over the cycle is as follows, if the temperature of the diluted exhaust is kept within ± 11K over the cycle by using a heat exchanger:

M_{TOTW} = $1{,}293 * t * K_v * p_A / T^{0{,}5}$

where

M_{TOTW} = mass of the diluted gas on wet basis over the cycle

t = cycle time, s

K_V = *calibration coefficient of the critical flow venturi for standard conditions,*

p_A = absolute pressure at venturi inlet, kPa

T = absolute temperature at venturi inlet, K

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$M_{TOTW,i} = 1{,}293 * \Delta t_i * K_V * p_A / T^{0,5}$

where

Δt_i = time interval, s

SST-CVS system

The calculation of the mass flow over the cycle is as follows if the temperature of the diluted exhaust is kept within ± 11 K over the cycle by using a heat exchanger:

$M_{TOTW} = 1{,}293 * Q_{SSV}$

where,

$$Q_{SSV} = A_0 d^2 C_d P_A \sqrt{\left[\frac{1}{T}\left(r^{1.4286} - r^{1.7143}\right) \cdot \left(\frac{1}{1-\beta^4 r^{1.4286}}\right)\right]}$$

A_0 = collection of constants and units conversions

= 0,006111 in SI units of $\left(\frac{m^3}{\min}\right)\left(\frac{K^{\frac{1}{2}}}{kPa}\right)\left(\frac{1}{mm^2}\right)$

d = diameter of the SST throat, m

C_d = discharge coefficient of the SSV

P_A = absolute pressure at venturi inlet, kPa

T = temperature at the venturi inlet, K

r = ratio of the SST throat to inlet absolute, static pressure = $1 - \frac{\Delta P}{P_A}$

ß = ratio of the SST throat diameter, d, to the inlet pipe inner diameter = $\frac{d}{D}$

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$M_{TOTW} = 1{,}293 * Q_{SSV} * \Delta t_i$

where

$$Q_{SSV} = A_0 d^2 C_d P_A * \sqrt{\left[\frac{1}{T}\left(r^{1.4286} - r^{1.7143}\right)\left(\frac{1}{1-\beta^4 r^{1.4286}}\right)\right]}$$

Δt_i = time interval, s

The real time calculation shall be initialized with either a reasonable value for C_d, such as 0.98, or a reasonable value of Q_{ssv}. If the calculation is initialized with Q_{ssv}, the initial value of Q_{ssv} shall be used to evaluate Re.

During all emissions tests, the Reynolds number at the SST throat must be in the range of Reynolds numbers used to derive the calibration curve developed in Appendix 2 section 3.2.

2.2.2. NOx Correction for Humidity

As the NOx emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air humidity with the factors given in the following formulae.

$$k_H = \frac{1}{1 - 0{,}0182 \times (H_a - 10{,}71) + 0{,}0045 \times (T_a - 298)}$$

where,

T_a = temperature of the air in K

Ha = humidity of the intake air water per kg dry air

in which,

$$H_a = \frac{6{,}220 * R_a * p_a}{p_B - p_a * R_a * 10^{-2}}$$

R_a = relative humidity of the intake air, %

p_a = saturation vapour pressure of the intake air, kPa

p_B = total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.2.3. Calculation of the Emission Mass Flow

2.2.3.1. Systems with Constant Mass Flow

For systems with heat exchanger, the mass of the pollutants M_{GAS} (g/test) shall be determined from the following equation:

M_{GAS} = u x conc x M_{TOTW}

where

u = ratio between density of the exhaust component and density of diluted exhaust gas, as reported in Table 4, point 2.1.2.1

$conc$ = average background corrected concentrations over the cycle from integration (mandatory for NO_x and HC) or bag measurement, ppm

M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in section 2.2.1, kg

As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air humidity with the factor k_H, as described in section 2.2.2.

Concentrations measured on a dry basis shall be converted to a wet basis in accordance with section 1.3.2 of this Appendix.

2.2.3.1.1. Determination of the Background Corrected Concentrations

The average background concentration of the gaseous pollutants in the dilution air shall be subtracted from measured concentrations to get the net concentrations of the pollutants. The average values of the background concentrations can be determined by the sample bag method or by continuous measurement with integration. The following formula shall be used.

$$\text{conc} = \text{conc}_e - \text{conc}_d * (1 - (1/\text{DF}))$$

where,

conc = concentration of the respective pollutant in the diluted exhaust gas, corrected by the amount of the respective pollutant contained in the dilution air, ppm

conc_e = concentration of the respective pollutant measured in the diluted exhaust gas, ppm

conc_d = concentration of the respective pollutant measured in the dilution air, ppm

DF = dilution factor

The dilution factor shall be calculated as follows:

$$\text{DF} = \frac{13{,}4}{conc_{e\,CO2} + (conc_{e\,HC} + conc_{eCO}) * 10^{-4}}$$

2.2.3.2. Systems with Flow Compensation

For systems without heat exchanger, the mass of the pollutants M_{GAS} (g/test) shall be determined by calculating the instantaneous mass emissions and integrating the instantaneous values over the cycle. Also, the background correction shall be applied directly to the instantaneous concentration value. The following formulae shall be applied:

$$M_{GAS} = \sum_{i=1}^{n} \left(M_{TOTW,i} \times conc_{e,i} \times u\right) - \left(M_{TOTW} \times conc_d \times \left(1 - 1/DF\right) \times u\right)$$

where,

$conc_{e,i}$ = instantaneous concentration of the respective pollutant measured in the diluted exhaust gas, ppm

$conc_d$ = concentration of the respective pollutant measured in the dilution air, ppm

u = ratio between density of the exhaust component and density of diluted exhaust gas, as reported in Table 4, point 2.1.2.1

$M_{TOTW,i}$ = instantaneous mass of the diluted exhaust gas (see section 2.2.1), kg

M_{TOTW} = total mass of diluted exhaust gas over the cycle (see section 2.2.1), kg

DF = dilution factor as determined in point 2.2.3.1.1.

As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for ambient air humidity with the factor k_H, as described in section 2.2.2.

2.2.4. Calculation of the Specific Emissions

The specific emissions (g/kWh) shall be calculated for each individual component in the following way:

$$Individual\ gas = M_{gas}/W_{act}$$

Where

W_{act} = actual cycle work as determined in Annex III Section 4.6.2, kWh

2.2.5. Calculation of the particulate emission

2.2.5.1. Calculation of the Mass Flow

The particulate mass M_{PT} (g/test) shall be calculated as follows:

$$M_{PT} = \frac{M_f}{M_{SAM}} * \frac{M_{TOTW}}{1000}$$

M_f = particulate mass sampled over the cycle, mg

M_{TOTW} = total mass of diluted exhaust gas over the cycle as determined in section 2.2.1, kg

M_{SAM} = mass of diluted exhaust gas taken from the dilution tunnel for collecting particulates, kg

and,

M_f = $M_{f,p} + M_{f,b}$, if weighed separately, mg

$M_{f,p}$ = particulate mass collected on the primary filter, mg

$M_{f,b}$ = particulate mass collected on the back-up filter, mg

If a double dilution system is used, the mass of the secondary dilution air shall be subtracted from the total mass of the double diluted exhaust gas sampled through the particulate filters.

M_{SAM} = M_{TOT} - M_{SEC}

where,

M_{TOT} = mass of double diluted exhaust gas through particulate filter, kg

M_{SEC} = mass of secondary dilution air, kg

If the particulate background level of the dilution air is determined in accordance with Annex III, section 4.4.4, the particulate mass may be background corrected. In this case, the particulate mass (g/test) shall be calculated as follows:

$$M_{PT} = \left[\frac{M_f}{M_{SAM}} - \left(\frac{M_d}{M_{DIL}} * \left(1 - \frac{1}{DF} \right) \right) \right] * \frac{M_{TOTW}}{1000}$$

where,

M_f, M_{SAM}, M_{TOTW} = see above

M_{DIL} = mass of primary dilution air sampled by background particulate sampler, kg

M_d = mass of the collected background particulates of the primary dilution air, mg

DF = dilution factor as determined in point 2.2.3.1.1

2.2.5.2. Particulate correction factor for humidity

As the particulate emission of diesel engines depends on ambient air conditions, the particulate concentration shall be corrected for ambient air humidity with the factor Kp given in the following formula.

$$k_p = \frac{1}{\left[1 + 0{,}0133 \times \left(H_a - 10{,}71 \right) \right]}$$

where

H_a = humidity of the intake air in g water per kg dry air

$$H_a = \frac{6{,}220 \times R_a \times p_a}{p_B - p_a \times R_a \times 10^{-2}}$$

R_a: relative humidity of the intake air, %

p_a: saturation vapour pressure of the intake air, kPa

p_B: total barometric pressure, kPa

Note: H_a may be derived from relative humidity measurement, as described above, or from dewpoint measurement, vapour pressure measurement or dry/wet bulb measurement using the generally accepted formulae.

2.2.5.3. Calculation of the Specific Emission

The particulate emission (g/kWh) shall be calculated in the following way:

$$PT = M_{PT} \times K_p / W_{act}$$

Where

Wact = actual cycle work as determined in Annex III Section 4.6.2, kWh

- The following appendix 4 to Annex III is inserted:

APPENDIX 4

NRTC ENGINE DYNAMOMETER SCHEDULE

Time s	Norm. Speed %	Norm. Torque %
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	1	3
25	1	3
26	1	3
27	1	3
28	1	3
29	1	3
30	1	6
31	1	6
32	2	1
33	4	13
34	7	18
35	9	21
36	17	20
37	33	42
38	57	46
39	44	33
40	31	0
41	22	27
42	33	43
43	80	49
44	105	47
45	98	70
46	104	36
47	104	65
48	96	71
49	101	62
50	102	51
51	102	50
52	102	46
53	102	41
54	102	31
55	89	2
56	82	0
57	47	1
58	23	1
59	1	3
60	1	8
61	1	3
62	1	5
63	1	6
64	1	4
65	1	4
66	0	6
67	1	4
68	9	21
69	25	56
70	64	26
71	60	31
72	63	20
73	62	24
74	64	8
75	58	44
76	65	10
77	65	12
78	68	23
79	69	30
80	71	30
81	74	15
82	71	23
83	73	20
84	73	21
85	73	19
86	70	33
87	70	34
88	65	47
89	66	47
90	64	53
91	65	45
92	66	38
93	67	49
94	69	39
95	69	39
96	66	42
97	71	29
98	75	29
99	72	23
100	74	22
101	75	24
102	73	30
103	74	24
104	77	6
105	76	12
106	74	39
107	72	30
108	75	22
109	78	64
110	102	34
111	103	28
112	103	28
113	103	19
114	103	32
115	104	25
116	103	38
117	103	39
118	103	34
119	102	44
120	103	38
121	102	43
122	103	34
123	102	41
124	103	44
125	103	37
126	103	27
127	104	13
128	104	30
129	104	19
130	103	28
131	104	40
132	104	32
133	101	63
134	102	54
135	102	52
136	102	51
137	103	40
138	104	34
139	102	36
140	104	44
141	103	44
142	104	33
143	102	27
144	103	26
145	79	53
146	51	37
147	24	23
148	13	33
149	19	55
150	45	30
151	34	7
152	14	4
153	8	16

Time s	Norm. Speed %	Norm. Torque %
154	15	6
155	39	47
156	39	4
157	35	26
158	27	38
159	43	40
160	14	23
161	10	10
162	15	33
163	35	72
164	60	39
165	55	31
166	47	30
167	16	7
168	0	6
169	0	8
170	0	8
171	0	2
172	2	17
173	10	28
174	28	31
175	33	30
176	36	0
177	19	10
178	1	18
179	0	16
180	1	3
181	1	4
182	1	5
183	1	6
184	1	5
185	1	3
186	1	4
187	1	4
188	1	6
189	8	18
190	20	51
191	49	19
192	41	13
193	31	16
194	28	21
195	21	17
196	31	21
197	21	8
198	0	14
199	0	12
200	3	8
201	3	22
202	12	20
203	14	20
204	16	17
205	20	18
206	27	34
207	32	33
208	41	31
209	43	31
210	37	33
211	26	18
212	18	29
213	14	51
214	13	11
215	12	9
216	15	33
217	20	25
218	25	17
219	31	29
220	36	66
221	66	40
222	50	13
223	16	24
224	26	50
225	64	23
226	81	20
227	83	11
228	79	23
229	76	31
230	68	24
231	59	33
232	59	3
233	25	7
234	21	10
235	20	19
236	4	10
237	5	7
238	4	5
239	4	6
240	4	6
241	4	5
242	7	5
243	16	28
244	28	25
245	52	53
246	50	8
247	26	40
248	48	29
249	54	39
250	60	42
251	48	18
252	54	51
253	88	90
254	103	84
255	103	85
256	102	84
257	58	66
258	64	97
259	56	80
260	51	67
261	52	96
262	63	62
263	71	6
264	33	16
265	47	45
266	43	56
267	42	27
268	42	64
269	75	74
270	68	96
271	86	61
272	66	0
273	37	0
274	45	37
275	68	96
276	80	97
277	92	96
278	90	97
279	82	96
280	94	81
281	90	85
282	96	65
283	70	96
284	55	95
285	70	96
286	79	96
287	81	71
288	71	60
289	92	65
290	82	63
291	61	47
292	52	37
293	24	0
294	20	7
295	39	48
296	39	54
297	63	58
298	53	31
299	51	24
300	48	40
301	39	0
302	35	18
303	36	16
304	29	17
305	28	21
306	31	15

Time s	Norm. Speed %	Norm. Torque %
307	31	10
308	43	19
309	49	63
310	78	61
311	78	46
312	66	65
313	78	97
314	84	63
315	57	26
316	36	22
317	20	34
318	19	8
319	9	10
320	5	5
321	7	11
322	15	15
323	12	9
324	13	27
325	15	28
326	16	28
327	16	31
328	15	20
329	17	0
330	20	34
331	21	25
332	20	0
333	23	25
334	30	58
335	63	96
336	83	60
337	61	0
338	26	0
339	29	44
340	68	97
341	80	97
342	88	97
343	99	88
344	102	86
345	100	82
346	74	79
347	57	79
348	76	97
349	84	97
350	86	97
351	81	98
352	83	83
353	65	96
354	93	72
355	63	60
356	72	49
357	56	27
358	29	0
359	18	13
360	25	11
361	28	24
362	34	53
363	65	83
364	80	44
365	77	46
366	76	50
367	45	52
368	61	98
369	61	69
370	63	49
371	32	0
372	10	8
373	17	7
374	16	13
375	11	6
376	9	5
377	9	12
378	12	46
379	15	30
380	26	28
381	13	9
382	16	21
383	24	4
384	36	43
385	65	85
386	78	66
387	63	39
388	32	34
389	46	55
390	47	42
391	42	39
392	27	0
393	14	5
394	14	14
395	24	54
396	60	90
397	53	66
398	70	48
399	77	93
400	79	67
401	46	65
402	69	98
403	80	97
404	74	97
405	75	98
406	56	61
407	42	0
408	36	32
409	34	43
410	68	83
411	102	48
412	62	0
413	41	39
414	71	86
415	91	52
416	89	55
417	89	56
418	88	58
419	78	69
420	98	39
421	64	61
422	90	34
423	88	38
424	97	62
425	100	53
426	81	58
427	74	51
428	76	57
429	76	72
430	85	72
431	84	60
432	83	72
433	83	72
434	86	72
435	89	72
436	86	72
437	87	72
438	88	72
439	88	71
440	87	72
441	85	71
442	88	72
443	88	72
444	84	72
445	83	73
446	77	73
447	74	73
448	76	72
449	46	77
450	78	62
451	79	35
452	82	38
453	81	41
454	79	37
455	78	35
456	78	38
457	78	46
458	75	49
459	73	50

Time s	Norm. Speed %	Norm. Torque %
460	79	58
461	79	71
462	83	44
463	53	48
464	40	48
465	51	75
466	75	72
467	89	67
468	93	60
469	89	73
470	86	73
471	81	73
472	78	73
473	78	73
474	76	73
475	79	73
476	82	73
477	86	73
478	88	72
479	92	71
480	97	54
481	73	43
482	36	64
483	63	31
484	78	1
485	69	27
486	67	28
487	72	9
488	71	9
489	78	36
490	81	56
491	75	53
492	60	45
493	50	37
494	66	41
495	51	61
496	68	47
497	29	42
498	24	73
499	64	71
500	90	71
501	100	61
502	94	73
503	84	73
504	79	73
505	75	72
506	78	73
507	80	73
508	81	73
509	81	73
510	83	73
511	85	73
512	84	73
513	85	73
514	86	73
515	85	73
516	85	73
517	85	72
518	85	73
519	83	73
520	79	73
521	78	73
522	81	73
523	82	72
524	94	56
525	66	48
526	35	71
527	51	44
528	60	23
529	64	10
530	63	14
531	70	37
532	76	45
533	78	18
534	76	51
535	75	33
536	81	17
537	76	45
538	76	30
539	80	14
540	71	18
541	71	14
542	71	11
543	65	2
544	31	26
545	24	72
546	64	70
547	77	62
548	80	68
549	83	53
550	83	50
551	83	50
552	85	43
553	86	45
554	89	35
555	82	61
556	87	50
557	85	55
558	89	49
559	87	70
560	91	39
561	72	3
562	43	25
563	30	60
564	40	45
565	37	32
566	37	32
567	43	70
568	70	54
569	77	47
570	79	66
571	85	53
572	83	57
573	86	52
574	85	51
575	70	39
576	50	5
577	38	36
578	30	71
579	75	53
580	84	40
581	85	42
582	86	49
583	86	57
584	89	68
585	99	61
586	77	29
587	81	72
588	89	69
589	49	56
590	79	70
591	104	59
592	103	54
593	102	56
594	102	56
595	103	61
596	102	64
597	103	60
598	93	72
599	86	73
600	76	73
601	59	49
602	46	22
603	40	65
604	72	31
605	72	27
606	67	44
607	68	37
608	67	42
609	68	50
610	77	43
611	58	4
612	22	37

Time s	Norm. Speed %	Norm. Torque %
613	57	69
614	68	38
615	73	2
616	40	14
617	42	38
618	64	69
619	64	74
620	67	73
621	65	73
622	68	73
623	65	49
624	81	0
625	37	25
626	24	69
627	68	71
628	70	71
629	76	70
630	71	72
631	73	69
632	76	70
633	77	72
634	77	72
635	77	72
636	77	70
637	76	71
638	76	71
639	77	71
640	77	71
641	78	70
642	77	70
643	77	71
644	79	72
645	78	70
646	80	70
647	82	71
648	84	71
649	83	71
650	83	73
651	81	70
652	80	71
653	78	71
654	76	70
655	76	70
656	76	71
657	79	71
658	78	71
659	81	70
660	83	72
661	84	71
662	86	71
663	87	71
664	92	72
665	91	72
666	90	71
667	90	71
668	91	71
669	90	70
670	90	72
671	91	71
672	90	71
673	90	71
674	92	72
675	93	69
676	90	70
677	93	72
678	91	70
679	89	71
680	91	71
681	90	71
682	90	71
683	92	71
684	91	71
685	93	71
686	93	68
687	98	68
688	98	67
689	100	69
690	99	68
691	100	71
692	99	68
693	100	69
694	102	72
695	101	69
696	100	69
697	102	71
698	102	71
699	102	69
700	102	71
701	102	68
702	100	69
703	102	70
704	102	68
705	102	70
706	102	72
707	102	68
708	102	69
709	100	68
710	102	71
711	101	64
712	102	69
713	102	69
714	101	69
715	102	64
716	102	69
717	102	68
718	102	70
719	102	69
720	102	70
721	102	70
722	102	62
723	104	38
724	104	15
725	102	24
726	102	45
727	102	47
728	104	40
729	101	52
730	103	32
731	102	50
732	103	30
733	103	44
734	102	40
735	103	43
736	103	41
737	102	46
738	103	39
739	102	41
740	103	41
741	102	38
742	103	39
743	102	46
744	104	46
745	103	49
746	102	45
747	103	42
748	103	46
749	103	38
750	102	48
751	103	35
752	102	48
753	103	49
754	102	48
755	102	46
756	103	47
757	102	49
758	102	42
759	102	52
760	102	57
761	102	55
762	102	61
763	102	61
764	102	58
765	103	58

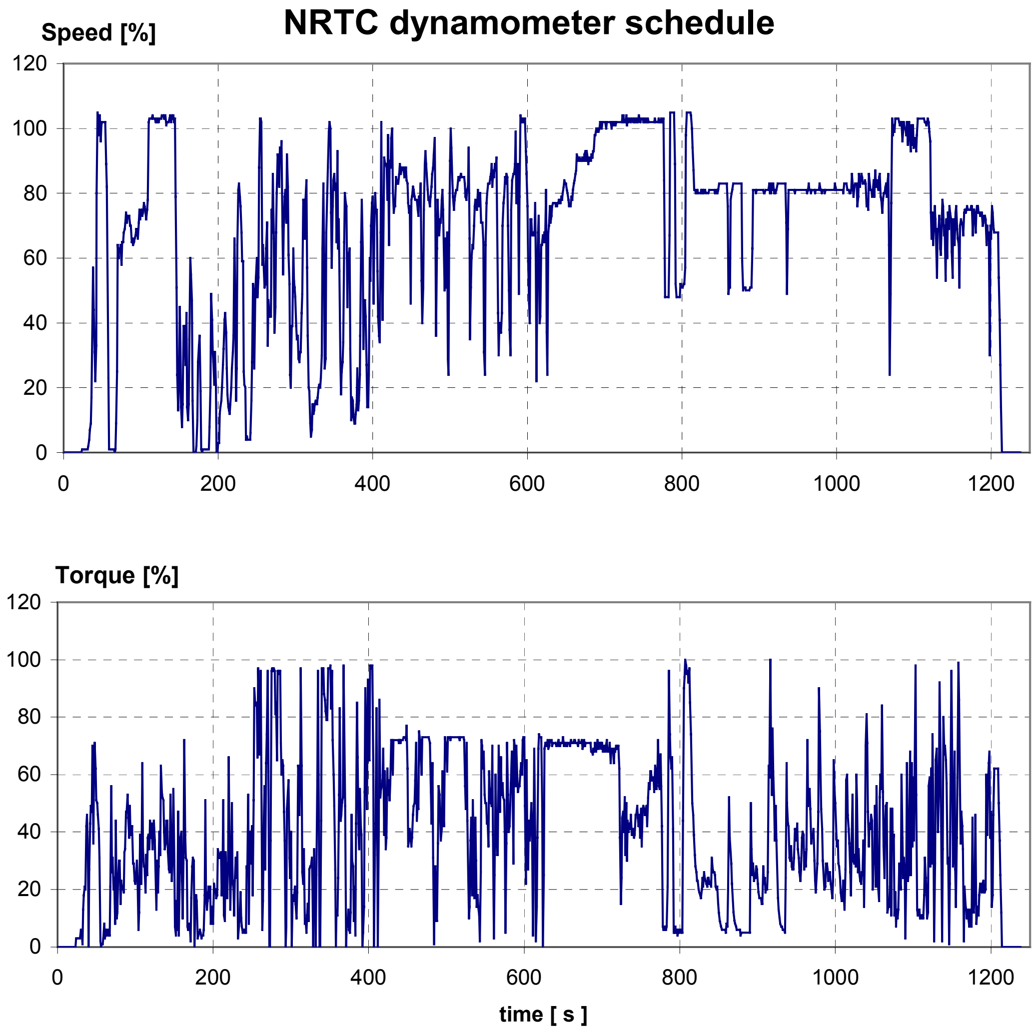
Time	Norm. Speed	Norm. Torque
s	%	%
766	102	59
767	102	54
768	102	63
769	102	61
770	103	55
771	102	60
772	102	72
773	103	56
774	102	55
775	102	67
776	103	56
777	84	42
778	48	7
779	48	6
780	48	6
781	48	7
782	48	6
783	48	7
784	67	21
785	105	59
786	105	96
787	105	74
788	105	66
789	105	62
790	105	66
791	89	41
792	52	5
793	48	5
794	48	7
795	48	5
796	48	6
797	48	4
798	52	6
799	51	5
800	51	6
801	51	6
802	52	5
803	52	5
804	57	44
805	98	90
806	105	94
807	105	100
808	105	98
809	105	95
810	105	96
811	105	92
812	104	97
813	100	85
814	94	74
815	87	62
816	81	50
817	81	46
818	80	39
819	80	32
820	81	28
821	80	26
822	80	23
823	80	23
824	80	20
825	81	19
826	80	18
827	81	17
828	80	20
829	81	24
830	81	21
831	80	26
832	80	24
833	80	23
834	80	22
835	81	21
836	81	24
837	81	24
838	81	22
839	81	22
840	81	21
841	81	31
842	81	27
843	80	26
844	80	26
845	81	25
846	80	21
847	81	20
848	83	21
849	83	15
850	83	12
851	83	9
852	83	8
853	83	7
854	83	6
855	83	6
856	83	6
857	83	6
858	83	6
859	76	5
860	49	8
861	51	7
862	51	20
863	78	52
864	80	38
865	81	33
866	83	29
867	83	22
868	83	16
869	83	12
870	83	9
871	83	8
872	83	7
873	83	6
874	83	6
875	83	6
876	83	6
877	83	6
878	59	4
879	50	5
880	51	5
881	51	5
882	51	5
883	50	5
884	50	5
885	50	5
886	50	5
887	50	5
888	51	5
889	51	5
890	51	5
891	63	50
892	81	34
893	81	25
894	81	29
895	81	23
896	80	24
897	81	24
898	81	28
899	81	27
900	81	22
901	81	19
902	81	17
903	81	17
904	81	17
905	81	15
906	80	15
907	80	28
908	81	22
909	81	24
910	81	19
911	81	21
912	81	20
913	83	26
914	80	63
915	80	59
916	83	100
917	81	73
918	83	53

Time s	Norm. Speed %	Norm. Torque %
919	80	76
920	81	61
921	80	50
922	81	37
923	82	49
924	83	37
925	83	25
926	83	17
927	83	13
928	83	10
929	83	8
930	83	7
931	83	7
932	83	6
933	83	6
934	83	6
935	71	5
936	49	24
937	69	64
938	81	50
939	81	43
940	81	42
941	81	31
942	81	30
943	81	35
944	81	28
945	81	27
946	80	27
947	81	31
948	81	41
949	81	41
950	81	37
951	81	43
952	81	34
953	81	31
954	81	26
955	81	23
956	81	27
957	81	38
958	81	40
959	81	39
960	81	27
961	81	33
962	80	28
963	81	34
964	83	72
965	81	49
966	81	51
967	80	55
968	81	48
969	81	36
970	81	39
971	81	38
972	80	41
973	81	30
974	81	23
975	81	19
976	81	25
977	81	29
978	83	47
979	81	90
980	81	75
981	80	60
982	81	48
983	81	41
984	81	30
985	80	24
986	81	20
987	81	21
988	81	29
989	81	29
990	81	27
991	81	23
992	81	25
993	81	26
994	81	22
995	81	20
996	81	17
997	81	23
998	83	65
999	81	54
1000	81	50
1001	81	41
1002	81	35
1003	81	37
1004	81	29
1005	81	28
1006	81	24
1007	81	19
1008	81	16
1009	80	16
1010	83	23
1011	83	17
1012	83	13
1013	83	27
1014	81	58
1015	81	60
1016	81	46
1017	80	41
1018	80	36
1019	81	26
1020	86	18
1021	82	35
1022	79	53
1023	82	30
1024	83	29
1025	83	32
1026	83	28
1027	76	60
1028	79	51
1029	86	26
1030	82	34
1031	84	25
1032	86	23
1033	85	22
1034	83	26
1035	83	25
1036	83	37
1037	84	14
1038	83	39
1039	76	70
1040	78	81
1041	75	71
1042	86	47
1043	83	35
1044	81	43
1045	81	41
1046	79	46
1047	80	44
1048	84	20
1049	79	31
1050	87	29
1051	82	49
1052	84	21
1053	82	56
1054	81	30
1055	85	21
1056	86	16
1057	79	52
1058	78	60
1059	74	55
1060	78	84
1061	80	54
1062	80	35
1063	82	24
1064	83	43
1065	79	49
1066	83	50
1067	86	12
1068	64	14
1069	24	14
1070	49	21
1071	77	48

Time s	Norm. Speed %	Norm. Torque %
1072	103	11
1073	98	48
1074	101	34
1075	99	39
1076	103	11
1077	103	19
1078	103	7
1079	103	13
1080	103	10
1081	102	13
1082	101	29
1083	102	25
1084	102	20
1085	96	60
1086	99	38
1087	102	24
1088	100	31
1089	100	28
1090	98	3
1091	102	26
1092	95	64
1093	102	23
1094	102	25
1095	98	42
1096	93	68
1097	101	25
1098	95	64
1099	101	35
1100	94	59
1101	97	37
1102	97	60
1103	93	98
1104	98	53
1105	103	13
1106	103	11
1107	103	11
1108	103	13
1109	103	10
1110	103	10
1111	103	11
1112	103	10
1113	103	10
1114	102	18
1115	102	31
1116	101	24
1117	102	19
1118	103	10
1119	102	12
1120	99	56
1121	96	59
1122	74	28
1123	66	62
1124	74	29
1125	64	74
1126	69	40
1127	76	2
1128	72	29
1129	66	65
1130	54	69
1131	69	56
1132	69	40
1133	73	54
1134	63	92
1135	61	67
1136	72	42
1137	78	2
1138	76	34
1139	67	80
1140	70	67
1141	53	70
1142	72	65
1143	60	57
1144	74	29
1145	69	31
1146	76	1
1147	74	22
1148	72	52
1149	62	96
1150	54	72
1151	72	28
1152	72	35
1153	64	68
1154	74	27
1155	76	14
1156	69	38
1157	66	59
1158	64	99
1159	51	86
1160	70	53
1161	72	36
1162	71	47
1163	70	42
1164	67	34
1165	74	2
1166	75	21
1167	74	15
1168	75	13
1169	76	10
1170	75	13
1171	75	10
1172	75	7
1173	75	13
1174	76	8
1175	76	7
1176	67	45
1177	75	13
1178	75	12
1179	73	21
1180	68	46
1181	74	8
1182	76	11
1183	76	14
1184	74	11
1185	74	18
1186	73	22
1187	74	20
1188	74	19
1189	70	22
1190	71	23
1191	73	19
1192	73	19
1193	72	20
1194	64	60
1195	70	39
1196	66	56
1197	68	64
1198	30	68
1199	70	38
1200	66	47
1201	76	14
1202	74	18
1203	69	46
1204	68	62
1205	68	62
1206	68	62
1207	68	62
1208	68	62
1209	68	62
1210	54	50
1211	41	37
1212	27	25
1213	14	12
1214	0	0
1215	0	0
1216	0	0
1217	0	0
1218	0	0
1219	0	0
1220	0	0
1221	0	0
1222	0	0
1223	0	0
1224	0	0

Time s	Norm. Speed %	Norm. Torque %	Time s	Norm. Speed %	Norm. Torque %	Time s	Norm. Speed %	Norm. Torque %
1225	0	0						
226	0	0						
1227	0	0						
1228	0	0						
1229	0	0						
1230	0	0						
1231	0	0						
1232	0	0						
1233	0	0						
1234	0	0						
1235	0	0						
1236	0	0						
1237	0	0						
1238	0	0						

A graphical display of the NRTC dynamometer schedule is shown here below



- The following new appendix 5 to Annex III is inserted:

"Appendix 5

Durability requirements

1. EMISSION DURABILITY PERIOD AND DETERIORATION FACTORS.

This appendix shall apply to CI engines Stage IIIA and IIIB only.

* * * * *

1.1. Manufacturers shall determine a Deterioration Factor (DF) value for each regulated pollutant for all Stage IIIA and IIIB engine families. Such DFs shall be used for type approval and production line testing.

1.1.1 Test to establish DF's shall be conducted as follows:

1.1.1.1 The manufacturer shall conduct durability tests to accumulate engine operating hours according to a test schedule that is selected on the basis of good engineering judgement to be representative of in-use engine operation in respect to characterizing emission performance deterioration. The durability test period should typically represent the equivalent of at least one quarter of the Emission Durability Period (EDP).

Service accumulation operating hours may be acquired through running engines on a dynamometer test bed or from actual in-field machine operation. Accelerated durability tests can be applied whereby the service accumulation test schedule is performed at a higher load factor than typically experienced in the field. The acceleration factor relating the number of engine durability test hours to the equivalent number of EDP hours shall be determined by the engine manufacturer based on good engineering judgement.

During the period of the durability test, no emission sensitive components can be serviced or replaced other than to the routine service schedule recommended by the manufacturer.

The test engine, subsystems, or components to be used to determine exhaust emission DF's for an engine family, or for engine families of equivalent emission control system technology, shall be selected by the engine manufacturer on the basis of good engineering judgement. The criteria is that the test engine should represent the emission deterioration characteristic of the engine families that will apply the resulting DF values for certification approval. Engines of different bore and stroke, different configuration, different air management systems, different fuel systems can be considered as equivalent in respect to emissions deterioration characteristics if there is a reasonable technical basis for such determination.

DF values from another manufacturer can be applied if there is a reasonable basis for considering technology equivalence with respect to emissions deterioration, and evidence that the tests have been carried according to the specified requirements.

Emissions testing will be performed according to the procedures defined in this directive for the test engine after initial run-in but before any service accumulation, and at the completion of the durability. Emission tests can also be performed at intervals during the service accumulation test period, and applied in determining the deterioration trend.

1.1.1.2 The service accumulation tests or the emissions tests performed to determine deterioration must not be witnessed by the approval authority.

1.1.1.3 Determination of DF values from Durability Tests

An additive DF is defined as the value obtained by subtraction of the emission value determine at the beginning of the EDP, from the emissions value determined to represent the emission performance at the end of the EDP.

A multiplicative DF is defined as the emission level determined for the end of the EDP divided by the emission value recorded at the beginning of the EDP.

Separate DF values shall be established for each of the pollutants covered by the legislation. In the case of establishing a DF value relative to the NOx+HC standard, for an additive DF, this is determined based on the sum of the pollutants notwithstanding that a negative deterioration for one pollutant may not offset deterioration for the other. For a multiplicative NOx+HC DF, separate HC and NOx DF's shall be determined and applied separately when calculating the deteriorated emission levels from an emissions test result before combining the resultant deteriorated NOx and HC values to esatablish compliance with the standard.

In cases where the testing is not conducted for the full EDP, the emission values at the end of the EDP is determined by extrapolation of the emission deterioration trend established for the test period, to the full EDP.

When emissions test results have been recorded periodically during the service accumulation durability testing, standard statistical processing techniques based on good practice shall be applied to determine the emission levels at the end of the EDP; statistical significance testing can be applied in the determination of the final emissions values.

If the calculation results in a value of less than 1.00 for a multiplicative DF, or less than 0.00 for an additive DF, then the DF shall be 1.0 or 0.00, respectively.

1.1.1.4 A manufacturer may, with the approval of the type approval authority, use DF values established from results of durability tests conducted to obtain DF values for certification of on-road HD CI engines. This will be allowed if there is technological equivalency between the test on-road engine and the non-road engine families applying the DF values for certification. The DF values derived from on-road engine emission durability test results, must be calculated on the basis of EDP values defined in Paragraph 2.

1.1.1.5 In the case where an engine family uses established technology, an analysis based on good engineering practices may be used in lieu of testing to determine a deterioration factor for that engine family subject to approval of the type approval authority.

1.2 DF information in approval applications

1.2.1 Additive DF's shall be specified for each pollutant in an engine family certification application for CI engines not using any aftertreatment device.

1.2.2 Multiplicative DF's shall be specified for each pollutant in an engine family certification application for CI engines using an aftertreatment device.

1.2.3 The manufacture shall furnish the Type Approval agency on request with information to support the DF values. This would typically include emission test results, service accumulation test schedule, maintenance procedures together with information to support engineering judgements of technological equivalency, if applicable.

2. EMISSION DURABILITY PERIODS FOR STAGE IIIA AND IIIB ENGINES.

2.1. Manufacturers shall use the EDP inTable 1 of this paragraph.

Table 1: EDP categories for CI Stage IIIA and IIIB Engines (hours)

Category (power band)	Useful life (hours) EDP
≤ 37 kW (constant speed engines)	3.000
≤ 37 kW (not constant speed engines)	5.000
> 37 kW	8.000
Engines for the use in inland waterway vessels	10.000

4. ANNEX V IS AMENDED AS FOLLOWS:

- The current headings are replaced by the following:

TECHNICAL CHARACTERISTICS OF REFERENCE FUEL PRESCRIBED FOR APPROVAL TESTS AND TO VERIFY CONFORMITY OF PRODUCTION

NON-ROAD MOBILE MACHINERY REFERENCE FUEL FOR CI ENGINES TYPE APPROVED TO MEET STAGE I, II and IIIA LIMIT VALUES AND FOR ENGINES TO BE USED IN INLAND WATERWAY VESSELS.

- The following new headings and tables are inserted after current table on reference fuel for diesel as follows:

NON-ROAD MOBILE MACHINERY REFERENCE FUEL FOR CI ENGINES TYPE APPROVED TO MEET STAGE IIIB LIMIT VALUES.

Parameter	Unit	Limits (1)		Test Method
		Minimum	maximum	
Cetane number (2)			54,0	EN-ISO 5165
Density at 15°C	kg/m^3	833	837	EN-ISO 3675
Distillation:				
50% point	°C	245	-	EN-ISO 3405
95% point	°C	345	350	EN-ISO 3405
- Final boiling point	°C	-	370	EN-ISO 3405
Flash point	°C	55	-	EN 22719
CFPP	°C	-	-5	EN 116
Viscosity at 40°C	mm^2/s	2,3	3,3	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	3,0	6,0	IP 391
Sulphur content (3)	mg/kg	-	10	ASTM D 5453
Copper corrosion		-	class 1	EN-ISO 2160
Conradson carbon residue (10% DR)	% m/m	-	0,2	EN-ISO 10370
Ash content	% m/m	-	0,01	EN-ISO 6245

Parameter	Unit	Limits (1)		Test Method
		Minimum	maximum	
Water content	% m/m	-	0,02	EN-ISO 12937
Neutralisation (strong acid) number	mg KOH/g	-	0,02	ASTM D 974
Oxidation stability (4)	mg/ml	-	0,025	EN-ISO 12205
Lubricity (HFRR wear scar diameter at 60°C)	µm	-	400	CEC F-06-A-96

Parameter	Unit	Limits (1)		Test Method
		Minimum	maximum	
FAME	prohibited			

(1) The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 "Petroleum products – Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).

Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the questions as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

(2) The range for cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

(3) The actual sulphur content of the fuel used for the Type I test shall be reported.

(4) Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life.

5. APPENDIX 1 TO ANNEX VII IS REPLACED BY THE FOLLOWING:

“Appendix 1

TEST RESULTS FOR COMPRESSION IGNITION ENGINES

TEST RESULTS

1. INFORMATION CONCERNING THE CONDUCT OF THE NRSC TEST[1]:

1.1. Reference fuel used for test

1.1.1. Cetane number: ……………………………………………………………..

1.1.2. Sulphur content: …………………………………………………………….

1.1.3. Density ………………………………………………………………………

1.2. Lubricant

1.2.1. Make(s): ……………………………………………………………………..

1.2.2. Type(s): ………………………………………………………………………

(state percentage of oil in mixture if lubricant and fuel are mixed)

1.3. Engine driven equipment (if applicable)

1.3.1. Enumeration and identifying details: ………………………………………..

1.3.2. Power absorbed at indicated engine speeds (as specified by the manufacturer):

	Power P_{AE} (kW) absorbed at various engine speeds (^{1}), taking into account Appendix 3 of this Annex	
Equipment	Intermediate (if applicable)	Rated
Total:		

(^{1}) Must not be greater than 10% of the power measured during the test.

---

[1] For the case of several parent engines to be indicated for each of them

1.4. Engine performance

1.4.1. Engine speeds:

Idle: . ……………………………………………………………………..…….rpm

Intermediate: ……………………………………………………………. rpm

Rated: ……………………………………………………………………… rpm

1.4.2. Engine power[1]

	Power setting (kW) at various engine speeds	
Condition	Intermediate (if applicable)	Rated
Maximum power measured on test (P_M) (kW) (a)		
Total power absorbed by engine driven equipment as per section 1.3.2 of this Appendix, or section 3.1 of Annex III (P_{AE}) (kW) (b)		
Net engine power as specified in section 2.4 of Annex I (kW) (c)		
c = a + b		

1.5. Emission levels

1.5.1. Dynamometer setting (kW)

	Dynamometer setting (kW) at various engine speeds	
Percent Load	Intermediate (if applicable)	Rated
10 (if applicable)		
25 (if applicable)		
50		
75		
100		

---

[1] Uncorrected power measured in accordance with the provisions of section 2.4 of Annex I.

1.5.2. Emission results on the NRSC test :

CO: . ……………..g/kWh

HC: . ……………..g/kWh

NOx: . ……………g/kWh

NMHC+NOx: …...g/kWh

Particulates: . ……..g/kWh

1.5.3. Sampling system used for the NRSC test:

1.5.3.1. Gaseous emissions[1]:…………………………………………………...

1.5.3.2. Particulates[1]:……………………………………………………………

1.5.3.2.1. Method[2]: single/multiple filter

2. INFORMATION CONCERNING THE CONDUCT OF THE NRTC TEST[3]:

2.1. Emission results on the NRTC test:

CO: . ……………..g/kWh

NMHC: …………..g/kWh

NOx: . ……………g/kWh

Particulates: . ……..g/kWh

NMHC+NOx : ……g/kWh

2.2. Sampling system used for the NRTC test:

Gaseous emissions(1):…………………………………………………...

Particulates(1):……………………………………………………………

Method(2): single/multiple filter

---

[1] Indicate figure numbers defined in Annex VI section 1

[2] Delete as appropriate

[3] For the case of several parent engines to be indicated for each of them

6. ANNEX XII IS AMENDED AS FOLLOWS:

- a new paragraph 3 is added as follows:

3. For engines categories H, I, and J (stage IIIA) and engines category K, L and M (stage IIIB) as defined in Article 9 section 3, the following type-approvals and, where applicable, the pertaining approval marks are recognised as being equivalent to an approval to this Directive;

3.1 Type-approvals to Directive 88/77/EEC as amended by Directive 99/96/EC which are in compliance with stages B1, B2 or C provided for in Article 2 and section 6.2.1 of Annex I.

3.2 UN-ECE Regulation 49.03 series of amendments which are in compliance with stages B1, B2 and C provided for in paragraph 5.2.

ANNEX II

"Annex VI

ANALITYCAL AND SAMPLING SYSTEM

1. GASEOUS AND PARTICULATE SAMPLING SYSTEMS

Figure Number	Description
2	Exhaust gas analysis system for raw exhaust
3	Exhaust gas analysis system for dilute exhaust
4	Partial flow, isokinetic flow, suction blower control, fractional sampling
5	Partial flow, isokinetic flow, pressure blower control, fractional sampling
6	Partial flow, CO2 or NO_x control, fractional sampling
7	Partial flow, CO2 or carbon balance, total sampling
8	Partial flow, single venturi and concentration measurement, fractional sampling
9	Partial flow, twin venturi or orifice and concentration measurement, fractional sampling
10	Partial flow, multiple tube splitting and concentration measurement, fractional sampling
11	Partial flow, flow control, total sampling
12	Partial flow, flow control, fractional sampling
13	Full flow, positive displacement pump or critical flow venturi, fractional sampling
14	Particulate sampling system
15	Dilution system for full flow system

1.1. Determination of the gaseous emissions

Section 1.1.1 and Figures 2 and 3 contain detailed descriptions of the recommended sampling and analysing systems. Since various configurations can produce equivalent results, exact conformance with these figures is not required. Additional components such as instruments, valves, solenoids, pumps and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.

1.1.1. Gaseous exhaust components CO, CO2, HC, NOx

An analytical system for the determination of the gaseous emissions in the raw or diluted exhaust gas is described based on the use of:

- HFID analyser for the measurement of hydrocarbons,
- NDIR analysers for the measurement of carbon monoxide and carbon dioxide,
- HCLD or equivalent analyser for the measurement of nitrogen oxide.

For the raw exhaust gas (see Figure 2), the sample for all components may be taken with one sampling probe or with two sampling probes located in close proximity and internally split to the different analysers. Care must be taken that no condensation of exhaust components (including water and sulphuric acid) occurs at any point of the analytical system.

For the diluted exhaust gas (see Figure 3), the sample for the hydrocarbons shall be taken with another sampling probe than the sample for the other components. Care must be taken that no condensation of exhaust components (including water and sulphuric acid) occurs at any point of the analytical system.

Figure 2

Flow diagram of exhaust gas analysis system for CO, NOx and HC

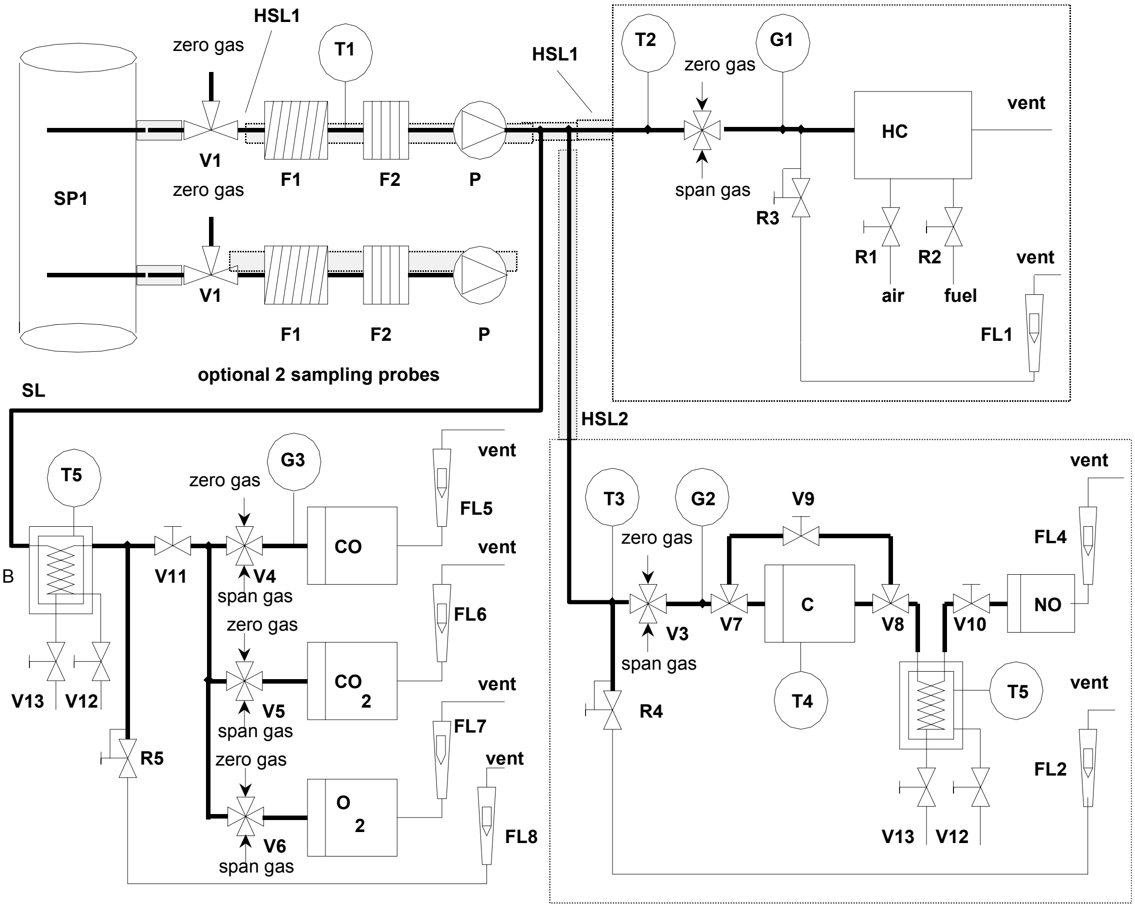
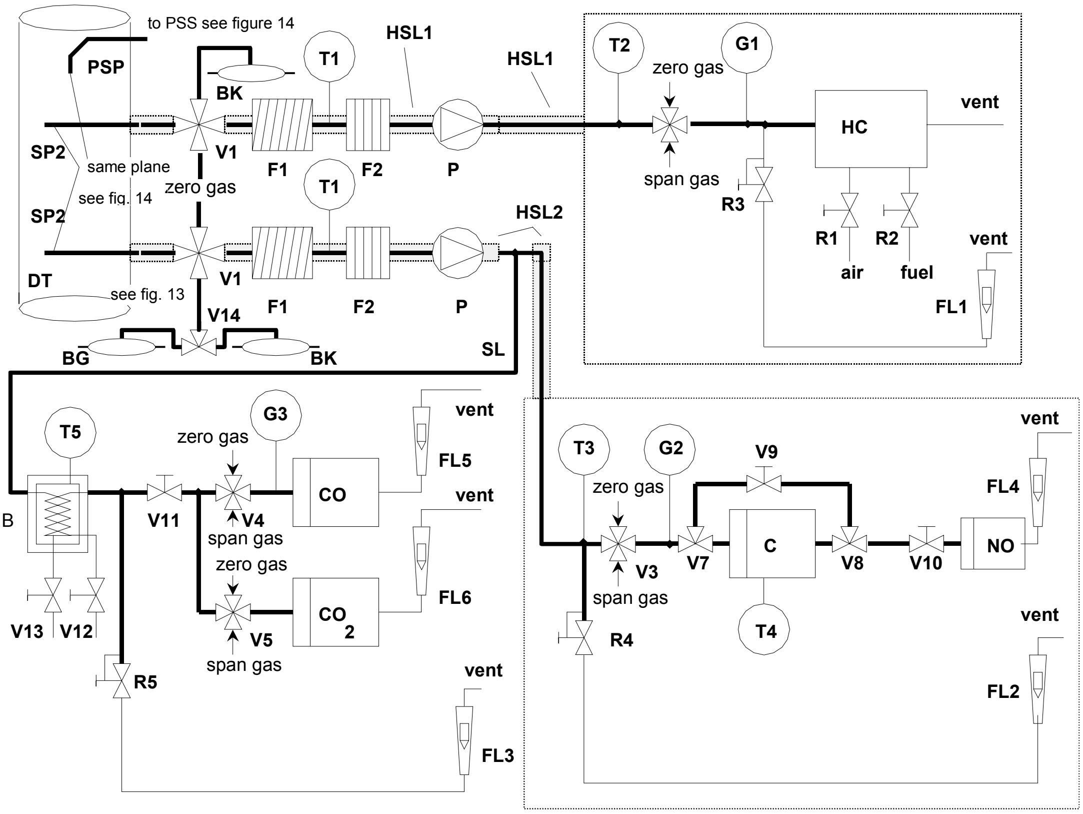


Figure 3

Flow diagram of dilute exhaust gas analysis system for CO, CO2, NOx and HC



Descriptions - Figures 2 and 3

General statement:

All components in the sampling gas path must be maintained at the temperature specified for the respective systems.

- *SP1 raw exhaust gas sampling probe (Figure 2 only)*

A stainless steel straight closed and multihole probe is recommended. The inside diameter shall not be greater than the inside diameter of the sampling line. The wall thickness of the probe shall not be greater than 1 mm. There shall be a minimum of three holes in three different radial planes sized to sample approximately the same flow. The probe must extend across at least 80 % of the diameter of the exhaust pipe.

- *SP2 dilute exhaust gas HC sampling probe (Figure 3 only)*

The probe shall:

- be defined as the first 254 mm to 762 mm of the hydrocarbon sampling line (HSL3),
- have a 5 mm minimum inside diameter,

  - be installed in the dilution tunnel DT (section 1.2.1.2) at a point where the dilution air and exhaust gas are well mixed (i.e. approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel),

  - be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies,

  - be heated so as to increase the gas stream temperature to 463 K (190 °C) ± 10 K at the exit of the probe.

- *SP3 dilute exhaust gas CO, CO2, NOx sampling probe (Figure 3 only)*

  The probe shall:

  - be in the same plane as SP2,

  - be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies,

  - be heated and insulated over its entire length to a minimum temperature of 328 K (55 °C) to prevent water condensation.

- *HSL1 heated sampling line*

  The sampling line provides gas sampling from a single probe to the split point(s) and the HC analyser.

  The sampling line shall:

  - have a 5 mm minimum and a 13,5 mm maximum inside diameter,

  - be made of stainless steel or PTFE,

  - maintain a wall temperature of 463 (190 °C) ± 10 K as measured at every separately controlled heated section, if the temperature of the exhaust gas at the sampling probe is equal or below 463 K (190 °C),

  - maintain a wall temperature greater than 453 K (180 °C) if the temperature of the exhaust gas at the sampling probe is above 463 K (190 °C),

  - maintain a gas temperature of 463 K (190 °C) ± 10 K immediately before the heated filter (F2) and the HFID.

- *HSL2 heated NO_x sampling line*

  The sampling line shall:

  - maintain a wall temperature of 328 to 473 K (55 to 200 °C) up to the converter when using a cooling bath, and up to the analyser when a cooling bath is not used,

  - be made of stainless steel or PTFE.

Since the sampling line need only be heated to prevent condensation of water and sulphuric acid, the samplingline temperature will depend on the sulphur content of the fuel.

- *SL sampling line for CO (CO_2)*

The line shall be made of PTFE or stainless steel. It may be heated or unheated.

- *BK background bag (optional; Figure 3 only)*

For the measurement of the background concentrations.

- *BG sample bag (optional; Figure 3 CO and CO2 only)*

For the measurement of the sample concentrations.

- *F1 heated pre-filter (optional)*

The temperature shall be the same as HSL1.

- *F2 heated filter*

The filter shall extract any solid particles from the gas sample prior to the analyser. The temperature shall be the same as HSL1. The filter shall be changed as needed.

- *P heated sampling pump*

The pump shall be heated to the temperature of HSL1.

- *HC*

Heated flame ionization detector (HFID) for the determination of the hydrocarbons. The temperature shall be kept at 453 to 473 K (180 to 200 °C).

- *CO, CO2*

NDIR analysers for the determination of carbon monoxide and carbon dioxide.

- *NO2*

(H)CLD analyser for the determination of the oxides of nitrogen. If a HCLD is used it shall be kept at a temperature of 328 to 473 K (55 to 200 °C).

- *C converter*

A converter shall be used for the catalytic reduction of NO_2 to NO prior to analysis in the CLD or HCLD.

- *B cooling bath*

To cool and condense water from the exhaust sample. The bath shall be maintained at a temperature of 273 to 277 K (0 to 4 °C) by ice or refrigeration. It is optional if the analyser is free from water vapour interference as determined in Annex III, Appendix 2, sections 1.9.1 and 1.9.2.

Chemical dryers are not allowed for removing water from the sample.

- *T1, T2, T3 temperature sensor*

  To monitor the temperature of the gas stream.

- *T4 temperature sensor*

  Temperature of the NO_2-NO converter.

- *T5 temperature sensor*

  To monitor the temperature of the cooling bath.

- *G1, G2, G3 pressure gauge*

  To measure the pressure in the sampling lines.

- *R1, R2 pressure regulator*

  To control the pressure of the air and the fuel, respectively, for the HFID.

- *R3, R4, R5 pressure regulator*

  To control the pressure in the sampling lines and the flow to the analysers.

- *FL1, FL2, FL3 flow-meter*

  To monitor the sample bypass flow.

- *FL4 to FL7 flowmeter (optional)*

  To monitor the flow rate through the analysers.

- *V1 to V6 selector valve*

  Suitable valving for selecting sample, span gas or zero gas flow to the analyser.

- *V7, V8 solenoid valve*

  To bypass the NO_2-NO converter.

- *V9 needle valve*

  To balance the flow through the NO_2-NO converter and the bypass.

- *V10, V11 needle valve*

  To regulate the flows to the analysers.

- *V12, V13 toggle valve*

  To drain the condensate from the bath B.

- *V14 selector valve*

Selecting the sample or background bag.

1.2. Determination of the particulates

Sections 1.2.1 and 1.2.2 and Figures 4 to 15 contain detailed descriptions of the recommended dilution and sampling systems. Since various configurations can produce equivalent results, exact conformance with these figures is not required. Additional components such as instruments, valve, solenoids, pumps and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based on good engineering judgement.

1.2.1. Dilution system

1.2.1.1. Partial flow dilution system (Figures 4 to 12)[1]

A dilution system is described based on the dilution of a part of the exhaust stream. Splitting of the exhaust stream and the following dilution process may be done by different dilution system types. For subsequent collection of the particulates, the entire dilute exhaust gas or only a portion of the dilute exhaust gas may be passed to the particulate sampling system (section 1.2.2, Figure 14). The first method is referred to as *total sampling type*, the second method as *fractional sampling type*.

The calculation of the dilution ratio depends on the type of system used.

The following types are recommended:

- *isokinetic systems* (Figures 4 and 5)

With these systems, the flow into the transfer tube is matched to the bulk exhaust flow in terms of gas velocity and/or pressure, thus requiring an undisturbed and uniform exhaust flow at the sampling probe. This is usually achieved by using a resonator and a straight approach tube upstream of the sampling point. The split ratio is then calculated from easily measurable values like tube diameters. It should be noted that isokinesis is only used for matching the flow conditions and not for matching the size distribution. The latter is typically not necessary, as the particles are sufficiently small as to follow the fluid streamlines,

- *flow controlled systems with concentration measurement* (Figures 6 to 10)

With these systems, a sample is taken from the bulk exhaust stream by adjusting the dilution air flow and the total dilution exhaust flow. The dilution ratio is determined from the concentrations of tracer gases, such as CO2 or NOx, naturally occurring in the engine exhaust. The concentrations in the dilution exhaust gas and in the dilution air are measured, whereas the concentration in the raw exhaust gas can be either measured directly or determined from fuel flow and the carbon balance equation, if the fuel composition is known.

---

[1] Figures 4 to 12 show many types of partial flow dilution systems, which normally can be used for the steady-state test (NRSC). But, because of very severe constraints of the transient tests, only those partial flow dilution systems (Figures 4 to 12) able to fulfill all the requirements quoted in the section "Partial flow dilution system specifications" of Annex III, Appendix 1, Paragraph 2.4, are accepted for the transient test (NRTC).

The systems may be controlled by the calculated dilution ratio (Figures 6 and 7) or by the flow into the transfer tube (Figures 8, 9 and 10),

- *flow controlled systems with flow measurement* (Figures 11 and 12)

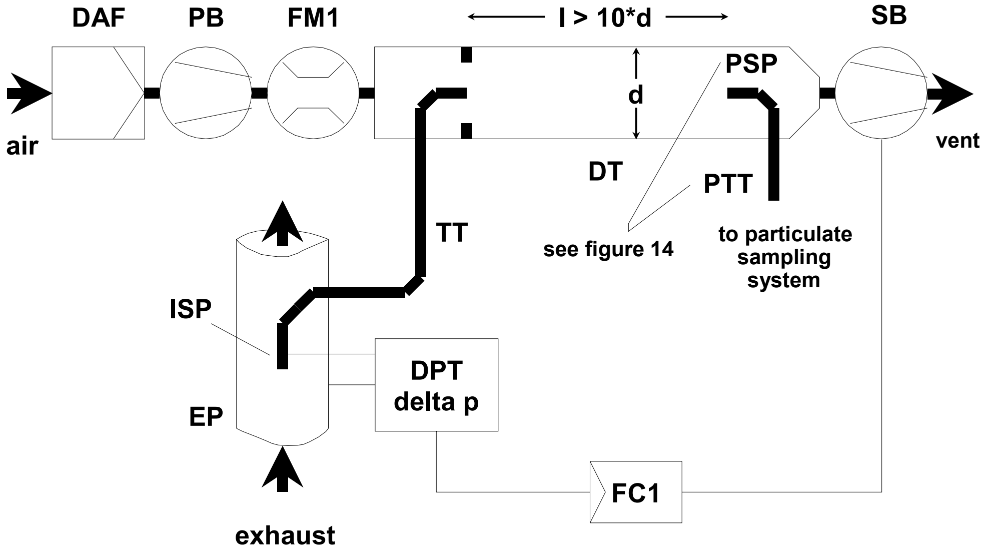
With these systems, a sample is taken from the bulk exhaust stream by setting the dilution air flow and the total dilution exhaust flow. The dilution ratio is determined from the difference of the two flow rates. Accurate calibration of the flow-meters relative to one another is required, since the relative magnitude of the two flow rates can lead to significant errors at higher dilution ratios (Figures 9 and above). Flow control is very straightforward by keeping the dilute exhaust flow rate constant and varying the dilution air flow rate, if needed.

In order to realize the advantages of the partial flow dilution systems, attention must be paid to avoiding the potential problems of loss of particulates in the transfer tube, ensuring that a representative sample is taken from the engine exhaust, and determination of the split ratio.

The systems described pay attention to these critical areas.

Figure 4

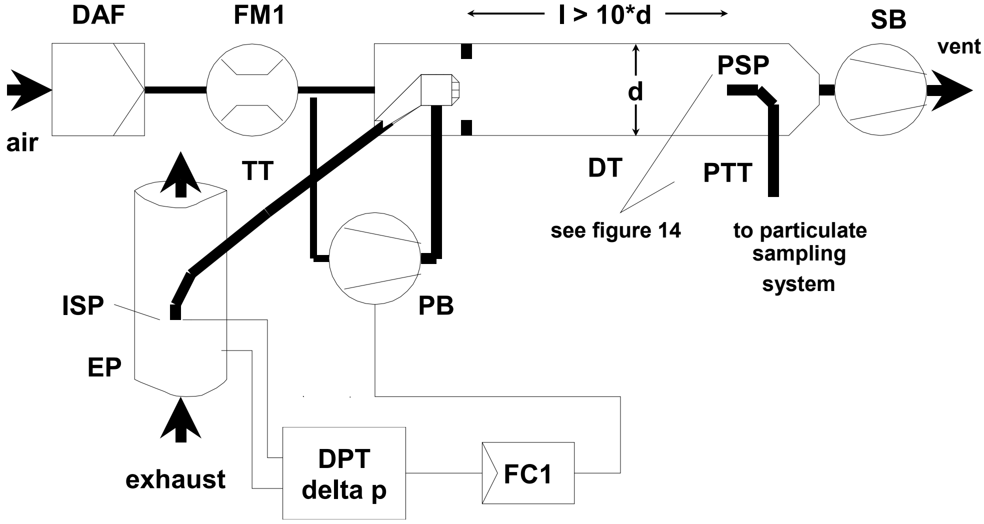
Partial flow dilution system with isokinetic probe and fractional sampling (SB control)



Raw exhaust gas is transferred from the exhaust pipe to EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the suction blower SB to maintain a differential pressure of zero at the tip of the probe. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution air flow rate is measured with the flow measurement device FM1. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

Figure 5

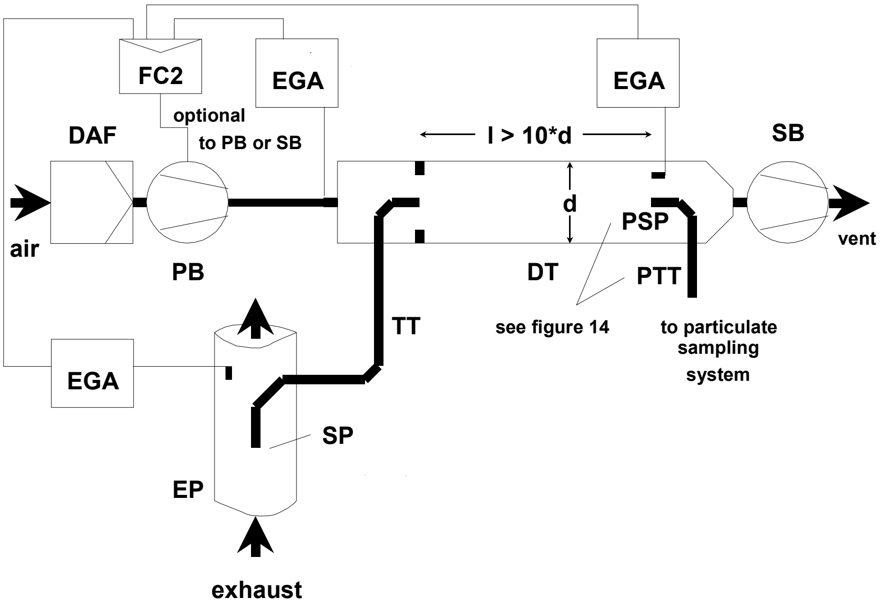
Partial flow dilution system with isokinetic probe and fractional sampling (PB control)



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the isokinetic sampling probe ISP. The differential pressure of the exhaust gas between exhaust pipe and inlet to the probe is measured with the pressure transducer DPT. This signal is transmitted to the flow controller FC1 that controls the pressure blower PB to maintain a differential pressure of zero at the tip of the probe. This is done by taking a small fraction of the dilution air whose flow rate has already been measured with the flow measurement device FM1, and feeding it to TT by means of a pneumatic orifice. Under these conditions, exhaust gas velocities in EP and ISP are identical, and the flow through ISP and TT is a constant fraction (split) of the exhaust gas flow. The split ratio is determined from the cross sectional areas of EP and ISP. The dilution air is sucked through DT by the suction blower SB, and the flow rate is measured with FM1 at the inlet to DT. The dilution ratio is calculated from the dilution air flow rate and the split ratio.

Figure 6

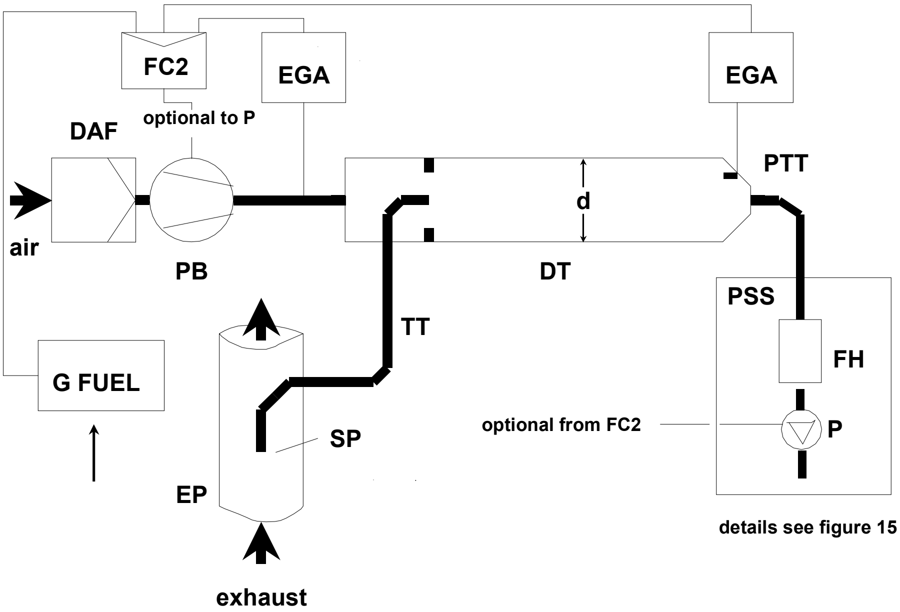
Partial flow dilution system with CO2 or NOx concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The concentrations of a tracer gas (CO2 or NOx) are measured in the raw and diluted exhaust gas as well as in the dilution air with the exhaust gas analyser(s) EGA. These signals are transmitted to the flow controller FC2 that controls either the pressure blower PB or the suction blower SB to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the tracer gas concentrations in the raw exhaust gas, the diluted exhaust gas, and the dilution air.

Figure 7

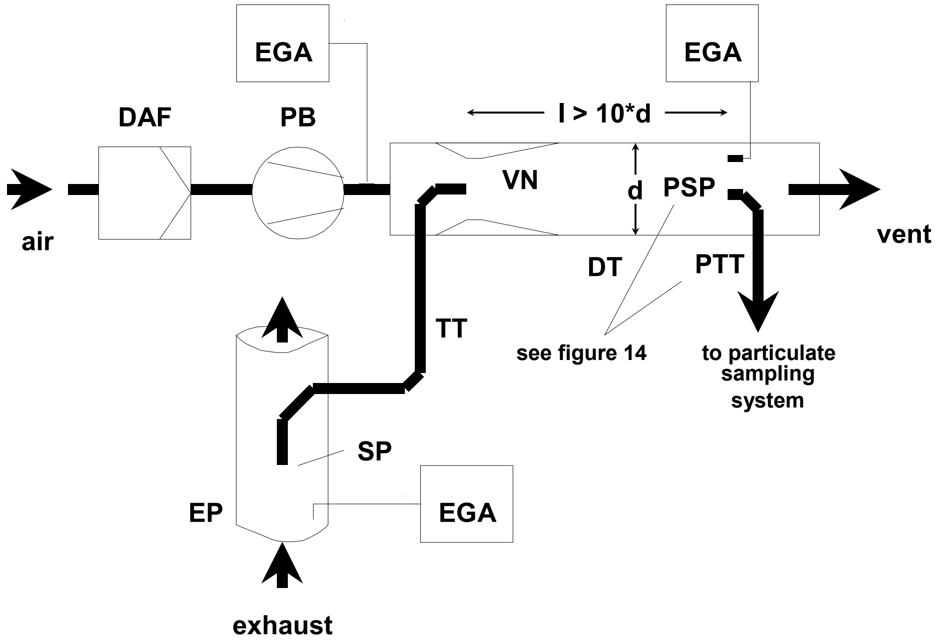
Partial flow dilution system with CO2 concentration measurement, carbon balance and total sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The CO2 concentrations are measured in the diluted exhaust gas and in the dilution air with the exhaust gas analyser(s) EGA. The CO2 and fuel flow GFUEL signals are transmitted either to the flow controller FC2, or to the flow controller FC3 of the particulate sampling system (see Figure 14). FC2 controls the pressure blower PB, while FC3 controls the particulate sampling system (see Figure 14), thereby adjusting the flows into and out of the system so as to maintain the desired exhaust split and dilution ratio in DT. The dilution ratio is calculated from the CO2 concentrations and GFUEL using the carbon balance assumption.

Figure 8

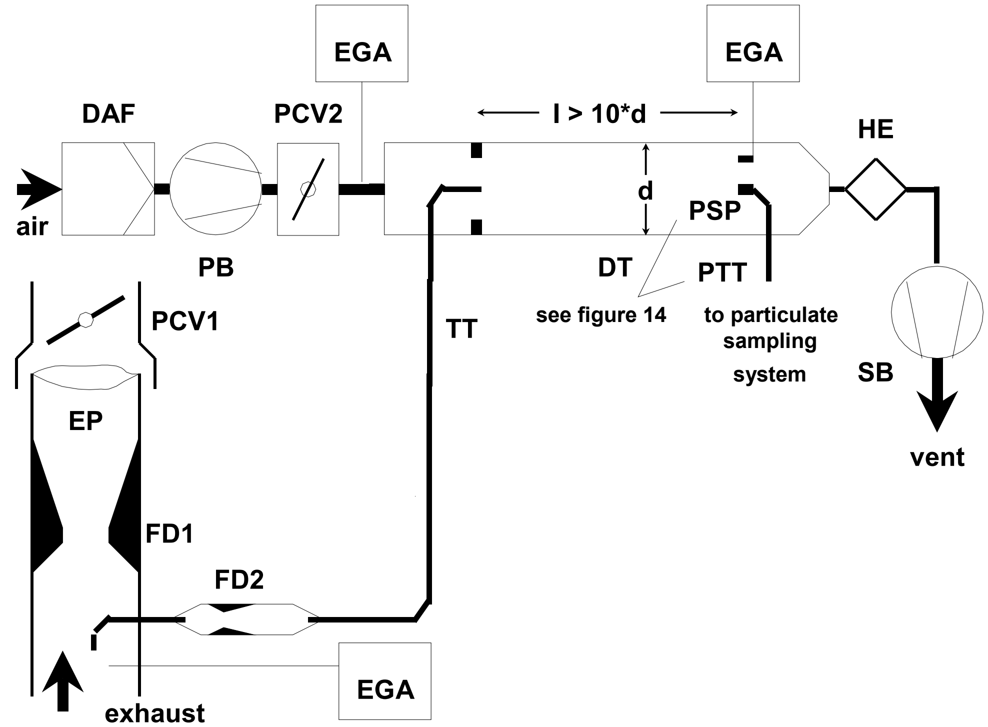
Partial flow dilution system with single venturi, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT due to the negative pressure created by the venturi VN in DT. The gas flow rate through TT depends on the momentum exchange at the venturi zone, and is therefore affected by the absolute temperature of the gas at the exit of TT. Consequently, the exhaust split for a given tunnel flow rate is not constant, and the dilution ratio at low load is slightly lower than at high load. The tracer gas concentrations (CO2 or NOx) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA, and the dilution ratio is calculated from the values so measured.

Figure 9

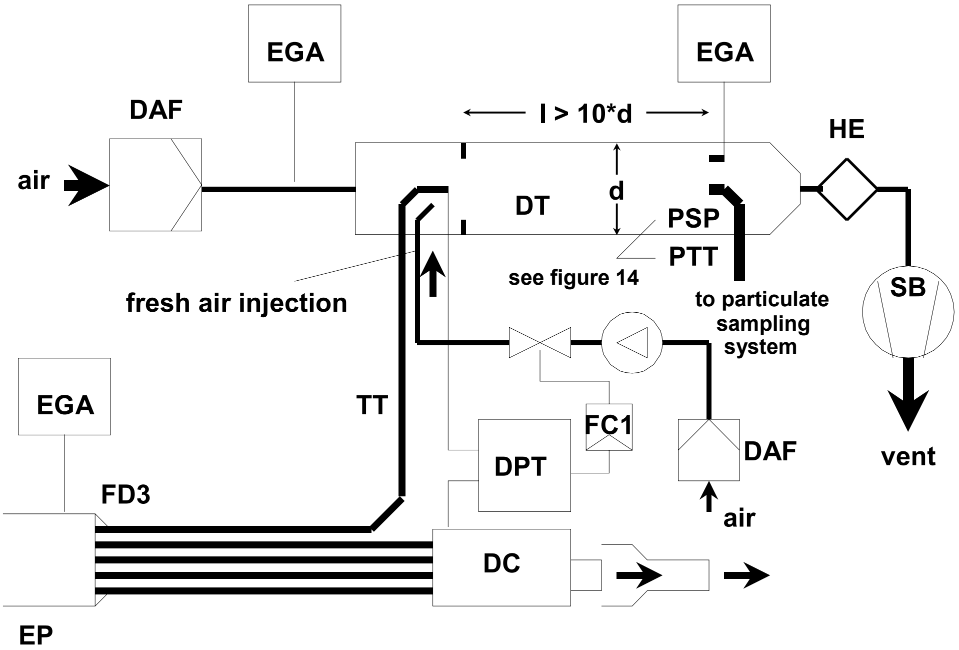
Partial flow dilution system twin venturi or twin orifice, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT by a flow divider that contains a set of orifices or venturis. The first one (FD1) is located in EP, the second one (FD2) in TT. Additionally, two pressure control valves (PCV1 and PCV2) are necessary to maintain a constant exhaust split by controlling the backpressure in EP and the pressure in DT. PCV1 is located downstream of SP in EP, PCV2 between the pressure blower PB and DT. The tracer gas concentrations (CO2 or NOx) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split, and may be used to adjust PCV1 and PCV2 for precise split control. The dilution ratio is calculated from the tracer gas oncentrations.

Figure 10

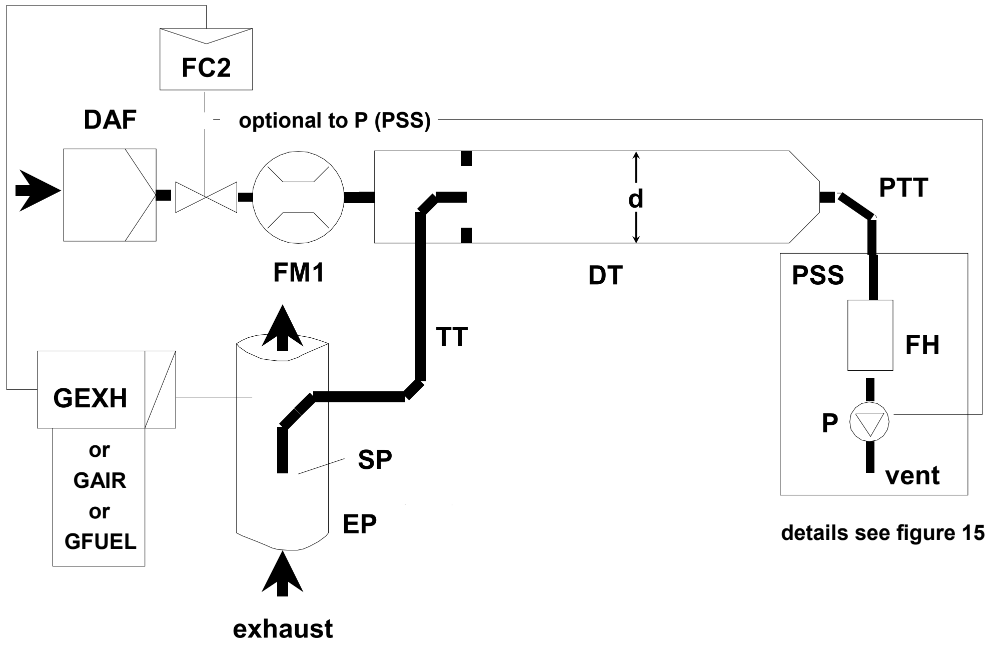
Partial flow dilution system with multiple tube splitting, concentration measurement and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the transfer tube TT by the flow divider FD3 that consists of a number of tubes of the same dimensions (same diameter, length and bed radius) installed in EP. The exhaust gas through one of these tubes is lead to DT, and the exhaust gas through the rest of the tubes is passed through the damping chamber DC. Thus, the exhaust split is determined by the total number of tubes. A constant split control requires a differential pressure of zero between DC and the outlet of TT, which is measured with the differential pressure transducer DPT. A differential pressure of zero is achieved by injecting fresh air into DT at the outlet of TT. The tracer gas concentrations (CO2 or NOx) are measured in the raw exhaust gas, the diluted exhaust gas, and the dilution air with the exhaust gas analyser(s) EGA. They are necessary for checking the exhaust split and may be used to control the injection air flow rate for precise split control. The dilution ratio is calculated from the tracer gas concentrations.

Figure 11

Partial flow dilution system with flow control and total sampling

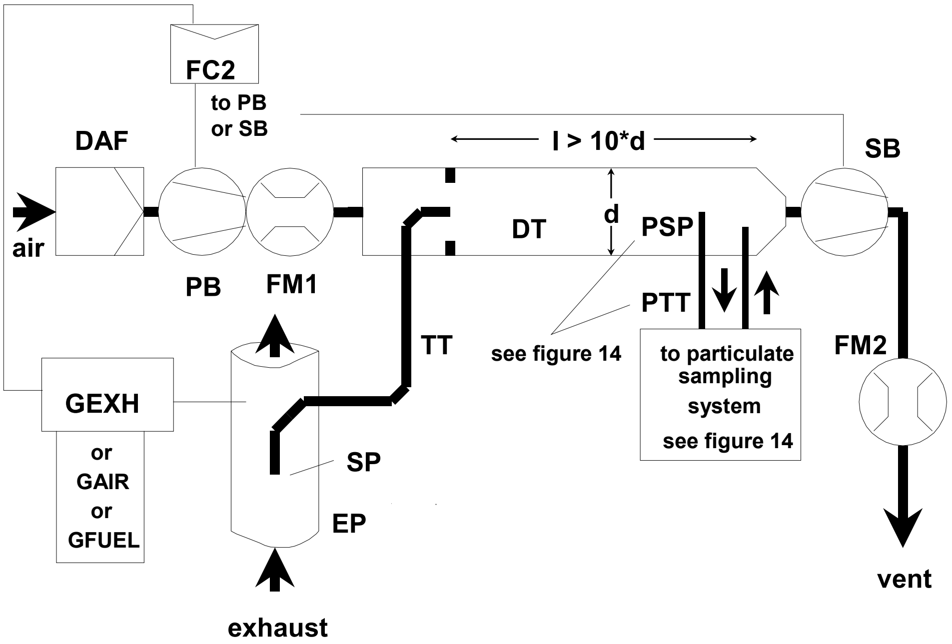


Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The total flow through the tunnel is adjusted with the flow controller FC3 and the sampling pump P of the particulate sampling system (see Figure 16)

The dilution air flow is controlled by the flow controller FC2, which may use G_{EXH}, G_{AIR} or G_{FUEL} as command signals, for the desired exhaust split. The sample flow into DT is the difference of the total flow and the dilution air flow. The dilution air flow rate is measured with flow measurement device FM1, the total flow rate with the flow measurement device FM3 of the particulate sampling system (see Figure 14). The dilution ratio is calculated from these two flow rates.

Figure 12

Partial flow dilution system with flow control and fractional sampling



Raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The exhaust split and the flow into DT is controlled by the flow controller FC2 that adjusts the flows (or speeds) of the pressure blower PB and the suction blower SB, accordingly. This is possible since the sample taken with the particulate sampling system is returned into DT. GEXH, GAIR or GFUEL may be used as command signals for FC2. The dilution air flow rate is measured with the flow measurement device FM1, the total flow with the flow measurement device FM2. The dilution ratio is calculated from these two flow rates.

Description - Figures 4 to 12

- *EP exhaust pipe*

The exhaust pipe may be insulated. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less. Bends will be minimized to reduce inertial deposition. If the system includes a test bed silencer, the silencer may also be insulated.

For an isokinetic system, the exhaust pipe must be free of elbows, bends and sudden diameter changes for at least six pipe diameters upstream and three pipe diameters downstream of the tip of the probe. The gas velocity at the sampling zone must be higher than 10 m/s except at idle mode. Pressure oscillations of the exhaust gas must not exceed ± 500 Pa on the average. Any steps to reduce pressure oscillations beyond using a chassis-type exhaust system (including silencer and after-treatment device) must not alter engine performance nor cause the deposition of particulates.

For systems without isokinetic probes, it is recommended to have a straight pipe of six pipe diameters upstream and three pipe diameters downstream of the tip of the probe.

- *SP sampling probe (Figures 6 to 12)*

The minimum inside diameter shall be 4 mm. The minimum diameter ratio between exhaust pipe and probe shall be four. The probe shall be an open tube facing upstream on the exhaust pipe centre-line, or a multiple hole probe as described under SP1 in section 1.1.1.

- *ISP isokinetic sampling probe (Figures 4 and 5)*

The isokinetic sampling probe must be installed facing upstream on the exhaust pipe centre-line where the flow conditions in section EP are met, and designed to provide a proportional sample of the raw exhaust gas. The minimum inside diameter shall be 12 mm.

A control system is necessary for isokinetic exhaust splitting by maintaining a differential pressure of zero between EP and ISP. Under these conditions exhaust gas velocities in EP and ISP are identical and the mass flow through ISP is a constant fraction of the exhaust gas flow. The ISP has to be connected to a differential pressure transducer. The control to provide a differential pressure of zero between EP and ISP is done with blower speed or flow controller.

- *FD1, FD2 flow divider (Figure 9)*

A set of venturis or orifices is installed in the exhaust pipe EP and in the transfer tube TT, respectively, to provide a proportional sample of the raw exhaust gas. A control system consisting of two pressure control valves PCV1 and PCV2 is necessary for proportional splitting by controlling the pressures in EP and DT.

- *FD3 flow divider (Figure 10)*

A set of tubes (multiple tube unit) is installed in the exhaust pipe EP to provide a proportional sample of the raw exhaust gas. One of the tubes feeds exhaust gas to the dilution tunnel DT, whereas the other tubes exit exhaust gas to a damping chamber DC. The tubes must have the same dimensions (same diameter, length, bend radius), so that the exhaust split depends on the total number of tubes. A control system is necessary for proportional splitting by maintaining a differential pressure of zero between the exit of the multiple tube unit into DC and the exit of TT. Under these conditions, exhaust gas velocities in EP and FD3 are proportional, and the flow TT is a constant fraction of the exhaust gas flow. The two points have to be connected to a differential pressure transducer DPT. The control to provide a differential pressure of zero is done with the flow controller FC1.

- *EGA exhaust gas analyser (Figures 6 to 10)*

CO2 or NOx analysers may be used (with carbon balance method CO2 only). The analysers shall be calibrated like the analysers for the measurement of the gaseous emissions. One or several analysers may be used to determine the concentration differences.

The accuracy of the measuring systems has to be such that the accuracy of $G_{EDFW,i}$ is within ± 4 %.

- *TT transfer tube (Figures 4 to 12)*

  The particulate sample transfer tube shall be:

  - as short as possible, but not more than 5 m in length,
  - equal to or greater than the probe diameter, but not more than 25 mm in diameter,
  - exiting on the centre-line of the dilution tunnel and pointing downstream.

If the tube is 1 metre or less in length, it is to be insulated with material with a maximum thermal conductivity of 0,05 W/(m · K) with a radial insulation thickness corresponding to the diameter of the probe. If the tube is longer than 1 metre, it must be insulated and heated to a minimum wall temperature of 523 K (250 °C).

Alternatively, the transfer tube wall temperatures required may be determined through standard heat transfer calculations.

- *DPT differential pressure transducer (Figures 4, 5 and 10)*

The differential pressure transducer shall have a range of ± 500 Pa or less.

- *FC1 flow controller (Figures 4, 5 and 10)*

For the isokinetic systems (Figures 4 and 5) a flow controller is necessary to maintain a differential pressure of zero between EP and ISP. The adjustment can be done by:

a) controlling the speed or flow of the suction blower (SB) and keeping the speed of the pressure blower (PB) constant during each mode (Figure 4);

or

b) adjusting the suction blower (SB) to a constant mass flow of the diluted exhaust and controlling the flow of the pressure blower PB, and therefore the exhaust sample flow in a region at the end of the transfer tube (TT) (Figure 5).

In the case of a pressure controlled system the remaining error in the control loop must not exceed ± 3 Pa. The pressure oscillations in the dilution tunnel must not exceed ± 250 Pa on average.

For a multi-tube system (Figure 10) a flow controller is necessary for proportional exhaust splitting to maintain a differential pressure of zero between the outlet of the multi-tube unit and the exit of TT. The adjustment can be done by controlling the injection air flow rate into DT at the exit of TT.

- *PCV1, PCV2 pressure control valve (Figure 9)*

Two pressure control valves are necessary for the twin venturi/twin orifice system for proportional flow splitting by controlling the backpressure of EP and the pressure in DT. The valves shall be located downstream of SP in EP and between PB and DT.

- *DC damping chamber (Figure 10)*

A damping chamber shall be installed at the exit of the multiple tube unit to minimize the pressure oscillations in the exhaust pipe EP.

- *VN venturi (Figure 8)*

A venturi is installed in the dilution tunnel DT to create a negative pressure in the region of the exit of the transfer tube TT. The gas flow rate through TT is determined by the momentum exchange at the venturi zone, and is basically proportional to the flow rate of the pressure blower PB leading to a constant dilution ratio. Since the momentum exchange is affected by the temperature at the exit of TT and the pressure difference between EP and DT, the actual dilution ratio is slightly lower at low load than at high load.

- *FC2 flow controller (Figures 6, 7, 11 and 12; optional)*

A flow controller may be used to control the flow of the pressure blower PB and/or the suction blower SB. It may be connected to the exhaust flow or fuel flow signal and/or to the CO_2 or NO_x differential signal.

When using a pressurized air supply (Figure 11) FC2 directly controls the air flow.

- *FM1 flow measurement device (Figures 6, 7, 11 and 12)*

Gas meter or other flow instrumentation to measure the dilution air flow. FM1 is optional if PB is calibrated to measure the flow.

- *FM2 flow measurement device (Figure 12)*

Gas meter or other flow instrumentation to measure the diluted exhaust gas flow. FM2 is optional if the suction blower SB is calibrated to measure the flow.

- *PB pressure blower (Figures 4, 5, 6, 7, 8, 9 and 12)*

To control the dilution air flow rate, PB may be connected to the flow controllers FC1 or FC2. PB is not required when using a butterfly valve. PB may be used to measure the dilution air flow, if calibrated.

- *SB suction blower (Figures 4, 5, 6, 9, 10 and 12)*

For fractional sampling systems only. SB may be used to measure the dilute exhaust gas flow, if calibrated.

- *DAF dilution air filter (Figures 4 to 12)*

It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. The dilution air shall have a temperature of 298 K (25 °C) ± 5 K.

At the manufacturer's request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

- *PSP particulate sampling probe (Figures 4, 5, 6, 8, 9, 10 and 12)*

The probe is the leading section of PTT and

- shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel DT centre-line of the dilution systems approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel,
- shall be 12 mm in minimum inside diameter,
- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel,
- may be insulated.

- *DT dilution tunnel (Figures 4 to 12)*

The dilution tunnel:

- shall be of a sufficient length to cause complete mixing of the exhaust and dilution air under turbulent flow conditions,
- shall be constructed of stainless steel with:
  - a thickness to diameter ratio of 0,025 or less for dilution tunnels of greater than 75 mm inside diameter,
  - a nominal wall thickness of not less than 1,5 mm for dilution tunnels of equal to or less than 75 mm inside diameter,
- shall be at least 75 mm in diameter for the fractional sampling type,
- is recommended to be at least 25 mm in diameter for the total sampling type.
- may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel.
- may be insulated.

The engine exhaust shall be thoroughly mixed with the dilution air. For fractional sampling systems, the mixing quality shall be checked after introduction into service by means of a CO_2 profile of the tunnel with the engine running (at least four equally spaced measuring points). If necessary, a mixing orifice may be used.

Note: If the ambient temperature in the vicinity of the dilution tunnel (DT) is below 293 K (20 °C), precautions should be taken to avoid particle losses onto the cool walls of the dilution tunnel. Therefore, heating and/or insulating the tunnel within the limits given above is recommended.

At high engine loads, the tunnel may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293 K (20 °C).

- *HE heat exchanger (Figures 9 and 10)*

The heat exchanger shall be of sufficient capacity to maintain the temperature at the inlet to the suction blower SB within ± 11 K of the average operating temperature observed during the test.

1.2.1.2. Full flow dilution system (Figure 13)

A dilution system is described based upon the dilution of the total exhaust using the constant volume sampling (CVS) concept. The total volume of the mixture of exhaust and dilution air must be measured. Either a PDP or a CFV or a SSV system may be used.

For subsequent collection of the particulates, a sample of the dilute exhaust gas is passed to the particulate sampling system (section 1.2.2, Figures 14 and 15). If this is done directly, it is referred to as single dilution. If the sample is diluted once more in the secondary dilution tunnel, it is referred to as double dilution. This is useful, if the filter face temperature requirement cannot be met with single dilution. Although partly a dilution system, the double dilution system is described as a modification of a particulate sampling system in section 1.2.2, Figure 15, since it shares most of the parts with a typical particulate sampling system.

The gaseous emissions may also be determined in the dilution tunnel of a full flow dilution system. Therefore, the sampling probes for the gaseous components are shown in Figure 13 but do not appear in the description list. The respective requirements are described in section 1.1.1.

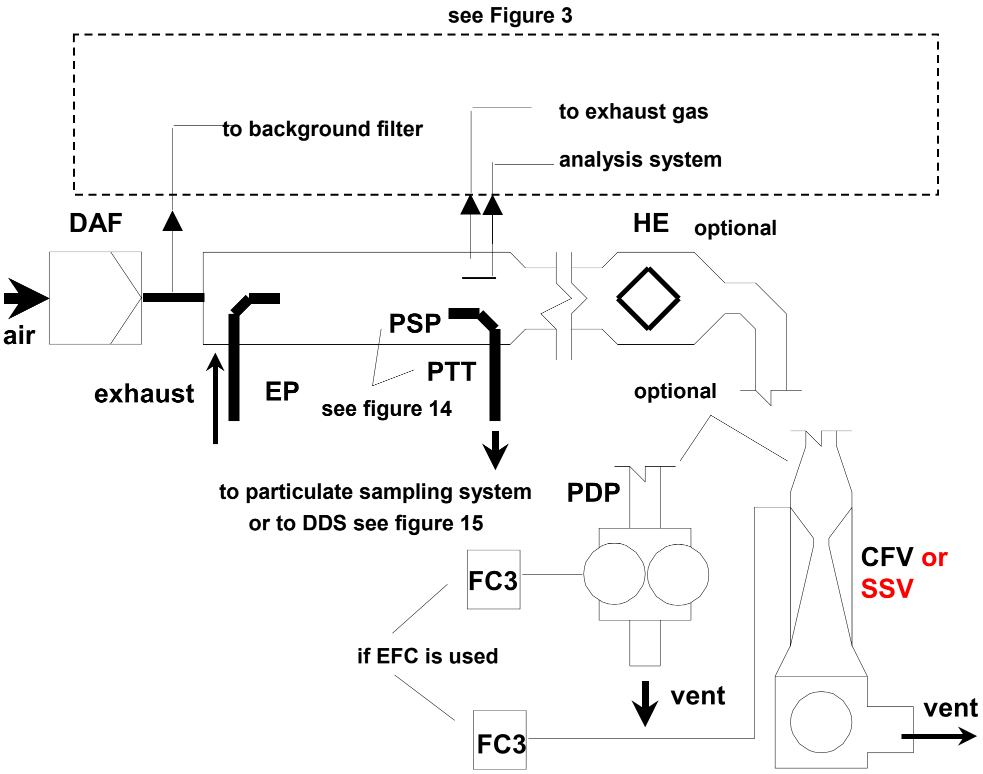
Descriptions - Figure 13

- *EP exhaust pipe*

  The exhaust pipe length from the exit of the engine exhaust manifold, turbocharger outlet or after-treatment device to the dilution tunnel is required to be not more than 10 m. If the system exceeds 4 m in length, then all tubing in excess of 4 m shall be insulated, except for an in-line smoke-meter, if used. The radial thickness of the insulation must be at least 25 mm. The thermal conductivity of the insulating material must have a value no greater than 0,1 W/(m · K) measured at 673 K (400 °C). To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0,015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less.

Figure 13

Full flow dilution system



The total amount of raw exhaust gas is mixed in the dilution tunnel DT with the dilution air. The diluted exhaust gas flow rate is measured either with a positive displacement pump PDP or with a critical flow venturi CFV or with a sub-sonic venturi SSV. A heat exchanger HE or electronic flow compensation EFC may be used for proportional particulate sampling and for flow determination. Since particulate mass determination is based on the total diluted exhaust gas flow, the dilution ratio is not required to be calculated.

- *PDP positive displacement pump*

The PDP meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system back pressure must not be artificially lowered by the PDP or dilution air inlet system. Static exhaust back pressure measured with the CVS system operating shall remain within ± 1,5 kPa of the static pressure measured without connection to the CVS at identical engine speed and load.

The gas mixture temperature immediately ahead of the PDP shall be within ± 6 K of the average operating temperature observed during the test, when no flow compensation is used.

Flow compensation can only be used if the temperature at the inlet of the PDP does not exceed 50 °C (323 K).

- *CFV critical flow venturi*

  CFV measures total diluted exhaust flow by maintaining the flow at choked conditions (critical flow). Static exhaust backpressure measured with the CFV system operating shall remain within ± 1,5 kPa of the static pressure measured without connection to the CFV at identical engine speed and load. The gas mixture temperature immediately ahead of the CFV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation is used.

- *SSV sub-sonic venturi*

SSV measures total diluted exhaust flow as a function of inlet pressure, inlet temperature, pressure drop between the SSV inlet and throat. Static exhaust backpressure measured with the SSV system operating shall remain within ± 1,5 kPa of the static pressure measured without connection to the SSV at identical engine speed and load. The gas mixture temperature immediately ahead of the SSV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation is used.

- *HE heat exchanger (optional if EFC is used)*

  The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above.

- *EFC electronic flow compensation (optional if HE is used)*

  If the temperature at the inlet to either the PDP or CFV or SSV is not kept within the limits stated above, a flow compensation system is required for continuous measurement of the flow rate and control of the proportional sampling in the particulate system. To that purpose, the continuously measured flow rate signals are used to correct the sample flow rate through the particulate filters of the particulate sampling system (see Figures 14 and 15), accordingly.

- *DT dilution tunnel*

  The dilution tunnel:

  - shall be small enough in diameter to cause turbulent flow (Reynolds number greater than 4000) of sufficient length to cause complete mixing of the exhaust and dilution air. A mixing orifice may be used,

  - shall be at least 75 mm in diameter,

  - may be insulated.

  The engine exhaust shall be directed downstream at the point where it is introduced into the dilution tunnel, and thoroughly mixed.

  When using single dilution, a sample from the dilution tunnel is transferred to the particulate sampling system (section 1.2.2, Figure 14). The flow capacity of the PDP or CFV or SSV must be sufficient to maintain the diluted exhaust at a temperature of less than or equal to 325 K (52 °C) immediately before the primary particulate filter.

When using double dilution, a sample from the dilution tunnel is transferred to the secondary dilution tunnel where it is further diluted, and then passed through the sampling filters (section 1.2.2, Figure 15). The flow capacity of the PDP or CFV or SSV must be sufficient to maintain the diluted exhaust stream in the DT at a temperature of less than or equal to 464 K (191 °C) at the sampling zone. The secondary dilution system must provide sufficient secondary dilution air to maintain the doubly-diluted exhaust stream at a temperature of less than or equal to 325 K (52 °C) immediately before the primary particulate filter.

- *DAF dilution air filter*

  It is recommended that the dilution air be filtered and charcoal scrubbed to eliminate background hydrocarbons. The dilution air shall have a temperature of 298 K (25 °C) ± 5 K. At the manufacturer's request the dilution air shall be sampled according to good engineering practice to determine the background particulate levels, which can then be subtracted from the values measured in the diluted exhaust.

- *PSP particulate sampling probe*

  The probe is the leading section of PTT and

  - shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel DT centre-line of the dilution systems approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel,

  - shall be 12 mm in minimum inside diameter,

  - may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel,

  - may be insulated.

1.2.2. Particulate sampling system (Figures 14 and 15)

The particulate sampling system is required for collecting the particulates on the particulate filter. In the case of total sampling partial flow dilution, which consists of passing the entire dilute exhaust sample through the filters, dilution (section 1.2.1.1, Figures 7 and 11) and sampling system usually form an integral unit. In the case of fractional sampling partial flow dilution or full flow dilution, which consists of passing through the filters only a portion of the diluted exhaust, the dilution (section 1.2.1.1, Figures 4, 5, 6, 8, 9, 10 and 12 and section 1.2.1.2, Figure 13) and sampling systems usually form different units.

In this Directive, the double dilution system DDS (Figure 15) of a full flow dilution system is considered as a specific modification of a typical particulate sampling system as shown in Figure 14. The double dilution system includes all important parts of the particulate sampling system, like filter holders and sampling pump, and additionally some dilution features, like a dilution air supply and a secondary dilution tunnel.

In order to avoid any impact on the control loops, it is recommended that the sample pump be running throughout the complete test procedure. For the single filter method, a bypass system shall be used for passing the sample through the sampling filters at the desired times. Interference of the switching procedure on the control loops must be minimized.

Descriptions - Figures 14 and 15

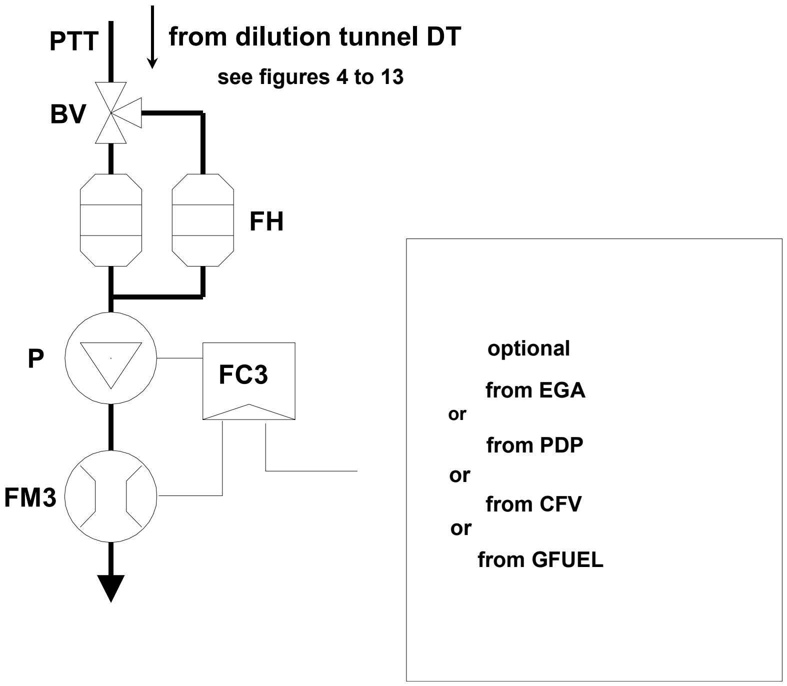
- *PSP particulate sampling probe (Figures 14 and 15)*

  The particulate sampling probe shown in the figures is the leading section of the particulate transfer tube PTT. The probe:

  - shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel DT centre-line of the dilution systems (see section 1.2.1), approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel),
  - shall be 12 mm in minimum inside diameter,
  - may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel,
  - may be insulated.

Figure 14

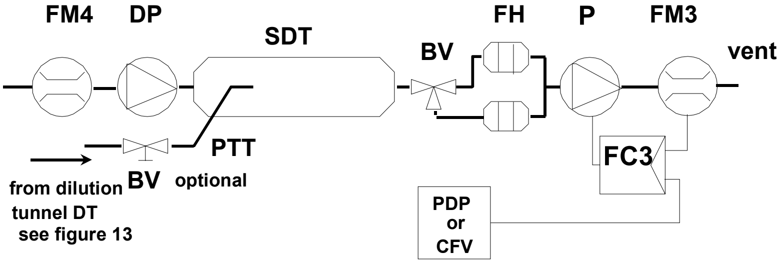
Particulate sampling system



A sample of the diluted exhaust gas is taken from the dilution tunnel DT of a partial flow or full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT by means of the sampling pump P. The sample is passed through the filter holders(s) FH that contain the particulate sampling filters. The sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 13) is used, the diluted exhaust gas flow is used as command signal for FC3.

Figure 15

Dilution system (full flow system only)



A sample of the diluted exhaust gas is transferred from the dilution tunnel DT of a full flow dilution system through the particulate sampling probe PSP and the particulate transfer tube PTT to the secondary dilution tunnel SDT, where it is diluted once more. The sample is then passed through the filter holder(s) FH that contain the particulate sampling filters. The dilution air flow rate is usually constant whereas the sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see Figure 13) is used, the total diluted exhaust gas flow is used as command signal for FC3.

- *PTT particulate transfer tube (Figures 14 and 15)*

  The particulate transfer tube must not exceed 1 020 mm in length, and must be minimized in length whenever possible.

  The dimensions are valid for:

  - the partial flow dilution fractional sampling type and the full flow single dilution system from the probe tip to the filter holder,
  - the partial flow dilution total sampling type from the end of the dilution tunnel to the filter holder,
  - the full flow double dilution system from the probe tip to the secondary dilution tunnel.

  The transfer tube:

  - may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel,
  - may be insulated.

- *SDT secondary dilution tunnel (Figure 15)*

  The secondary dilution tunnel should have a minimum diameter of 75 mm and should be sufficient length so as to provide a residence time of at least 0,25 seconds for the doubly-diluted sample. The primary filter holder, FH, shall be located within 300 mm of the exit of the SDT.

  The secondary dilution tunnel:

  - may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel,

  - may be insulated.

- *FH filter holder(s) (Figures 14 and 15)*

  For primary and back-up filters one filter housing or separate filter housings may be used. The requirements of Annex III, Appendix 1, section 1.5.1.3 have to be met.

  The filter holder(s):

  - may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre-heating, provided the air temperature does not exceed 325 K (52 °C),

  - may be insulated.

- *P sampling pump (Figures 14 and 15)*

  The particulate sampling pump shall be located sufficiently distant from the tunnel so that the inlet gas temperature is maintained constant (± 3 K), if flow correction by FC3 is not used.

- *DP dilution air pump (Figure 15) (full flow double dilution only)*

  The dilution air pump shall be located so that the secondary dilution air is supplied at a temperature of 298 K (25 °C) ± 5 K.

- *FC3 flow controller (Figures 14 and 15)*

  A flow controller shall be used to compensate the particulate sample flow rate for temperature and backpressure variations in the sample path, if no other means are available. The flow controller is required if electronic flow compensation EFC (see Figure 13) is used.

- *FM3 flow measurement device (Figures 14 and 15) (particulate sample flow)*

  The gas meter or flow instrumentation shall be located sufficiently distant from the sample pump so that the inlet gas temperature remains constant (± 3 K), if flow correction by FC3 is not used.

- *FM4 flow measurement device (Figure 15) (dilution air, full flow double dilution only)*

  The gas meter or flow instrumentation shall be located so that the inlet gas temperature remains at 298 K (25 °C) ± 5 K.

- *BV ball valve (optional)*

  The ball valve shall have a diameter not less than the inside diameter of the sampling tube and a switching time of less than 0,5 seconds.

Note: If the ambient temperature in the vicinity of PSP, PTT, SDT, and FH is below 239 K (20 °C), precautions should be taken to avoid particle losses onto the cool wall of these parts. Therefore, heating and/or insulating these parts within the limits given in the respective descriptions is recommended. It is also recommended that the filter face temperature during sampling be not below 293 K (20 °C).

At high engine loads, the above parts may be cooled by a non-aggressive means such as a circulating fan, as long as the temperature of the cooling medium is not below 293 K (20 °C).

ANNEX III

"Annex XIII

PROVISIONS FOR ENGINES PLACED ON THE MARKET UNDER A "FLEXIBLE SCHEME"

1. By the request of an equipment manufacturer (OEM) an engine manufacturer might during the period between two stages of limit values place a limited number of engines on the market that only comply with the previous stage of emission limit values in accordance with the following provisions.

2. An approval authority shall, on the request by an OEM allow the placing on the market of a limited number of engines in each power band that do not comply with the mandatory emission limit values.

2.1. The number of engines exempted shall not exceed 20% of one yearly production of each power band calculated as the average of the latest 5 years of distribution on the EU market.

2.1.1 As an option to paragraph 2.1 a manufacturer may instead chooseto exempt a fixed number of pieces in one or more power bands not exceeding the following: 50 pieces for 130-560 kW, 100 pieces for 75-130 kW, 150 pieces for 37-75 kW and 200 pieces for 19-37 kW.

2.2. The approval authority shall provide the OEM with a set of labels to be placed on the equipment using the engines under the flexible scheme with the following text: "Machine no … (sequence of machines) of … (total number of machines in respective power band) in accordance with approval no ….

2.3. The approval authority should use the identifications in annex VIII to identify the approvals. Example (Austria): 12/2005/1.

2.4. The approval authority shall notify all other approval authorities by sending a copy of the decision to them.

2.5. The OEM shall provide the approval authority with all information necessary for the decision.

2.6. The OEM shall cover all costs caused for the approval authority by the procedure of this flexible scheme.

3. An engine manufacturer may place on the market engines under a flexible scheme covered by an approval in accordance with Paragraph 2 of this annex.

3.1. The engine manufacturer shall include the information on those engines and necessary documentation to the approval authority from which he apply for the type approval for the engine families concerned.

3.2. The engine manufacturer must put a label on those engines with the following text: "Engine placed on the market under flexible scheme.