Calculation of NOx Emissions in mg/Nm^3 (Dry at 5% O_2)
Diesel Generator at Prime Load

Iain Prentice
Aggreko Sustainability

March 19, 2026

Introduction

This document calculates the NOx concentration in mg/Nm^3 on a dry basis, corrected to 5% O_2, for a diesel generator operating at prime load. The calculation is based on the generator power output, fuel consumption, dry air intake flow, and the reported CO and HC emissions factors. A full elemental balance is carried out to determine the exhaust water content, dry oxygen concentration, and dry exhaust volume flow.

Given Data

- Prime power output: $P = 402$ kW
- Fuel consumption: $SFC = 204$ g/kWh output
- Dry air intake flow: $\dot{m}_{air} = 32$ kg/min
- Exhaust gas flow (datasheet, reference only): $\dot{m}_{exhaust} = 33$ kg/min
- NOx emissions factor: $E_{NOx} = 4.76$ g/kWh output
- CO emissions factor: $E_{CO} = 0.28$ g/kWh output
- HC emissions factor: $E_{HC} = 0.04$ g/kWh output

Assumptions

- Intake air is dry.
- Dry air contains 23.2% O_2 by mass and 76.8% N_2 by mass:

$$X_{O_2,air} = 0.232, \qquad X_{N_2,air} = 0.768$$

- Diesel fuel is approximated as $CH_{1.92}$.
- All burned hydrogen forms H_2O.
- All burned carbon forms CO_2, except for the fraction reported as CO.
- HC emissions are treated as unburned fuel.
- Minor species such as NOx and PM are neglected in the bulk exhaust composition balance because their effect on total exhaust molar flow is negligible.
- Standard molar volume:

$$1 \text{ kmol} = 22.414 \text{ Nm}^3$$

- Molecular weights used:

$$MW_{O_2} = 32 \text{ kg/kmol}$$
$$MW_{N_2} = 28 \text{ kg/kmol}$$
$$MW_{CO_2} = 44 \text{ kg/kmol}$$
$$MW_{CO} = 28 \text{ kg/kmol}$$
$$MW_{H_2O} = 18 \text{ kg/kmol}$$
$$MW_{fuel} = MW_{CH_{1.92}} = 12 + 1.92 = 13.92 \text{ kg/kmol}$$

Step 1: Convert Air and Exhaust Flows to kg/h

Dry air intake flow:

$$\dot{m}_{air} = 32 \ \frac{\text{kg}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ h}}$$
$$\dot{m}_{air} = 1920 \ \frac{\text{kg}}{\text{h}}$$

Exhaust gas flow from datasheet:

$$\dot{m}_{exhaust} = 33 \ \frac{\text{kg}}{\text{min}} \times \frac{60 \text{ min}}{1 \text{ h}}$$
$$\dot{m}_{exhaust} = 1980 \ \frac{\text{kg}}{\text{h}}$$

Step 2: Convert Fuel Consumption to kg/h

Fuel consumption is given as:

$$SFC = 204 \ \frac{\text{g}}{\text{kWh}}$$

Electrical output at prime load:

$$P = 402 \text{ kW} = 402 \ \frac{\text{kWh}}{\text{h}}$$

Fuel mass flow in g/h:

$$\dot{m}_{fuel,total} = 204 \ \frac{\text{g}}{\text{kWh}} \times 402 \ \frac{\text{kWh}}{\text{h}}$$
$$\dot{m}_{fuel,total} = 82008 \ \frac{\text{g}}{\text{h}}$$

Convert g/h to kg/h:

$$\dot{m}_{fuel,total} = 82008 \ \frac{\text{g}}{\text{h}} \times \frac{1 \text{ kg}}{1000 \text{ g}}$$
$$\dot{m}_{fuel,total} = 82.008 \ \frac{\text{kg}}{\text{h}}$$

Step 3: Convert HC and CO Emissions to kg/h

HC emissions factor:

$$E_{HC} = 0.04\ \frac{\text{g}}{\text{kWh}}$$

HC mass flow in g/h:

$$\dot{m}_{HC} = 0.04\ \frac{\text{g}}{\text{kWh}} \times 402\ \frac{\text{kWh}}{\text{h}}$$

$$\dot{m}_{HC} = 16.08\ \frac{\text{g}}{\text{h}}$$

Convert to kg/h:

$$\dot{m}_{HC} = 16.08\ \frac{\text{g}}{\text{h}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$

$$\dot{m}_{HC} = 0.01608\ \frac{\text{kg}}{\text{h}}$$

CO emissions factor:

$$E_{CO} = 0.28\ \frac{\text{g}}{\text{kWh}}$$

CO mass flow in g/h:

$$\dot{m}_{CO} = 0.28\ \frac{\text{g}}{\text{kWh}} \times 402\ \frac{\text{kWh}}{\text{h}}$$

$$\dot{m}_{CO} = 112.56\ \frac{\text{g}}{\text{h}}$$

Convert to kg/h:

$$\dot{m}_{CO} = 112.56\ \frac{\text{g}}{\text{h}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$

$$\dot{m}_{CO} = 0.11256\ \frac{\text{kg}}{\text{h}}$$

Step 4: Fuel Burned

The unburned HC is treated as fuel that did not combust. Therefore, the burned fuel mass flow is:

$$\dot{m}_{fuel,burned} = \dot{m}_{fuel,total} - \dot{m}_{HC}$$

$$\dot{m}_{fuel,burned} = 82.008\ \frac{\text{kg}}{\text{h}} - 0.01608\ \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{fuel,burned} = 81.99192\ \frac{\text{kg}}{\text{h}}$$

Step 5: Carbon and Hydrogen Fractions in Fuel

For the surrogate fuel $CH_{1.92}$:

Total molecular weight:

$$MW_{fuel} = 12 + 1.92 = 13.92\ \text{kg/kmol}$$

Carbon mass fraction:

$$X_C = \frac{12}{13.92}$$

$$X_C = 0.86207$$

Hydrogen mass fraction:

$$X_H = \frac{1.92}{13.92}$$

$$X_H = 0.13793$$

Step 6: Carbon and Hydrogen Mass Flows in Burned Fuel

Carbon mass flow in burned fuel:

$$\dot{m}_{C,burned} = X_C \times \dot{m}_{fuel,burned}$$

$$\dot{m}_{C,burned} = 0.86207 \times 81.99192 \ \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{C,burned} = 70.68269 \ \frac{\text{kg C}}{\text{h}}$$

Hydrogen mass flow in burned fuel:

$$\dot{m}_{H,burned} = X_H \times \dot{m}_{fuel,burned}$$

$$\dot{m}_{H,burned} = 0.13793 \times 81.99192 \ \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{H,burned} = 11.30923 \ \frac{\text{kg H}}{\text{h}}$$

Step 7: Carbon Leaving as CO

CO mass flow:

$$\dot{m}_{CO} = 0.11256 \ \frac{\text{kg}}{\text{h}}$$

Carbon mass fraction in CO:

$$\frac{12}{28}$$

Carbon mass flow in CO:

$$\dot{m}_{C,CO} = 0.11256 \ \frac{\text{kg}}{\text{h}} \times \frac{12}{28}$$

$$\dot{m}_{C,CO} = 0.04824 \ \frac{\text{kg C}}{\text{h}}$$

Step 8: Carbon Leaving as $\mathbf{CO_2}$

Carbon not in CO is assumed to leave as CO_2:

$$\dot{m}_{C,CO_2} = \dot{m}_{C,burned} - \dot{m}_{C,CO}$$

$$\dot{m}_{C,CO_2} = 70.68269 \ \frac{\text{kg C}}{\text{h}} - 0.04824 \ \frac{\text{kg C}}{\text{h}}$$

$$\dot{m}_{C,CO_2} = 70.63445 \ \frac{\text{kg C}}{\text{h}}$$

Convert carbon to CO_2 using the mass ratio $\frac{44}{12}$:

$$\dot{m}_{CO_2} = \dot{m}_{C,CO_2} \times \frac{44}{12}$$

$$\dot{m}_{CO_2} = 70.63445 \ \frac{\text{kg C}}{\text{h}} \times \frac{44}{12}$$

$$\dot{m}_{CO_2} = 258.99298 \ \frac{\text{kg CO}_2}{\text{h}}$$

Step 9: Hydrogen Leaving as H_2O

All burned hydrogen is assumed to form H_2O.

Mass ratio:

$$1 \text{ kg H} \rightarrow 9 \text{ kg H}_2\text{O}$$

Therefore:

$$\dot{m}_{H_2O} = 9 \times \dot{m}_{H,burned}$$

$$\dot{m}_{H_2O} = 9 \times 11.30923 \ \frac{\text{kg H}}{\text{h}}$$

$$\dot{m}_{H_2O} = 101.78307 \ \frac{\text{kg H}_2\text{O}}{\text{h}}$$

Step 10: Oxygen and Nitrogen Entering with Air

Oxygen entering with dry air:

$$\dot{m}_{O_2,in} = X_{O_2,air} \times \dot{m}_{air}$$

$$\dot{m}_{O_2,in} = 0.232 \times 1920 \ \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{O_2,in} = 445.44 \ \frac{\text{kg O}_2}{\text{h}}$$

Nitrogen entering with dry air:

$$\dot{m}_{N_2,in} = X_{N_2,air} \times \dot{m}_{air}$$

$$\dot{m}_{N_2,in} = 0.768 \times 1920 \ \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{N_2,in} = 1474.56 \ \frac{\text{kg N}_2}{\text{h}}$$

Step 11: Oxygen Consumed to Form CO_2

For carbon forming CO_2:

$$12 \text{ kg C} + 32 \text{ kg O}_2 \rightarrow 44 \text{ kg CO}_2$$

Therefore the oxygen required per kg carbon is:

$$\frac{32}{12} \ \frac{\text{kg O}_2}{\text{kg C}}$$

So:

$$\dot{m}_{O_2,CO_2} = \dot{m}_{C,CO_2} \times \frac{32}{12}$$

$$\dot{m}_{O_2,CO_2} = 70.63445 \ \frac{\text{kg C}}{\text{h}} \times \frac{32}{12}$$

$$\dot{m}_{O_2,CO_2} = 188.35852 \ \frac{\text{kg O}_2}{\text{h}}$$

Step 12: Oxygen Consumed to Form CO

For carbon forming CO:

$$12 \text{ kg C} + 16 \text{ kg O}_2 \rightarrow 28 \text{ kg CO}$$

Therefore the oxygen required per kg carbon is:

$$\frac{16}{12} \, \frac{\text{kg O}_2}{\text{kg C}}$$

So:

$$\dot{m}_{O_2,CO} = \dot{m}_{C,CO} \times \frac{16}{12}$$

$$\dot{m}_{O_2,CO} = 0.04824 \, \frac{\text{kg C}}{\text{h}} \times \frac{16}{12}$$

$$\dot{m}_{O_2,CO} = 0.06432 \, \frac{\text{kg O}_2}{\text{h}}$$

Step 13: Oxygen Consumed to Form H_2O

For hydrogen forming water:

$$1 \text{ kg H} + 8 \text{ kg O}_2 \rightarrow 9 \text{ kg H}_2\text{O}$$

Therefore:

$$\dot{m}_{O_2,H_2O} = 8 \times \dot{m}_{H,burned}$$

$$\dot{m}_{O_2,H_2O} = 8 \times 11.30923 \, \frac{\text{kg H}}{\text{h}}$$

$$\dot{m}_{O_2,H_2O} = 90.47384 \, \frac{\text{kg O}_2}{\text{h}}$$

Step 14: Total Oxygen Consumed

$$\dot{m}_{O_2,consumed} = \dot{m}_{O_2,CO_2} + \dot{m}_{O_2,CO} + \dot{m}_{O_2,H_2O}$$

$$\dot{m}_{O_2,consumed} = 188.35852 \, \frac{\text{kg}}{\text{h}} + 0.06432 \, \frac{\text{kg}}{\text{h}} + 90.47384 \, \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{O_2,consumed} = 278.89668 \, \frac{\text{kg O}_2}{\text{h}}$$

Step 15: Oxygen Remaining in the Exhaust

$$\dot{m}_{O_2,out} = \dot{m}_{O_2,in} - \dot{m}_{O_2,consumed}$$

$$\dot{m}_{O_2,out} = 445.44 \, \frac{\text{kg}}{\text{h}} - 278.89668 \, \frac{\text{kg}}{\text{h}}$$

$$\dot{m}_{O_2,out} = 166.54332 \, \frac{\text{kg O}_2}{\text{h}}$$

Step 16: Convert All Exhaust Species to kmol/h

Nitrogen:

$$\dot{n}_{N_2} = \frac{\dot{m}_{N_2,in}}{MW_{N_2}}$$

$$\dot{n}_{N_2} = \frac{1474.56 \text{ kg/h}}{28 \text{ kg/kmol}}$$

$$\dot{n}_{N_2} = 52.66286 \ \frac{\text{kmol}}{\text{h}}$$

Oxygen:

$$\dot{n}_{O_2} = \frac{\dot{m}_{O_2,out}}{MW_{O_2}}$$

$$\dot{n}_{O_2} = \frac{166.54332 \text{ kg/h}}{32 \text{ kg/kmol}}$$

$$\dot{n}_{O_2} = 5.20448 \ \frac{\text{kmol}}{\text{h}}$$

Carbon dioxide:

$$\dot{n}_{CO_2} = \frac{\dot{m}_{CO_2}}{MW_{CO_2}}$$

$$\dot{n}_{CO_2} = \frac{258.99298 \text{ kg/h}}{44 \text{ kg/kmol}}$$

$$\dot{n}_{CO_2} = 5.88620 \ \frac{\text{kmol}}{\text{h}}$$

Carbon monoxide:

$$\dot{n}_{CO} = \frac{\dot{m}_{CO}}{MW_{CO}}$$

$$\dot{n}_{CO} = \frac{0.11256 \text{ kg/h}}{28 \text{ kg/kmol}}$$

$$\dot{n}_{CO} = 0.00402 \ \frac{\text{kmol}}{\text{h}}$$

Water:

$$\dot{n}_{H_2O} = \frac{\dot{m}_{H_2O}}{MW_{H_2O}}$$

$$\dot{n}_{H_2O} = \frac{101.78307 \text{ kg/h}}{18 \text{ kg/kmol}}$$

$$\dot{n}_{H_2O} = 5.65462 \ \frac{\text{kmol}}{\text{h}}$$

Unburned HC:

$$\dot{n}_{HC} = \frac{\dot{m}_{HC}}{MW_{fuel}}$$

$$\dot{n}_{HC} = \frac{0.01608 \text{ kg/h}}{13.92 \text{ kg/kmol}}$$

$$\dot{n}_{HC} = 0.00116 \ \frac{\text{kmol}}{\text{h}}$$

Step 17: Total Wet and Dry Exhaust Molar Flow

Total wet exhaust molar flow:

$$\dot{n}_{wet} = \dot{n}_{N_2} + \dot{n}_{O_2} + \dot{n}_{CO_2} + \dot{n}_{CO} + \dot{n}_{H_2O} + \dot{n}_{HC}$$

$$\dot{n}_{wet} = 52.66286 + 5.20448 + 5.88620 + 0.00402 + 5.65462 + 0.00116\ \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{wet} = 69.41334\ \frac{\text{kmol}}{\text{h}}$$

Total dry exhaust molar flow excludes water:

$$\dot{n}_{dry} = \dot{n}_{wet} - \dot{n}_{H_2O}$$

$$\dot{n}_{dry} = 69.41334\ \frac{\text{kmol}}{\text{h}} - 5.65462\ \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{dry} = 63.75872\ \frac{\text{kmol}}{\text{h}}$$

Step 18: Water Content in Wet Exhaust

Wet-basis mole fraction of water:

$$y_{H_2O,wet} = \frac{\dot{n}_{H_2O}}{\dot{n}_{wet}}$$

$$y_{H_2O,wet} = \frac{5.65462\ \text{kmol/h}}{69.41334\ \text{kmol/h}}$$

$$y_{H_2O,wet} = 0.08146$$

Convert to % v/v wet basis:

$$\%v/v\ H_2O = 0.08146 \times 100$$

$$\%v/v\ H_2O = 8.15\%$$

Step 19: Oxygen Content in Dry Exhaust

Dry-basis mole fraction of oxygen:

$$y_{O_2,dry} = \frac{\dot{n}_{O_2}}{\dot{n}_{dry}}$$

$$y_{O_2,dry} = \frac{5.20448\ \text{kmol/h}}{63.75872\ \text{kmol/h}}$$

$$y_{O_2,dry} = 0.08163$$

Convert to % v/v dry basis:

$$\%v/v\ O_2 = 0.08163 \times 100$$

$$\%v/v\ O_2 = 8.16\%$$

Step 20: NOx Mass Flow in mg/h

NOx emissions factor:

$$E_{NOx} = 4.76 \ \frac{\text{g}}{\text{kWh}}$$

NOx mass flow in g/h:

$$\dot{m}_{NOx} = 4.76 \ \frac{\text{g}}{\text{kWh}} \times 402 \ \frac{\text{kWh}}{\text{h}}$$

$$\dot{m}_{NOx} = 1913.52 \ \frac{\text{g}}{\text{h}}$$

Convert to mg/h:

$$\dot{m}_{NOx} = 1913.52 \ \frac{\text{g}}{\text{h}} \times \frac{1000 \text{ mg}}{1 \text{ g}}$$

$$\dot{m}_{NOx} = 1{,}913{,}520 \ \frac{\text{mg}}{\text{h}}$$

Step 21: Convert Dry Exhaust Molar Flow to Dry Nm^3/h

$$\dot{V}_{dry} = \dot{n}_{dry} \times 22.414 \ \frac{\text{Nm}^3}{\text{kmol}}$$

$$\dot{V}_{dry} = 63.75872 \ \frac{\text{kmol}}{\text{h}} \times 22.414 \ \frac{\text{Nm}^3}{\text{kmol}}$$

$$\dot{V}_{dry} = 1429.17 \ \frac{\text{Nm}^3}{\text{h}}$$

Step 22: Calculate NOx Concentration in mg/Nm^3 Dry

$$C_{NOx,dry} = \frac{\dot{m}_{NOx}}{\dot{V}_{dry}}$$

$$C_{NOx,dry} = \frac{1{,}913{,}520 \text{ mg/h}}{1429.17 \text{ Nm}^3\text{/h}}$$

$$C_{NOx,dry} = 1338.90 \ \frac{\text{mg}}{\text{Nm}^3}$$

Step 23: Correct NOx to 5% O_2

The dry oxygen correction formula is:

$$C_{NOx,5\%O_2} = C_{NOx,dry} \times \frac{20.9 - 5}{20.9 - O_2}$$

Substituting the dry oxygen concentration:

$$C_{NOx,5\%O_2} = 1338.90 \ \frac{\text{mg}}{\text{Nm}^3} \times \frac{20.9 - 5}{20.9 - 8.16}$$

$$C_{NOx,5\%O_2} = 1338.90 \ \frac{\text{mg}}{\text{Nm}^3} \times \frac{15.9}{12.74}$$

$$C_{NOx,5\%O_2} = 1671.26 \ \frac{\text{mg}}{\text{Nm}^3}$$

Final Result

The calculated exhaust water vapour concentration is:

$$\boxed{8.15\%\ \text{v/v (wet basis)}}$$

The calculated dry oxygen concentration is:

$$\boxed{8.16\%\ \text{v/v (dry basis)}}$$

The calculated NOx concentration is:

$$\boxed{1,339\ \text{mg/Nm}^3\ \text{dry}}$$

The NOx concentration corrected to 5% O_2 is:

$$\boxed{1,671\ \text{mg/Nm}^3\ \text{dry at 5\% O}_2}$$