Position of the CIMAC WG 5 Exhaust Emissions Control about

"Requirements for Prime Mover Technique Specific Emission Limits Stationary Reciprocating Engine Plant"

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CIMAC (International Council on combustion engines) is an international organisation, founded in 1950 to promote technical and scientific knowledge in the field of internal combustion engines. It is supported by engine manufacturers, engine users, technical universities, research institutes, component suppliers, fuel and lubricating oil suppliers, classification societies and several other interested parties.

Within CIMAC there are several working groups. This position has been elaborated by the Working Group "Exhaust Emission Controls (EEC) Working Group (WG) subgroup land based power plant", dealing with stationary reciprocating engine power plants.

Abbreviations:

BREF	**Best Available Technique Reference Document**
CEMS	**Continuous Emission Monitoring**
CHP	**Combined Heat and Power; production of simultaneous electricity and heat**
CI	**Combustion Ignition (Diesel Engine)**
CO	**Carbon monoxide**
CO_2	**Carbon dioxide**
DA	**Degraded Airshed**
DF	**Dual Fuel, engine which needs a liquid fuel for the ignition of the low pressure gas, engine can operate at full load both in gas (low pressure gas)- or liquid fuel modes**
EA	**Environmental Assessment**
ECA	**Emission Control Area**
EHS	**Environmental Health and Safety**
EPA	**Environmental Protection Agency**
EU	**European Union**
Equator Principles	**Agreement between IFC and banks/other financial institutions to follow the social and environmental performance standards of IFC as a minimum in their projects in order to strengthen their environmental and social risk management**
FGD	**Flue Gas Desulphurization**
GHG	**Green House Gas**
GD	**Gas Diesel, diesel engine which needs a pilot liquid fuel for the ignition of the gas fuel, engine can operate at full load both in gas (high pressure gas)- or liquid fuel modes**
HHV	**Higher Heat Value**
ISO	**International Organization for Standardization**
g/kWh_e	**gram e.g. emission per produced electrical energy (kWh)**
$g/kWh_{heat + electricity}$	**gram e.g. emission produced per electrical and thermal energy (kWh)**
IFC	**International Finance Corporation, branch of World Bank**
IMO	**International Maritime Organisation**
JIS	**Japanese Industrial Standards**
LCP	**Large Combustion Plant**
LHV	**Lower Heat Value**

MCR	**Maximum Continuous Rating**
Miller concept	**A concept with an early inlet air valve closing thus suppressing the in cylinder combustion temperature reducing NOx formation**
MPG	**Micro Pilot Gas, engine which needs a liquid pilot fuel for the ignition of the gas. Can operate only in gas mode**
MWe	**MegaWatt electrical**
NDA	**Non Degraded Airshed**
MWth	**MegaWatt thermal (heat input or recovered heat)**
NESHAP	**National Emission Standard for Hazardous Pollutants**
NOx	**Nitrogen Oxides (sum of NO, NO2)**
NSPS	**New Source Performance Standard**
OECD	**Organisation of Economic Co-operation and Development**
O2	**Oxygen**
PM	**Particulate Matter (dry dust)**
R&D	**Research & Development**
Rpm	**revolution per minute**
SCR	**Selective Catalytic Reaction, method used for NOx abatement**
SG	**Spark Ignited; gas fired engine equipped with a spark plug or other ignition device**
SO_2	**Sulphur dioxide**
TA-LUFT	**Technische Anleitung zur Reinhaltung der Luft, German norm**
UK	**United Kingdom**
US	**United States of America**
WB	**World Bank**

1. Background

In 1990´s the stationary (reciprocating) engine power plant increased its´ market share rapidly and is today one of the leading prime mover techniques used around the world.

Both bigger base load reciprocating engine driven power plants with an output up to several hundreds of MW_e (electricity), decentralized smaller simultaneous heat and power (CHP) production plants, public grid stabilization, gas compression and crude oil pumping applications are common today. The main reasons for this development are the privatization, deregulation and decentralization of the markets in many countries combined with past decades development of high efficiency reciprocating engines suitable for base load operation. The deregulated power plant market is asking for cost-effective: multi fuel, reliable, fast deliveries (short construction times), operational flexible and environmental friendly solutions, features which the stationary (reciprocating) engine can provide.

Modern environmental legislation standards are technique specific, i.e. for each prime mover technology (boilers, gas turbines, stationary engines) own/separate regulations apply. Existing national/international legislation or guidelines with specific emission limits for *stationary engine (reciprocating engine) plants* can be found in e.g. Japan, Taiwan, India, UK, France, Germany, Finland, Ecuador, IFC (International Finance Corporation the private sector arm of World Bank) "Thermal Power Plants EHS (Environmental, Health and Safety) Guidelines 2008" /1A/, "General EHS Guidelines 2007" /1B/ and many other countries are developing such a regulations. The Performance Standards of IFC form the basis of the Equator Principles. EHS Guidelines are part of Performance Standard 3. Key finance banks have adopted the Equator Principles for financing projects with a capital cost of 10 million USD or above. Many public development financial institutions such as OECD Export Credit Agencies and European Development Finance institutions have also publicly announced the use of the Equator Principles. The Performance Standards have become a global benchmark for managing environmental and social risk by financial institutions. It is estimated that over 70 % of projects finance activities in emerging markets is now carried out in accordance with the Equator Principles /9/. EHS Guidelines have thus in practise become the minimum environmental norm in the power plant sector world wide. In Appendix 1 the IFC/WB Guidelines /1A, 1B/ emission limits for stationary engine plants are given.

One additional aspect seen in progressive legislations is the cost-effective environmental quality need driven approach, i.e. stricter limits in polluted zones (e.g. in cities) and leaner ones in "other areas", such trends can be observed in Japan /4/, IFC Guidelines /1A, 1B/ and India /5/. A similar approach is made by IMO for marine engines by the introduction of Emission Control Area (ECAs) with strigent NO_x and SO_x limits compared to normal areas.

In many places a general development in the environmental legislation seems to have been the following: in the past starting with boiler plants and today extended to boiler/gas turbine/stationary engine technique specific limits which is a logical development. Such a trend can be seen in the development of the IFC/WB EHS Guidelines for Power Plants (1988 and 2007/2008 versions). In the new IFC EHS Guidelines the Thermal Power Plants and General EHS Guidelines are *"joint Guidelines"* i.e. stack emission limits in either of these Guidelines (dependent on plant size) are referred to in the other sector specific Guidelines. By this approach the different prime movers: boiler, gas turbine or reciprocating (stationary) engine have their own technique specific emission limits in all 63 Guidelines (62 sector specific and General EHS Guidelines). However, there still exist many national emission legislation which seem to be primarily made with a view to boiler plants or gas turbine applications (in focus) but are considered to be extended with only minor or even without any modification to stationary reciprocating engines.

This document briefly explains the importance of technique specific emission regulations.

2. Stationary engine plant strengths

In this chapter some general features of the stationary engine plant are presented. The subchapters are:

- **engine types & fuel options**
- **environmental (technique development)**
- **other environmental advantages of the stationary engine power plant**
- **summary**

2.1. Engine types & fuel options

The low-speed (< 300 rpm) and medium-speed (300 < n < 1200 rpm) engines are often used in continuous power generation. High speed engines (> 1200 rpm) are mostly used in peak load applications, high-speed engines are often derived from truck engines or engines intended for the use in non-road mobile machinery applications like construction vehicles and locomotive/railcar engines. The most used engine types can further be divided into diesel, spark ignited, micro pilot and (low pressure gas) dual fuel engines. In the following unit sizes available and fuel options for the different engine types are given.

- **Diesel engines (CI)** (the medium speed four stroke trunk piston engine is available up to about 25 MW_e unit sizes and low speed two stroke crosshead piston engine up to about 90 MW_e unit sizes) operate on diesel oil, heavy fuel oil, crude oil, (**high pressure**) natural/associated gas (**GD**), fuel emulsions (e.g. Orimulsion), refinery vacuum residuals and sometimes even bio fuels (gas or oils, dependent on the engine type). In gas operation the pilot fuel share is typically up to 5 % of the total heat input. The smaller high speed engine types (unit size output up to a few MW) are mostly using diesel oil (distillates) as fuel.
- **Spark ignited (SG) Otto-type engines** (available up to about 10 MW_e unit sizes) operating primary on (low pressure) natural gas and depending on engine type sometimes on landfill, mining (coal bed), bio and even pyrolysis gases. This is a pure gas engine; it operates only on gaseous fuels. Ignition of the fuel gas is initiated with a spark plug or some other device. Bigger size engine units typically > 50 kW_e are nowadays usually of lean burn type, working according to the otto principle.
- **Dual fuel (DF) (and Micro Pilot (MPG)) engines** (available up to about 17 MW_e unit sizes), the primary fuel is (low pressure) natural gas with liquid pilot fuel (needed for ignition) share of 1 .. 2 % of heat input. Some DF engine types (except MPG type) are fuel versatile and can operate at full load in both liquid and gaseous fuel modes, the back-up fuel is such as diesel oil, heavy fuel oil, etc. The engine type is working according to the otto principle in gas mode and in liquid fuel operation according to the diesel principle.

2.2. Environmental (technique development)

As a result of an extensive R&D work NO_x-emissions from bigger liquid fuel fired **diesel engines** have been reduced remarkably by primary measures (typically up to about 40 %) since the 90´s of the past century. The NO_x formation rate in a diesel engine is largely temperature driven and consequently a function of the local high-temperature areas and their duration during combustion. Primary methods are:

- Low-NO_x combustion (“dry method”) has among others been focusing on optimizing the closing timing of the inlet valve (“Miller concept”) and design of fuel injection equipment on the engine; an early inlet valve closing suppresses the in-cylinder combustion temperature which reduces NO_x formation.
- “Wet methods”: Water has a positive influence on reducing NO_x formation by cutting temperature peaks in the combustion process. Methods such as water/fuel oil emulsion, humidification of the combustion air, etc. are available depending on the applicable engine design. These techniques have so far been used mostly in ship applications where the engines are used very differently compared to in a stationary plant. Special attention should be paid on the purity of the used water/steam otherwise fouling and corrosion will occur on the engine components which will heavily affect the reliability and availability of the stationary reciprocating plant. The water consumption need is significant.

In many parts of the world water is a scarce resource and should therefore preferable only be used for agriculture and other community needs and therefore “dry” inbuilt abatement methods are preferred. Mechanical, thermal loading and fuel consumption limitations, etc. aspects are factors to consider when applying primary NO_x reduction methods.

The strategy for liquid fired (< 300 MW_{th}) and gas fired stationary (reciprocating) engine plants is to fulfill the *IFC stack emission Guidelines /1A, 1B/* for installations located in a “non-degraded” air shed by using primary methods. This includes for the liquid fired engine a suitable choice of fuel, and the use of the Low-NO_x combustion concept. It is to note that the NO_x-limits stipulated are dependent on the engine type: diesel or DF (Dual Fuel) and for diesels (CI) also on bore size. Gas fired reciprocating engines have different NO_x emission limits dependent on type: SG, DF (MPG) or high pressure gas diesel (GD). In gas mode SG, and DF/ MPG engine types use the lean burn concept and GD engine tuning in order to comply with set NO_x-limits.

The sulphur dioxide (SO_2) and particulate emission mainly depend on the used fuel composition such as the sulphur and ash content. A low sulphur/ash liquid fuel or natural gas is the primary method to keep sulphur dioxide and particulate emissions low.

For plants in in areas (degraded air-sheds such as big cities) subject to strict requirements on the air emissions or where poor low-cost (high sulphur) fuel qualities are the only choice, secondary flue gas emission abatement equipment is available, if needed. It is also to note that in the IFC Guidelines /1A/ liquid fired reciprocating engine plants $\geq$ 300 MW_{th} have stricter emission limits than smaller size plants and these have to use a better fuel quality; in order to comply with set SO_2 and PM limits; and in many cases for NO_x abatement a SCR. It must be noted that some secondary emission reduction techniques set specific pre-requirements for a trouble free operation, e.g. SCR (Selective Catalytic Reduction) as follows:

- a minimum inlet flue gas temperature (dependent on the sulphur content of the fuel) is needed in order to avoid clogging of the SCR elements
- some trace metals which might be present in the fuel might act as catalyst poisons and can cause premature aging of the catalyst, etc.
- a soot blowing system is needed in the reactor, especially when operating on liquid fuels

- regular maintenance and inspection in order to maintain low ammonia slips that are harmful for components situated after the SCR reactor
- supply of reagents (pure ammonia, aqueous ammonia or urea) needs to be ensured
- proper disposal of used SCR-elements

Modern bigger **gas engine types (SG, MPG, DF) in gas mode** are usually of lean-burn type ("a lean mixture of combustion air and fuel is drawn or forced into the cylinder"). NO_x formation in an engine is a function of both flame temperature and residence time. Lean combustion decreases the fuel/air ratio in those zones where NO_x is formed and thus the peak temperature is lower and therefore thermal NO_x formation is suppressed. The lean-combustion concept is analogous to the dry low NO_x concept used in modern gas turbines. An added advantage with lean burn operation is the high output and efficiency. The gas fired lean-burn engine type fulfils most national legislation with primary methods only, sometimes in countries with stricter emission requirements (e.g. *German TA-LUFT 2002, federal US SI NSPS /7/, US NESHAP /8/*) an oxidation catalyst is needed for reducing unburned emissions (such as CO, formaldehydes, etc.).

Engines, which are using bio gases, bio oils, associated gases (e.g. in oil fields) or residual gases such as coal bed methane contribute also to a decrease in the green house gas emission. These fuels would otherwise be burned with a low efficiency e.g. in boiler plants or contribute unused to the atmospheric pollution or be replaced with a commercial fossil fuel (such as oil, etc.).

2.3. Other environmental advantages of the stationary engine power plant

- **Low water consumption**

  In many locations around the world water resources are limited. Radiator cooling is very suitable for the stationary engine plant and by this approach the *fresh water need of the power plant can be very low* (e.g. a 130 MW_e stationary engine plant with primary flue gas cleaning methods needs only a few m^3/h of make-up water. A same size electrical output cooling tower cooled steam boiler plant should need hundreds of m^3/h of fresh water).

- **High efficiency and thereby a low specific CO_2 emission**

  The stationary engine power plant is compact and can therefore be situated in urban or industrial areas close to the electricity and heat consumers. Thus *associated energy losses and land need for transmission lines and heat pipes are reduced.* The reciprocating engine has a high electrical efficiency ranging from 40 % for the medium size engines up to about 50 % for large engines in single cycle and even higher efficiencies in combined cycle operation. High efficiencies results in a *low specific fuel consumption (g/kWh_e) and as a consequence a low specific emission of CO_2* (today in focus due to the Kyoto Protocol and other international/national deliberations) the most important "green house" gas. The reciprocating engine is well suited for decentralized combined heat and power (CHP) simultaneous production of electricity and heat, i.e. for hot water, steam generation, cooling (with absorption chillers) systems, desalination of sea water systems, etc. The cogeneration projects can reach an overall efficiency up to *90 % or higher* depending on the application and as a consequence the specific CO_2 emission is further decreased (g/$kWh_{heat+electricity}$).

In some countries e.g. in the UK /2/ and Turkey /6/, an efficiency bonus is granted for high efficient stationary reciprocating engine units. In Turkey the efficiency bonus is also extended to include efficient CHP applications.

- **Fast load response**

The cold-start up time of a stationary diesel /gas engine power plant is short compared to a coal/oil fired boiler steam turbine plant or a combined cycle gas turbine plant. A warm medium speed diesel/gas engine has a quick response capability to network changes (a typical load application rate 20 % of MCR/minute, on some diesel engines ("emergency") even an up to a 30 % MCR/minute rate can be achieved), a normal coal/oil fired boiler steam turbine plant has a typical load application of about 5 % of MCR/minute. The stationary engine can therefore fast be utilized for the network spinning reserve and help to stabilize the grid. It is expected that in the near future more plants will be needed in order to stabilize the public grid due to the large increase in renewable energy production (e.g. wind and solar power) due to efforts to decrease greenhouse gas emissions (Kyoto Protocol impact) and enhanced sustainability in power production. This trend has already started in some industrial countries such as in the USA.

- **Flexibility, etc.**

A bigger stationary engine plant is usually consisting of several engines and is therefore flexible in operation (e.g. *optimal matching of different load demands*). On contrary to the turbine plants reciprocating engine plants can run on part load maintaining a high efficiency.

Stationary engine plant features are also: a *short construction time, easy maintenance (which does not require high-tech equipment and experience) and a robust design.*

2.4. Summary

When comparing emissions from a stationary engine power plant with other prime movers the exhaust gas emissions and other aspects should be considered in a balanced way. Each prime mover technique has its´ pros and cons. E.g. a liquid fired radiator cooled stationary (reciprocating) engine plant has a *lower fuel consumption (and thus a lower specific CO_2 and SO_2 (primary method: with same fuel oil) emissions per produced electricity*) due to the high efficiency 40 … 50 % (in single cycle mode, dependent on engine size) and *a much lower fresh water consumption* than the steam boiler power plant. Thus scarce natural resources are saved (fuel and fresh water).

In some countries this sustainable feature is rewarded via a granted efficiency bonus for emission limits.

3. Air emission concentration limit aspects

Some main features of the stationary engine plant are shown below, which deviate from the well-known steam-boiler plant (for which emission legislation exists in most countries).

If, the emission limits can not be achieved by use of primary methods a secondary reduction method is to be applied. The emission abatement technique will "face" the emission at "*actual" flue gas conditions which have a big impact* on its´ performance. Therefore emission limits should be expressed close to "actual conditions".

Flue gas aspects:

- **Flue gas outlet temperature (from prime sources)**
  - - Large bore reciprocating engine typically in order of 250 400 degree C
  - - Oil fired boiler typically about 170 degree C.

- **Oxygen content (a high oxygen content results in a bigger flue gas mass flow kg/MWh$_e$)**
  - Large bore reciprocating engine (> 1500 kW$_e$)
    - Oil mode 13 … 16 vol-% O_2
    - Gas mode 11 … 15 vol-% O_2
  - Oil fired boiler 2 … 5 vol-% O_2

- **Pressure**
  - Reciprocating (stationary) engine
    - Overpressure and pressure fluctuations in flue gas
  - Boiler
    - Even pressure in flue gas

For instance in IFC Guidelines /1A, 1B/ the following limits for particulates[1)] are given (in non-degraded air-sheds, NDA):

- Oil (boiler) fired power plant > 50 MW$_{th}$: 50 mg/Nm^3 (3 % O_2)
- Oil (boiler) fired power plant ≤ 50 MW$_e$: 50 … 150[2)] mg/Nm^3 (3 % O_2), ("middle value" 100 mg/Nm^3 used in below calculation)
- Stationary (reciprocating) engine power plant > 50 MW$_{th}$: 50 mg/Nm^3 (15 % O_2)
- Stationary (reciprocating) engine power plant ≤ 50 MW$_{th}$: 50 …100[3)] mg/Nm^3 (15 % O_2), ("middle value" 100 mg/Nm^3 used in below calculation)

Now when "adapting" *above limit figures* to the *"actual"* flue gas conditions the following results are obtained:

- Oil (boiler) fired power plant > 50 MW$_{th}$ (3 % O_2, 170 degree C):
  - about 31 mg/"actual" m^3
- Oil (boiler) fired power plant ≤ 50 MW$_{th}$ (3 % O_2, 170 degree C):
  - about 62 mg/"actual" m^3

[1)] Measurement method US EPA 17, ISO 9096 2003, JIS 8808 or principally similar other methods

[2)] if justified by Environmental Assessment

[3)] if justified by project specific considerations

- Stationary engine (engine driven) power plant > 50 MW_{th} (13 % O_2, 350 degree C):
    - about 29 mg/"actual" m^3
- Stationary engine (engine driven) power plant ≤ 50 MW_{th} (13 % O_2, 350 degree C):
    - about 58 mg/"actual" m^3

UK /2/ and EU LCP BREF /3/ has similar limits for particulates as IFC /1A, 1B/ for the stationary (reciprocating) engine plant.

In this context it may also be mentioned that the emission reference point for a liquid/gas fired gas turbine is 15 % O_2 and for a liquid/gas fired boiler plant 3 % O_2. The reasons for these approaches are the "actual conditions" of the flue gas.

From above can be seen that own technique specific emission limits are logical for stationary engine plants as is also the case in modern progressive environmental legislation in many countries and in IFC EHS Guidelines /1A, 1B/. In IFC EHS Guidelines, EU LCP BREF /3/, India /5/, Portugal /10/, Finland /11/, USA /7/, etc. 15 vol-% O_2 *is used as the emission concentration reference point for stationary (reciprocating) plants.*

4. Conclusion

Today the stationary engine plant belongs to the biggest prime mover techniques used in base load power generation and many other applications around the world.

When comparing emissions from the stationary engine power plant with other prime movers all exhaust gas emissions and other aspects (saving of natural resources such as raw water, fuel consumptions, etc.) should be considered in a balanced way. A practical approach is to give the emission limits as volume concentrations, which means that the emission can easily be measured directly and complicated calculations are avoided. Above text shows that for bigger stationary engines the reference point for the emission concentration should be set to 15 vol-% O_2.

A higher efficiency means that certain specific emission components produced (such as CO_2 and SO_2) become lower per produced electricity (g/kWh_e). This should be reflected by an efficiency incentive. Greenhouse gas (GHG) emissions and water consumption are expected to become more in focus in the future /9/.

Modern emission legislation has technique specific emission limits. An additional aspect in progressive norms is the cost-effective environmental quality need driven approach (e.g. different norms for city areas and "other" areas).

5. References

/1A/ IFC “Thermal Power Plants EHS Guidelines” 2008

/1B/ IFC “General EHS Guidelines”, 2007

/2/ UK: “The Environmental Protection Act 1990, part 1 (1995 Revision), (PG1/5(95): Secretary of State’s Guidance-Compression Ignition Engines, 20 – 50 MW Net rated Thermal Input”

/3/ EU (European Union) LCP (Large Combustion Plant) BREF (Reference Document on Best Available Techniques) , July 2006

/4/ Japan: “Nationwide general limits”

/5/ India: “Environment (Protection) Third Amendment Rules 2002”

/6/ Turkey, ”Industrial Air pollution Control Regulation”, July 2006

/7/ US-EPA SI NSPS: 40 CFR Parts 60, 63, 85, et al. “Standards for Performance for Stationary Spark Ignition Internal Combustion Engines .”, January 18, 2008

/8/ US-EPA: 40 CFR part 63 “National Emission Standards for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines; Final Rule”, June 15, 2004

/9/ IFC’s “Policy and Performance Standards on Social and Environmental Sustainability

and Policy on Disclosure of Information: Report on the First Three Years of Application”; July 29, 2009

/10/ Portugal: “Order no 677/2009”, June 2009

/11/ “Best Available Techniques (BAT) in Small 5 – 50 MW Combustion Plants in Finland”, September 2003

Appendix 1 (1/2):

IFC "Thermal Power Plants EHS Guidelines 2008"

Liquid Fuel	NDA: > 50 MW_{th}*	NDA: ≥ 300 MW_{th}**	DA: > 50 MW_{th}	DA: ≥ 300 MW_{th}**
PM emissions (mg/m^3, dry, 15 % O_2, 0 °C & 1 atm)	50	50	30	30
SO2 emissions (mg/m^3, dry, 15 % O_2, 0 °C & 1 atm) or wt-% S. N/A on biofuels.	1170 or max. 2.0 % S	585 or max. 1.0 % S	0.5 % S	0.2 % S
NOx emissions (mg/m^3, dry, 15 % O_2, 0 °C & 1 atm)	Diesel engine: 1460 (< 400 mm) 1850 (≥ 400 mm) - Dual Fuel engine: 2000 Bio oils ı 30 %	740 (contingent upon water availability for injection) Bio oils ı 30 %	400	400
Gas Fuel	NDA:*		DA:*	
PM emissions (mg/m^3, dry, 15 % O_2, 0 °C & 1 atm), for other gases than natural gas	50		30	
SO2 emissions (% S in fuel)	-		-	
NOx emissions (mg/m^3, dry, 15 % O_2, 0 °C & 1 atm)	- 200 (spark ignition) - 400 (dual fuel) - *** (compression ignition (CI)) - Other gases than natural gas + 30 %		- 200 (spark ignition on natural gas) - 400 (other)	

*** MW_{th} based on Higher Heat Value (HHV). NDA = Non Degraded Area, DA = Degraded Area**

**** Plants > 300 MW_{th} CEMS need for:**

- **Liquid fuel: NO_x and SO2 (if FGD)**
- **Natural Gas: NO_x**

***** Emission value should be evaluated on a case-by case basis through the EA process**

NOTE[1] all plant sizes:

- **Annual performance measurement of regulated emissions.**
- **Heavy metals also to be measured (liquid fuel)**

NOTE[2] Page 20 Table 6(A) "Emission Guidelines for Reciprocating Engines":
"EA may justify more stringent or less stringent limits due to ambient environment, technical and economic considerations provided there is compliance with applicable ambient air quality standards and incremental impacts are minimized"

Appendix 1 (2/2):

IFC General EHS Guidelines 2007 ***
for "3 .. 50 MW_{th} plant", unit mg/Nm^3 (15 % O_2) or as indicated, for plants operating > 500 h/year

Emission	**PM**	**SO_2**	**NO_x**
Liquid	50 .. 100*	1.5 .. 3 %*	Bore< 400 mm: 1460 .. 1600 ** Bore $\geq$400 mm: 1850
Gas	N/A	N/A	SG: 200 DF: 400 GD: 1600

* If justified by project specific justifications (economic feasibility, environmental capacity of site)

** If justified to maintain high energy efficiency

*** Higher performance levels should be applied to facilities in urban/industrial areas with degraded air-shed or close to ecologically sensitive areas.