Pontifícia Universidade Católica de Minas Gerais

ETHANOL INTERNATIONAL WORKSHOP 2012

COLD START EMISSIONS OF ETHANOL FUELLED VEHICLES

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OUTLINE

- Introduction
- Cold start technologies
- Simultaneous heating of intake air and injected ethanol
- Cold start time
- Cold start emissions
- Conclusions

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INTRODUCTION

- Ethanol properties cause difficult cold start and warm-up operation, with impacts on engine emissions
- Ethanol vaporization requires twice the energy required by gasoline (0.744 MJ/l $\times$ 0.325 MJ/l)
- Ethanol-fuelled engines do not start at temperatures below 13°C, while gasoline-fuelled engines can start at temperatures as low as - 40°C
- Ethanol vaporization temperature is 78°C, while the light gasoline components can vaporize from 40°C

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PHYSICAL-CHEMICAL PROPERTIES OF ETHANOL AND GASOLINE

PARAMETERS	E22	HYDROUS ETHANOL
Density (kg/m^3)	740	810
Low heating value (kcal/kg)	9400	5970
Stoichiometric air/fuel ratio	13.07 : 1	8.70 : 1
Chemical structure	$C_{6.39}H_{13.60}O_{0.61}$	$C_2H_{6.16}O_{1.08}$
Carbon content (wt %)	76.7	50.59
Hydrogen content (wt %)	13.6	12.98
Oxygen content (wt %)	9.7	36.42
Evaporation temperature (ºC)	40 to 220	78
Latent heat of vaporization (kcal/kg)	105	237
Motor octane number	80	87

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COLD START TECHNOLOGIES FOR FLEXIBLE FUEL VEHICLES

- Use of E85 blends
- Gasoline introduction through a calibrated hole
- Gasoline introduction through an extra fuel injector
- Gasoline introduction through an extra fuel injector and common rail
- Ethanol heating in the fuel injectors
- Ethanol heating in the fuel injectors plus intake air heating
- Aim at reduced cold start time and cold start emissions

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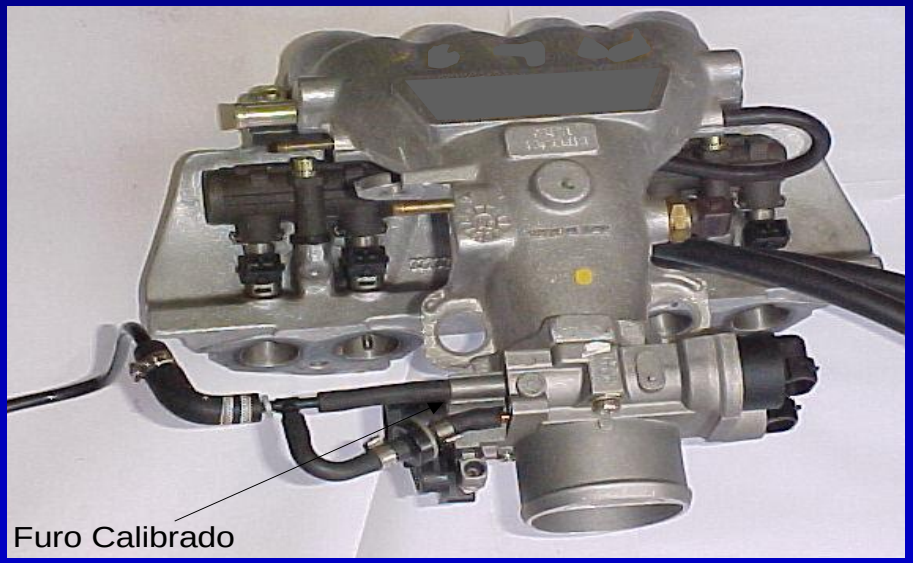
CALIBRATED HOLE AND EXTRA FUEL INJECTOR TECHNOLOGIES

CALIBRATED HOLE



EXTRA FUEL INJECTOR

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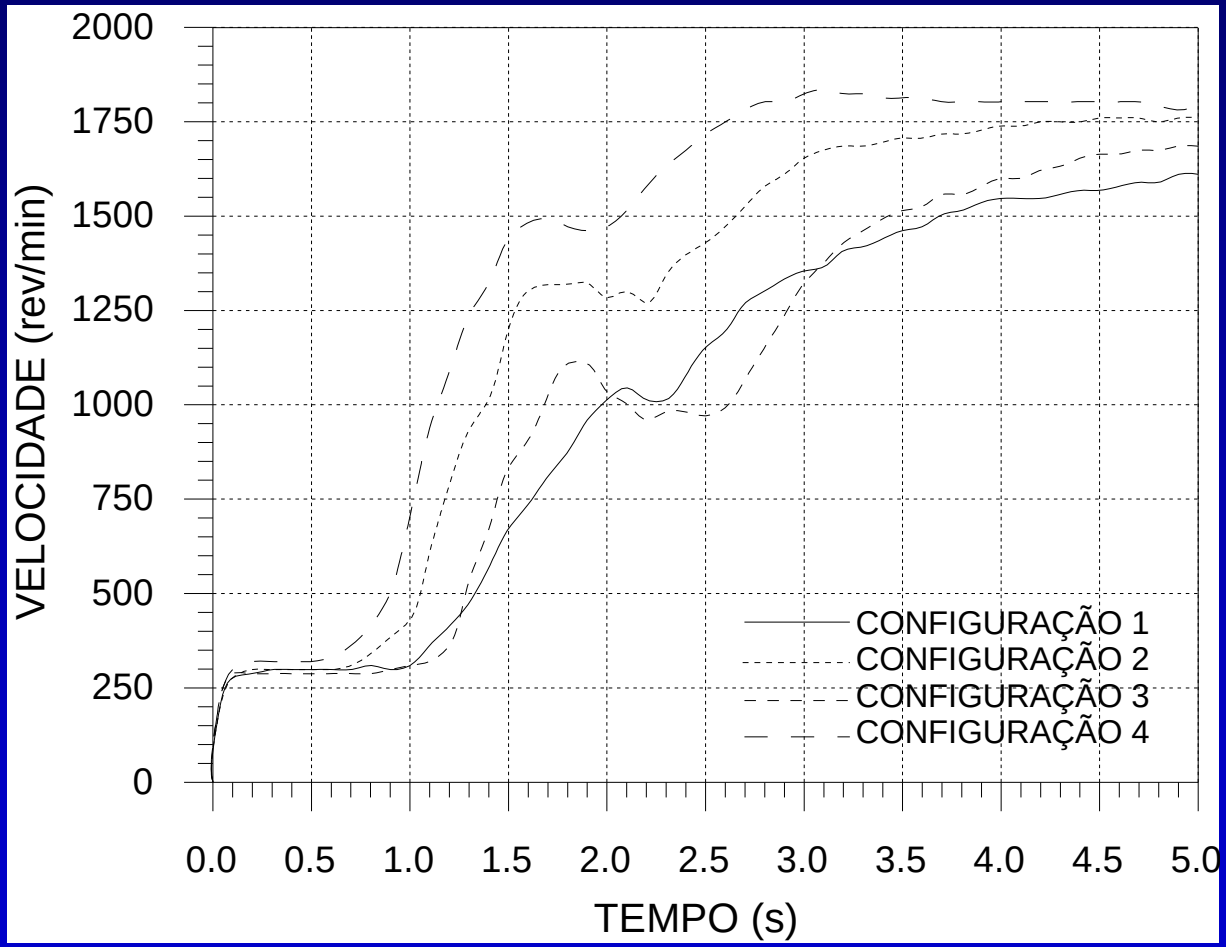
COLD START TIME FOR DIFFERENT CONFIGURATIONS



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EXTRA FUEL INJECTOR WITH COMMON RAIL TECHNOLOGY

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ETHANOL HEATING IN THE FUEL INJECTORS

- 950 W electric resistance required to heat ethanol in four injectors
- Cold start below 5°C between 2.0 s and 4.0 s
- Cold start time for intake air heating only using 600 W electric resistance between 10 s and 27 s

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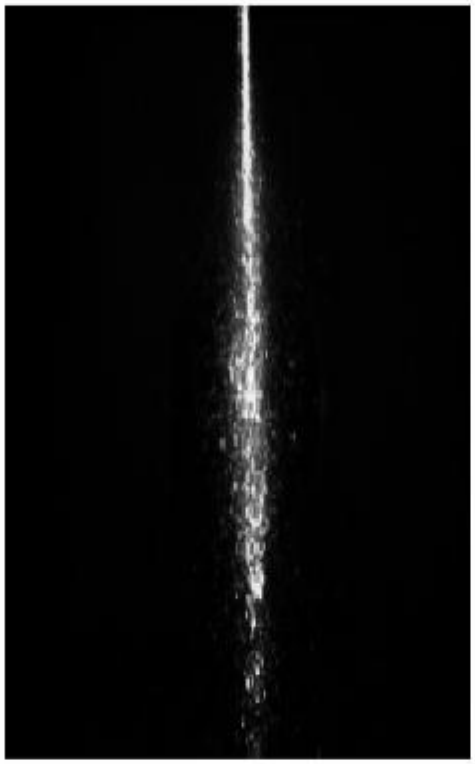
ETHANOL JET FLOW CHARACTERISTICS

NO HEATING



HEATED INJECTOR

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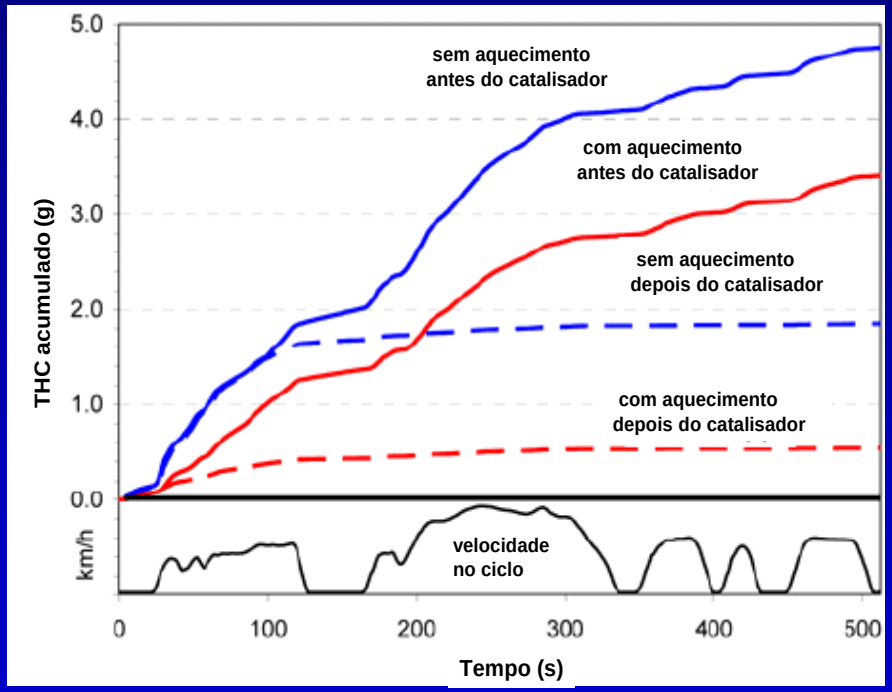
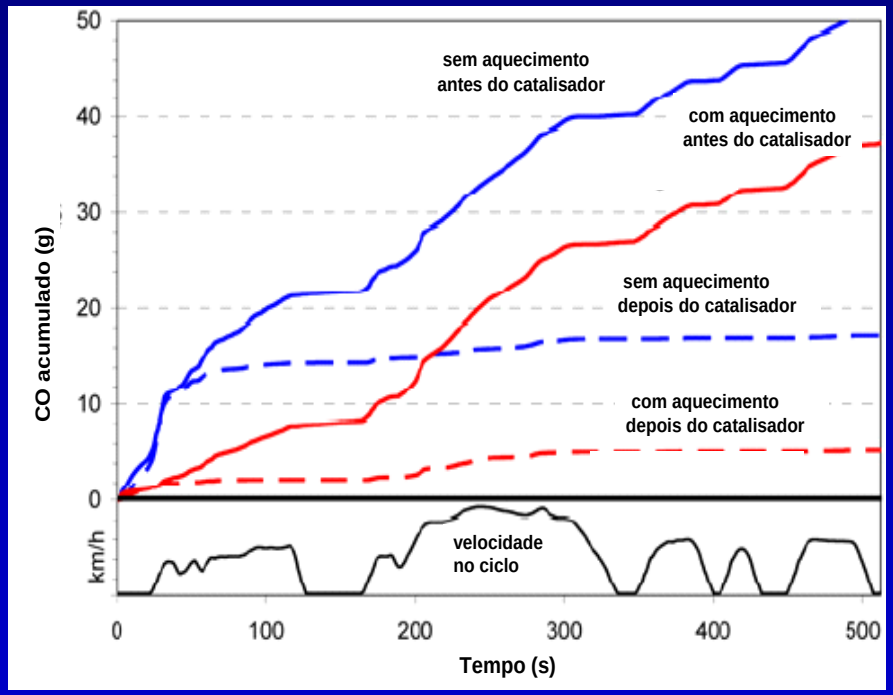
TOTAL HYDROCARBON AND CARBON MONOXIDE EMISSIONS





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CHARACTERISTICS OF POLLUTANT EMISSIONS DURING COLD START

- Catalytic converter efficiency is low during the first 55 s after cold start
- During this period HC and CO concentrations account for about 40% and 30% of the total amount during FTP-75 emission test schedule
- Aldehyde emissions are about 70% of the total amount during emission test cycle
- NO_X emissions during cold start is very low

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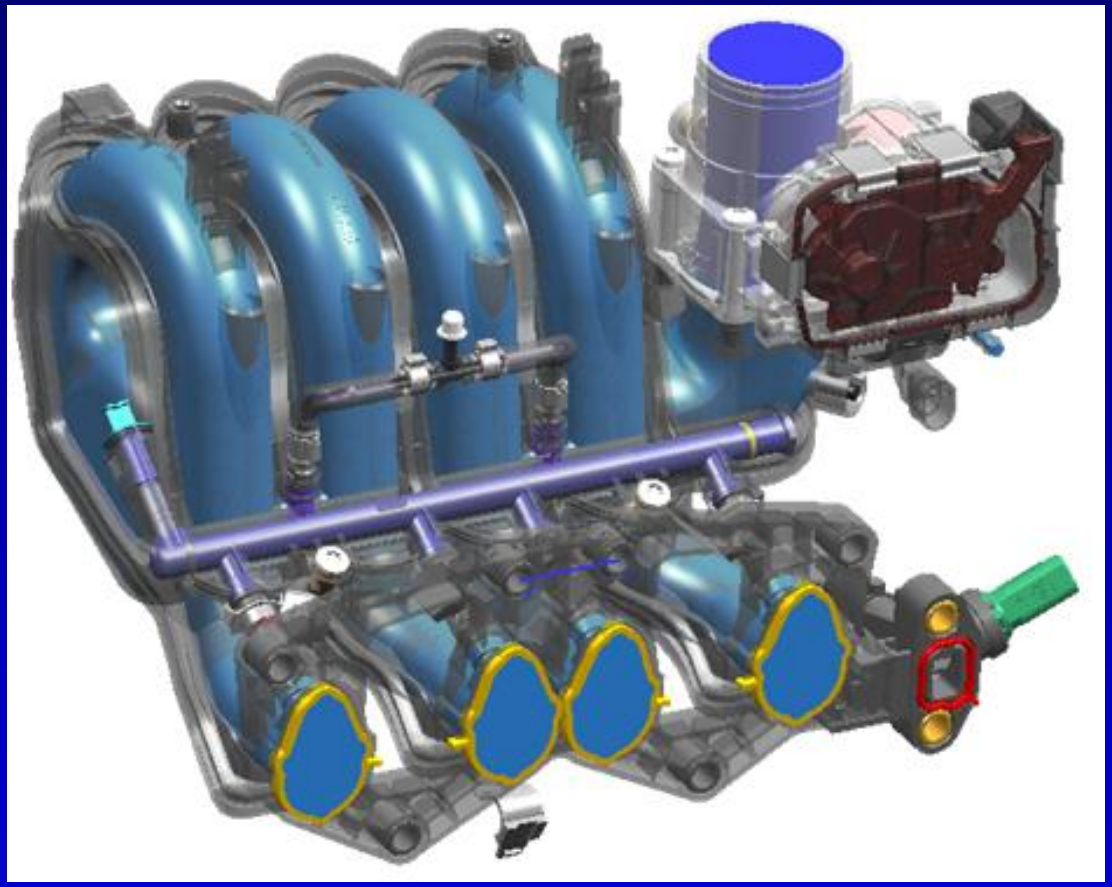
SIMULTANEOUS HEATING OF ETHANOL INJECTORS AND INTAKE AIR



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EXPERIMENTAL METHODOLOGY

- Production vehicle powered by a 1.4-liter, 8-valve, flex fuel engine operating with hydrous ethanol
- Cold start tests at 0ºC
- Emission tests following FTP-75 cycle at 25ºC
- Simultaneous heating of ethanol injectors and intake air activated 8.0 s before cold start
- Ethanol injection pressure 3.5 bar

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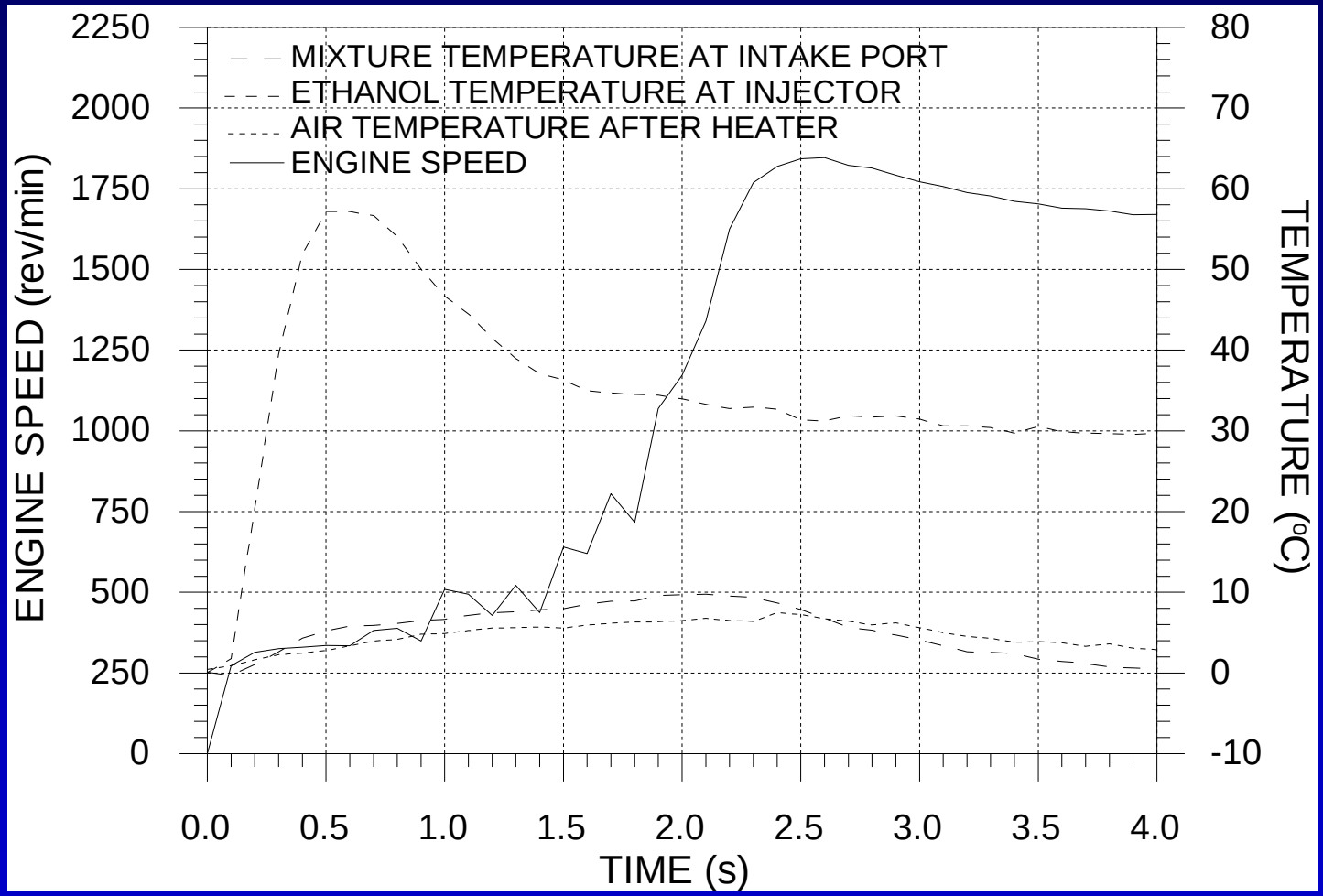
COLD START TIME AT 0°C



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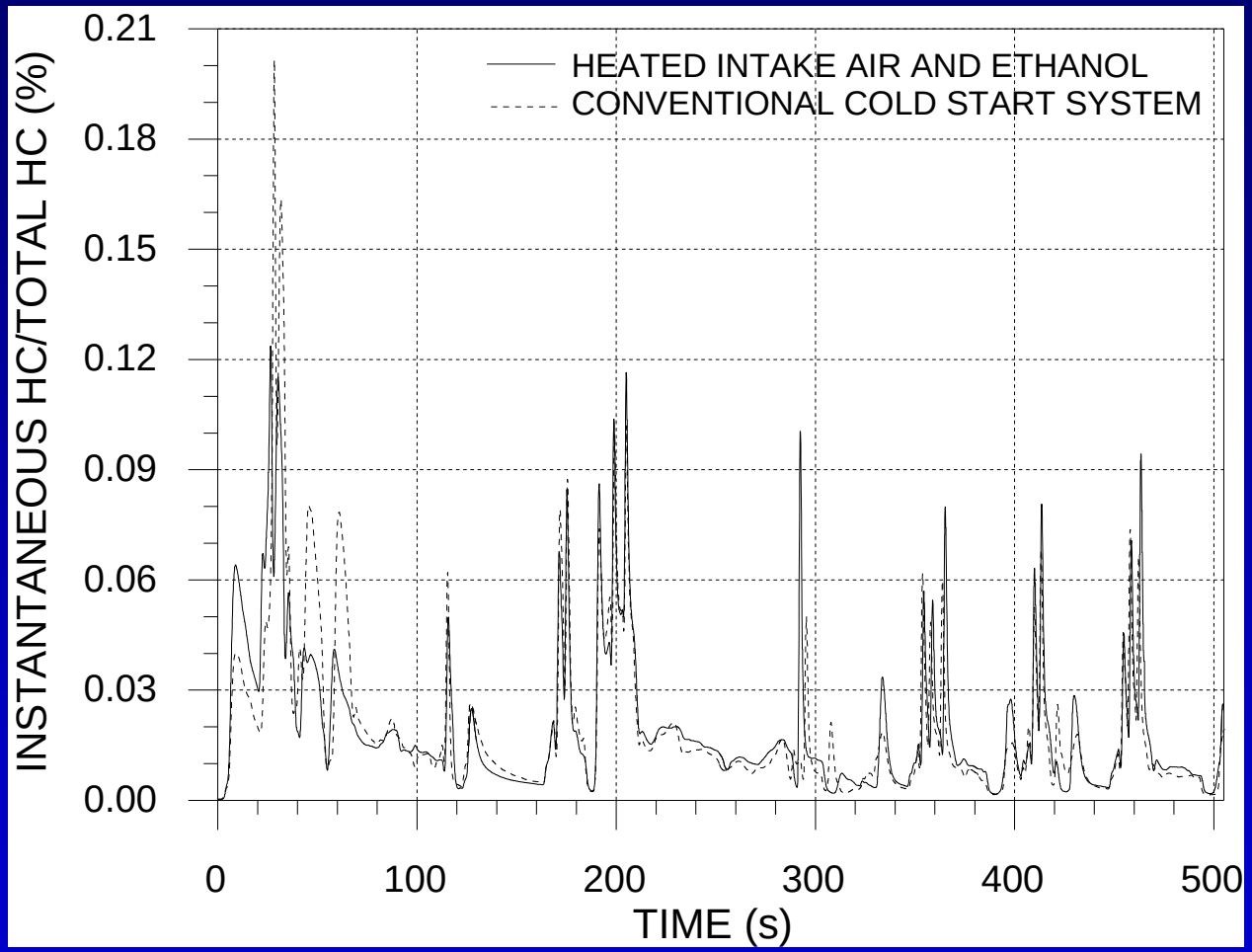
TIME-RESOLVED RELATIVE HYDROCARBON EMISSIONS



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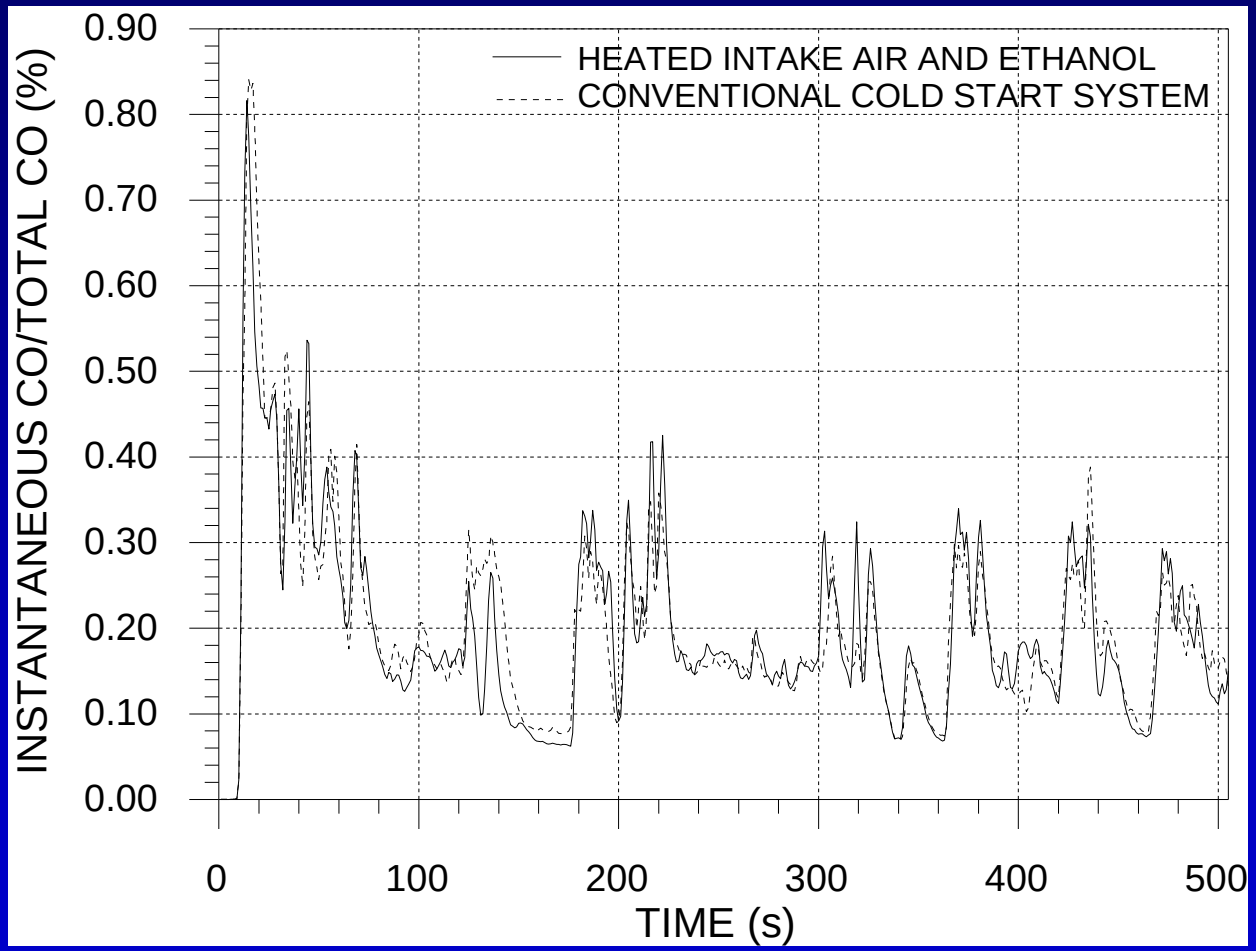
TIME-RESOLVED RELATIVE CARBON MONOXIDE EMISSIONS



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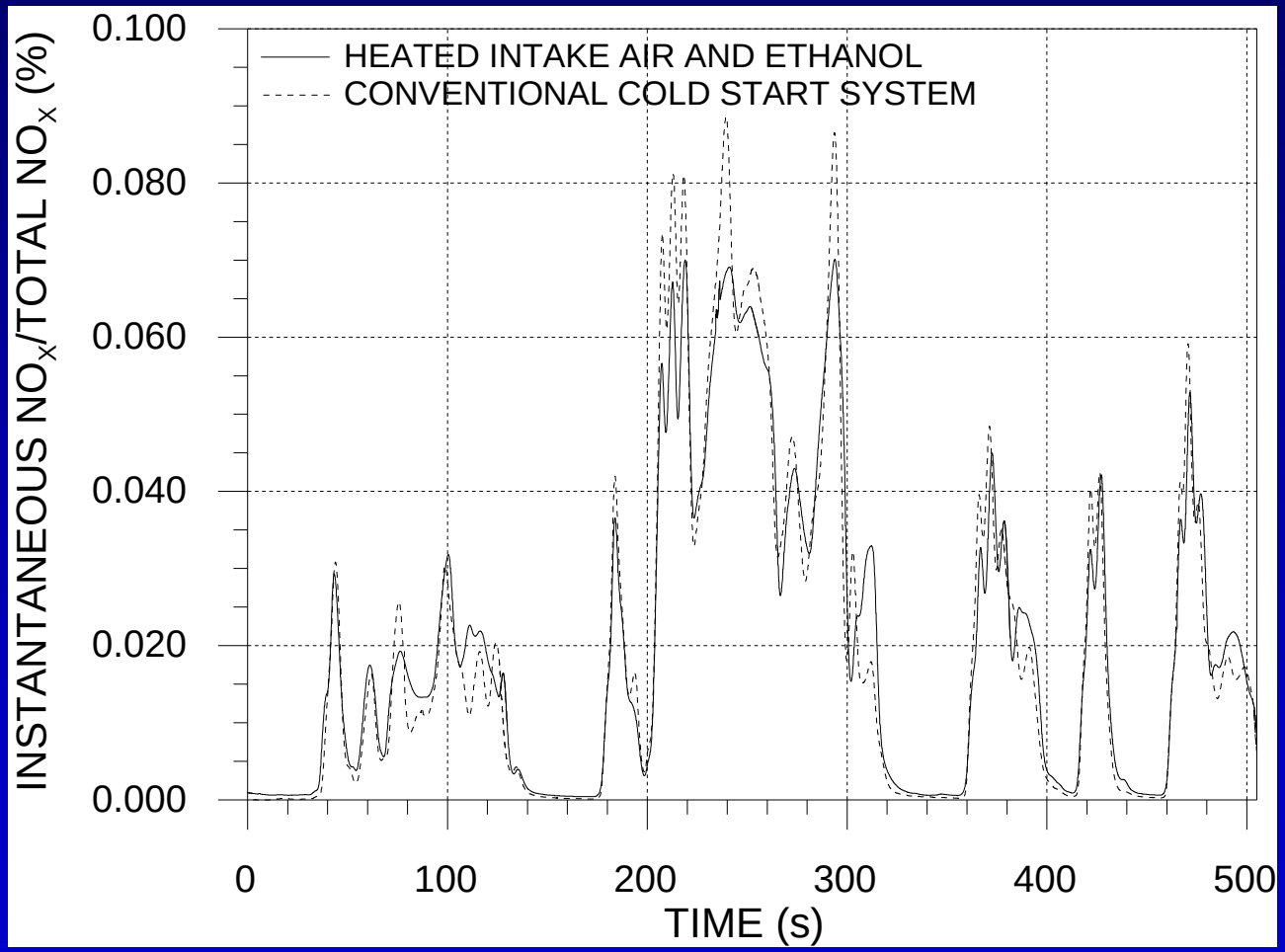
TIME-RESOLVED RELATIVE OXIDES OF NITROGEN EMISSIONS



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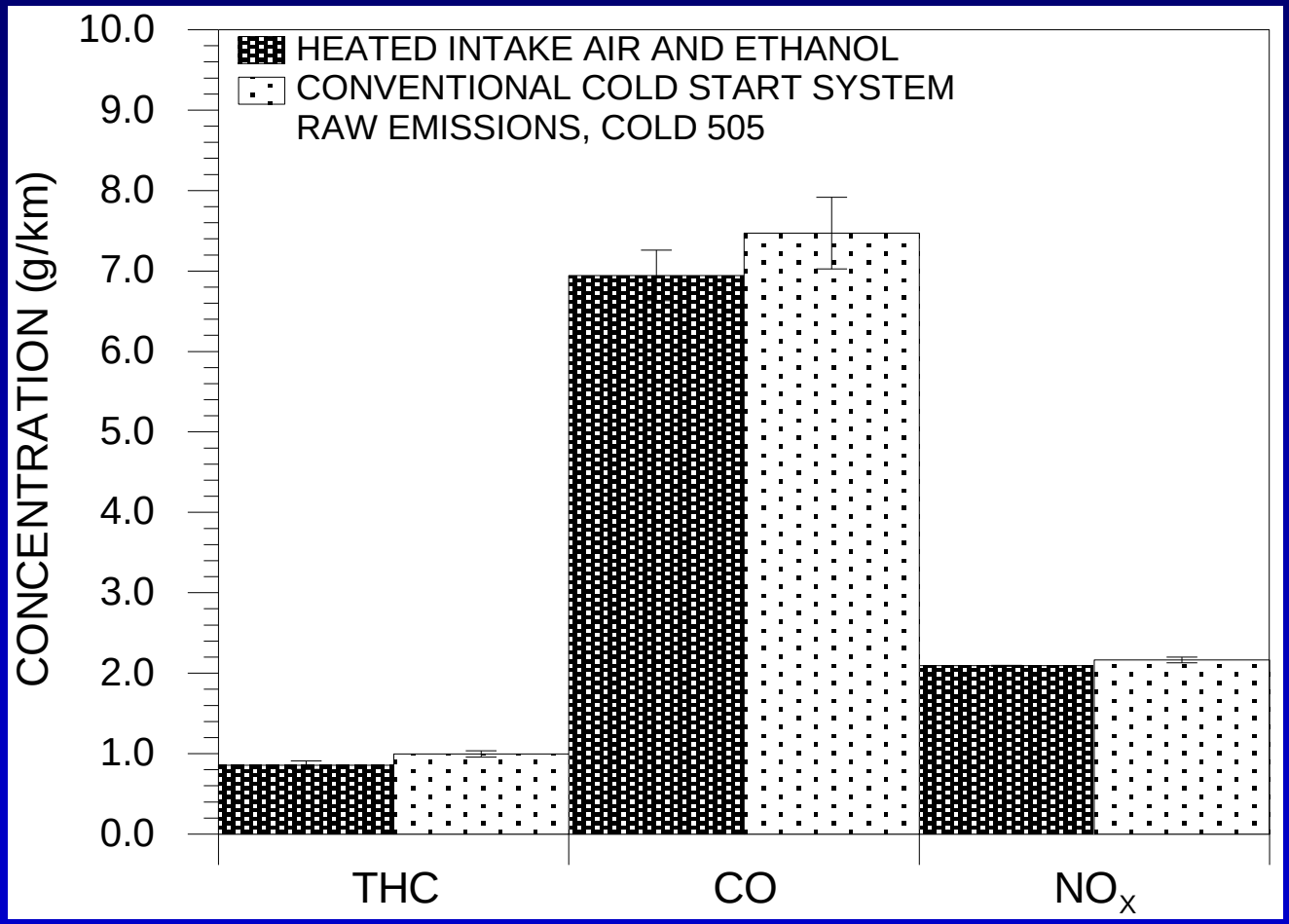
RAW EXHAUST HC, CO AND NO_X EMISSIONS AFTER COLD START



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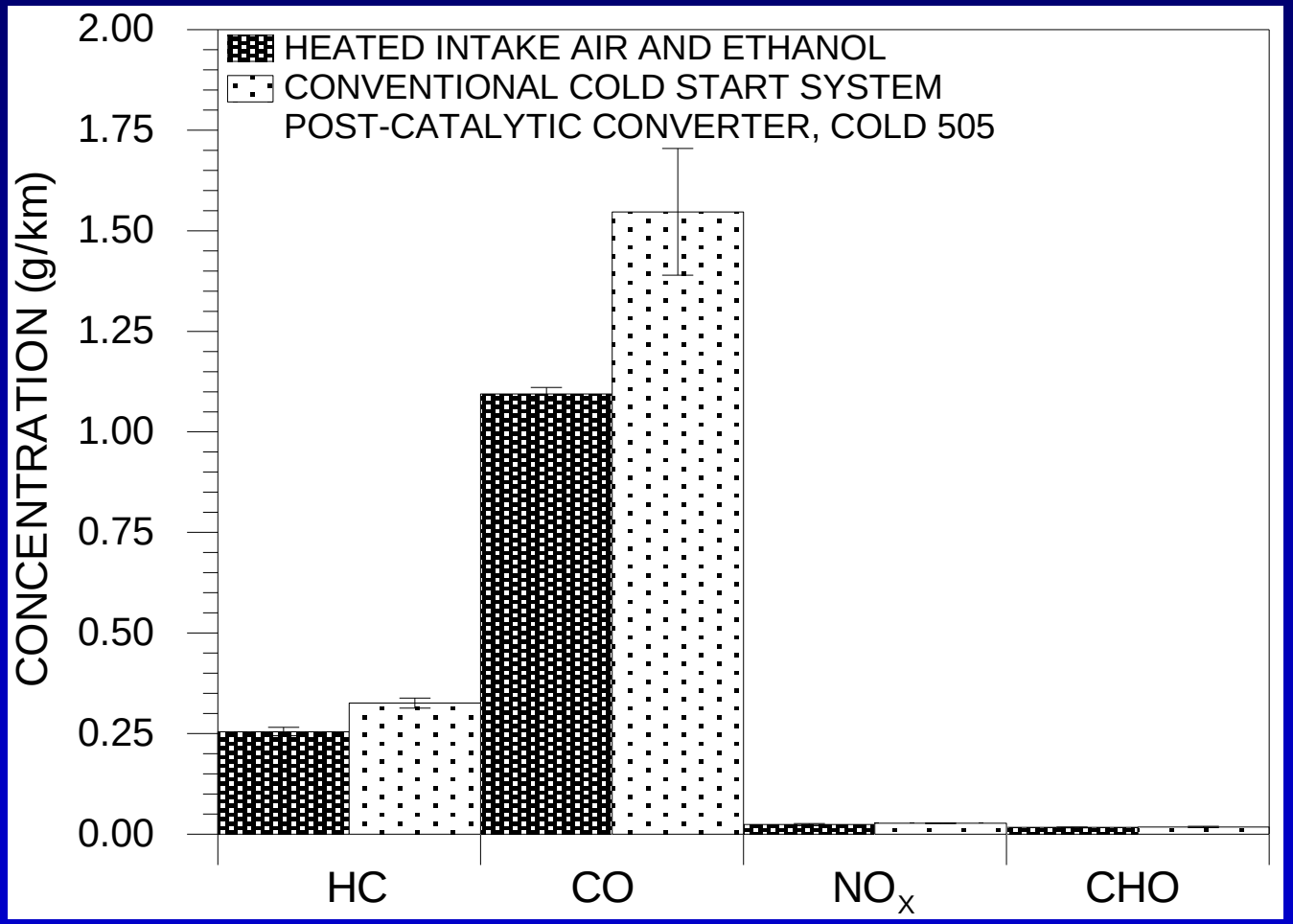
POST-CATALYST EXHAUST HC, CO, NO_X AND CHO EMISSIONS AFTER COLD START



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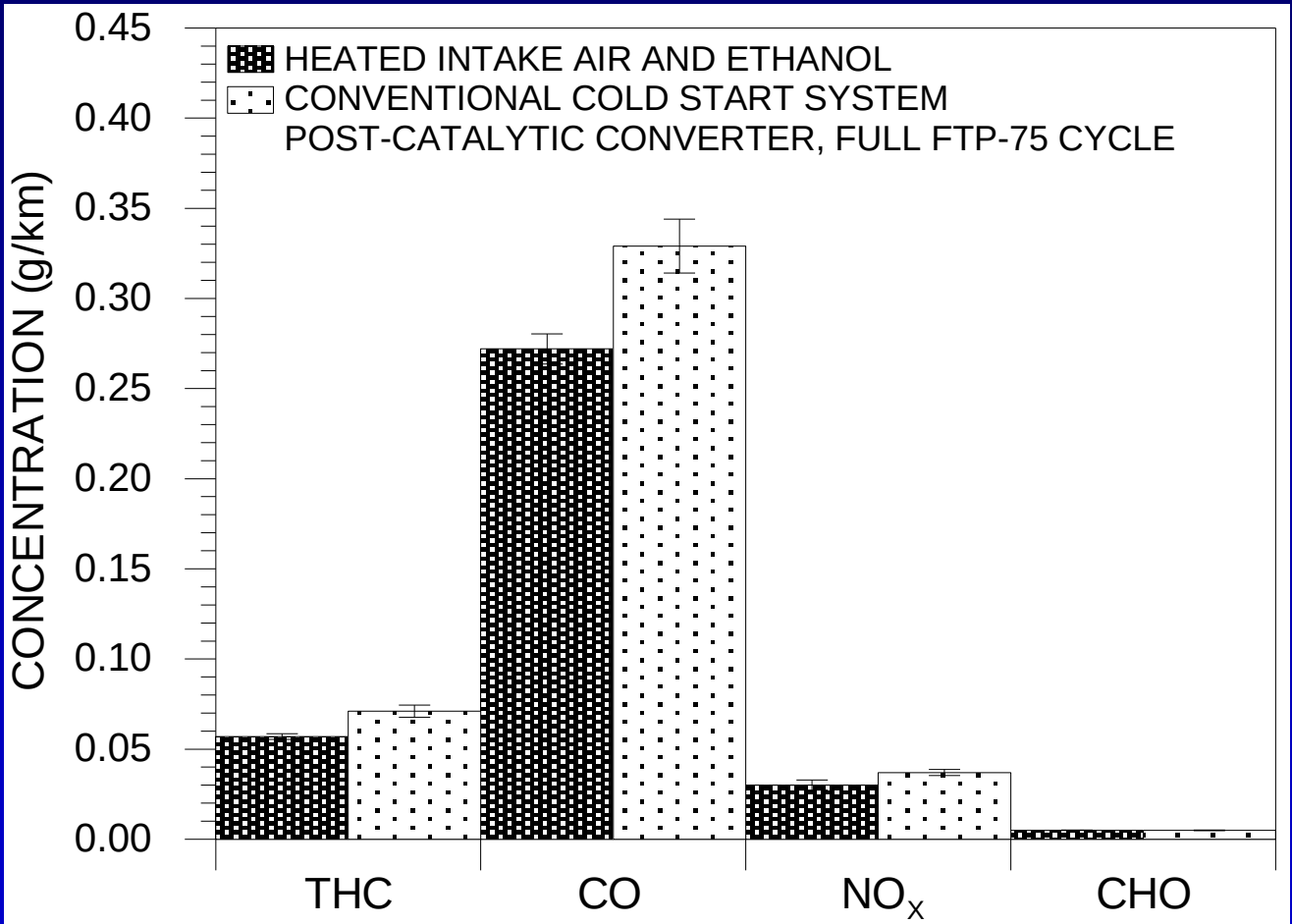
POST-CATALYST EXHAUST HC, CO, NO_X AND CHO EMISSIONS FOR FULL CYCLE



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CONCLUSIONS

- The use of 300 W electric resistance to heat the intake air together with 150 W electric resistances to heat ethanol injectors allowed for satisfactory cold start time
- At 0°C the cold start time defined by the period from ignition key switch until the engine reached 800 rev/min was 1.7 s, which is 15% below acceptable standards
- Simultaneous ethanol and intake air heating produced significant reductions on raw exhaust HC and CO emissions, especially in the first 150 s of the U.S. FTP-75 test schedule
- Catalytic converter efficiency for HC and CO reduction was also increased with heated intake air and ethanol
- NO_X and aldehyde emissions were not significantly altered by the new cold start system

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