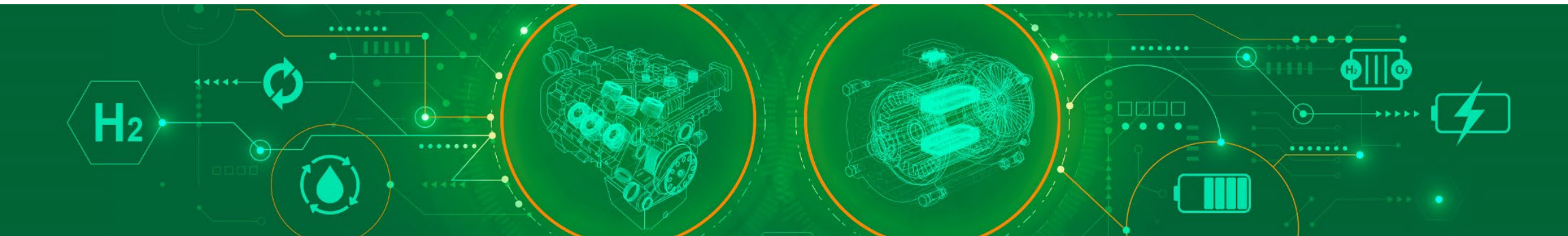


# EUROMOT proposal to amend the 05 series of amendments to UN Regulation 96

Submitted to June 2023 session of GRPE, to provide explanation of EUROMOT's proposed amendment to the 05 series of amendments to UN Regulation 96, to allow the type approval of engine operated solely on hydrogen.



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# Guiding principles

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- Preserve the outcome of EU/OICA amendments to R49
- Maintain a “lean approach” to the proposal – minimum necessary changes to allow type approval of hydrogen internal combustion engines
- Only include technical concepts that have been accepted in R49

Whilst also:

- Respecting the differences between R96 and R49
- Being conscious of international developments in NRMM emission calculations for alternative carbon free and low net carbon fuels

# Equivalent modifications

Area	R49 amendment	R96 proposal
Mono-fuel hydrogen engine	✓	✓
Lean burn, complete combustion	✓	✓
ISO 14687 Grade D hydrogen	✓	✓
Measure NOx, CO, HC, PM	✓	✓
CO <sub>2</sub> measurement not required	✓	✓
Raw sampling of gaseous emissions	✓	✓
Measurement equipment must comply at expected water content	✓	✓
Maintain sample gas carrying components >10°K over sample dew point	✓	✓
Mass based emissions method	✓	✓

# Differences in proposals

Area	R49 amendment	R96 proposal
Structure	Existing carbon containing methodology has been modified	Hydrogen treated in separate Annex
Terminology	“For engines where all the fuels used have a molar carbon to hydrogen ratio of 0”	“Engines operated solely on hydrogen”
Calculation modification	Based upon a fuel $H_{\alpha}C_{\beta}S_{\gamma}N_{\delta}O_{\epsilon}$	Not required. Compatibility ensured by constraining calculation options.

# Structural difference between R49 amendment and R96 proposal

R49



In the R49 amendment, existing methodology was modified to be compatible with lean-burn engines operated solely on hydrogen.

R96



In R96, it was decided to create a new Annex to contain the specific requirements for such engines.

Reasoning:

- R96 already contains both mass based and molar based emission calculations in alignment with GTR11, ISO 8178 and EU Stage V Regulation (EU) 2017/654
- The molar based calculations originate from US EPA 40CFR1065.655, for which a separate section dedicated to carbon-free fuels is currently under development ([2023-07955.pdf \(govinfo.gov\)](#))
- To reduce risk of inadvertently creating incompatibilities within R96 the existing Annex 5 is retained unchanged for fuels other than hydrogen
- This approach is consistent with how the existing natural gas dual-fuel requirements are addressed in R96 Annex 7

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# Terminology, scope

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- Framed by what EUROMOT wanted to avoid:
  - Making any unilateral definition of “zero CO<sub>2</sub>” in the NRMM sector.
  - Making use of the  $\beta$  constant – due to existence of multiple methodologies in development, and subsequent decision to avoid redefining  $\beta$  in R96 (see next slide).
  - Hindering future developments of R96 to account for additional “zero” or “net-zero” carbon fuels.
- Taking the above into account, the scope of the EUROMOT proposal has been limited to “engines operated solely on hydrogen” at this time.
  - Does not pre-determine any aspects that could relate to potential future amendment.

# Calculation modification differences between R49 and R96; Detail

- For each calculation step, there is an option available that either does not need to be altered for use with hydrogen, or that can be constrained in order to not require modification. This avoids the need to define a  $\beta$  factor, or alter the definition of the existing ratios

R49

R96 – Annex 11

**Exh molar mass/U gas factors:**

$$M_{e,i} = \frac{1 + \frac{q_{mf,i}}{q_{maw,i}}}{\frac{q_{mf,i}}{q_{maw,i}} \times \frac{\frac{\alpha}{4} + \frac{\varepsilon}{2} + \frac{\delta}{2}}{12,011 \times \beta + 1,00794 \times \alpha + 15,9994 \times \varepsilon + 14,0067 \times \delta + 32,065 \times \gamma} + \frac{H_a \times 10^{-3}}{2 \times 1,00794 + 15,9994} + \frac{1}{1 + H_a \times 10^{-3}}} \quad (41)$$



“Equation A.5-11 shall not be used to calculate u values for engines operated solely on hydrogen. The **values in Table A.11.1.** may be used for the raw exhaust gas u and component densities. Alternatively, **Equation A.5-12 may be used** to calculate u values.”

”

**Exhaust mass flow** (*Intake flow + fuel flow is already compatible, but Intake + AFR should be modified to allow ISM:*)

$$A/F_{st} = \frac{138,0 \times (\beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma)}{12,011 \times \beta + 1,00794 \times \alpha + 15,9994 \times \varepsilon + 14,0067 \times \delta + 32,065 \times \gamma} \quad (31)$$



“Equation A.5-18 shall not be used to calculate  $A/F_{st}$ , and instead a value of **34.2282** shall be used.”



# Conclusion

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- A lean amendment has been proposed to enable the type-approval of engines fuelled solely on gaseous hydrogen.
- Follows the principles adopted in the EU/OICA amendment to R49 (GRPE-87-30e).
- Minor amendments to R120, to include hydrogen as a reference fuel have been submitted in parallel.
- Minor administrative corrections to R96 and R120 submitted in separate documents.
- Subject to agreement from GRPE, EUROMOT intends to submit corresponding working documents for the January 2024 GRPE session.
- EUROMOT intends to continue working towards future amendments that would be inclusive of a wider range of alternative low and net zero carbon fuels and technologies.

**30**  
YEARS  
1991-2021

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