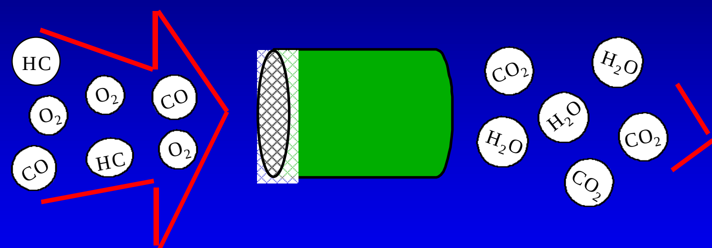
Understanding Catalyst Durability Issues for Two-and Three-Wheel Vehicles



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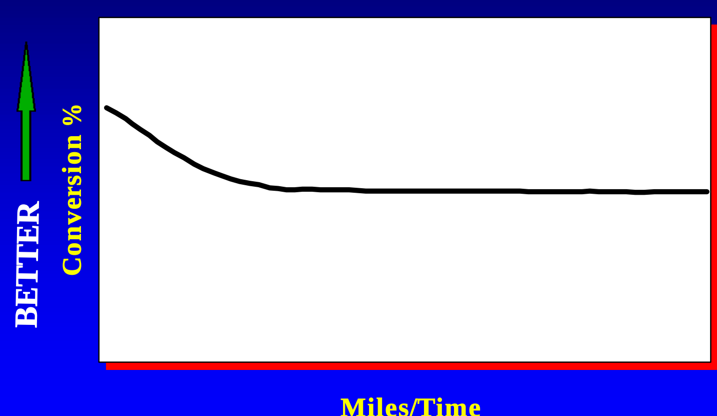
Typical Vehicular Catalyst Performance During Extended Use



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Catalyst Performance Over Time is Influenced by . . . .

- **Elevated Operating Temperatures**
  - Inlet exhaust temperature
  - Exhaust composition
  - Exotherm on the catalyst
- **Poisoning of Catalyst**
  - Fuel quality - unleaded fuel is critical
  - Motor oil quality
  - Engine components

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High Temperatures Cause . . . . .

- **Sintering of the noble metals**
  - Loss of active surface area
- **Alloying of precious metal components**
- **Sintering of washcoat components**
  - Loss of surface area
  - Loss of pore structure
  - Entrapment of noble metals
  - Changes in phases and chemical properties
    - Alumina
    - Stabilizers
    - Promoters

Result ⇨ Loss of Catalytic Activity and Accelerated Aging

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Exhaust-borne Poisons

- ***Physical Poisons - Mask and Cover Noble Metals***
  - **Phosphorus, Zinc, and Calcium From Oil**
  - **Silicon (Recycled Cleaning Fluids)**
  - **Manganese (MMT Additive)**
- **Chemical Poisons - React with Noble Metals**
  - **Lead and Halide Scavengers in Leaded Fuels**
  - **Sulfur Dioxide**

Result ⇨ Loss of Catalytic Activity

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Study Methodology

- **Catalyst Aging**
  - **Bench engine aging**
    - Elevated temperatures
    - Accelerated poisoning
- **Performance Evaluation**
  - **Chassis Dynamometer**
    - ECE-40 test method
    - 50 cc 2-stroke
  - **Stand Dynamometer**
    - Temperature sweep testing (light-off)
    - Automotive 4-stroke engine
- **Post Mortem Analysis**
  - **Physical Changes**
  - **Chemical Changes**

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Aging Conditions

	Description	Temp Range ($^{\circ}$C)
100-MMH	100 hours of multi-mode aging	500-860
25-SMH	25 hours of single mode high temperature aging	950
2S	2-stroke oil	---
B	Blended (2/1 2-stroke/4-stroke)	---

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Poisons

	2-stroke Oil (ppm)	4-stroke Oil (ppm)	2/1 Test Blend (ppm)
Calcium	210	540	320
Magnesium	1.7	810	271
Phosphorous	0.9	1000	333
Zinc	0.4	870	290

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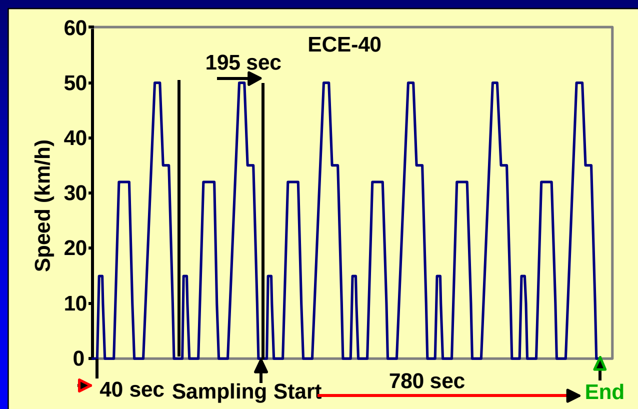
ECE-40 Test Method



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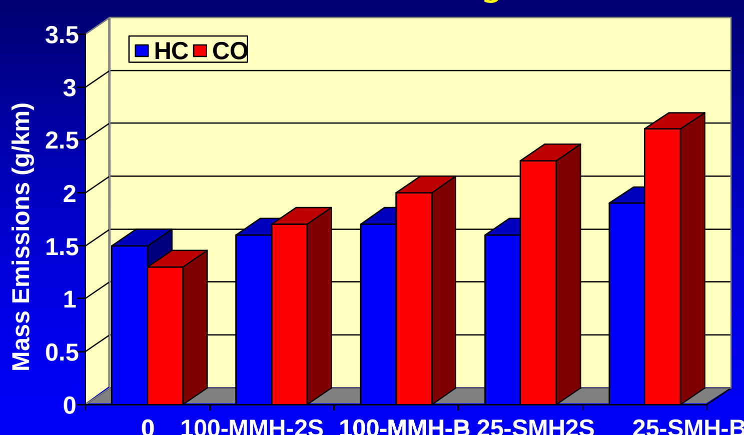
Post-catalyst Mass Emissions as a Function of Aging Environment During 50 cc 2-Stroke Vehicle Testing



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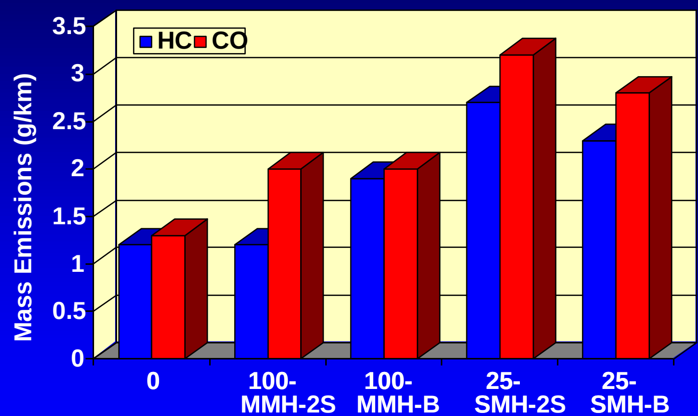
Post-catalyst Mass Emissions as a Function of Aging Environment During 50 cc 2-stroke Vehicle Testing with 2nd Air Injection



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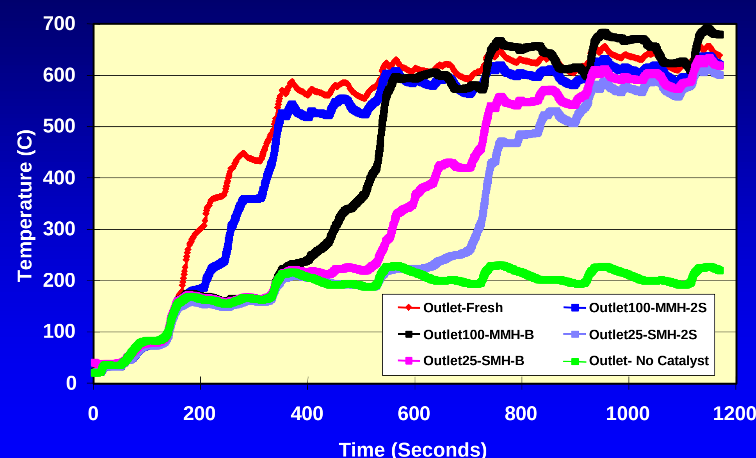
Catalyst Outlet Temperatures During ECE-40 Mass Emission Testing



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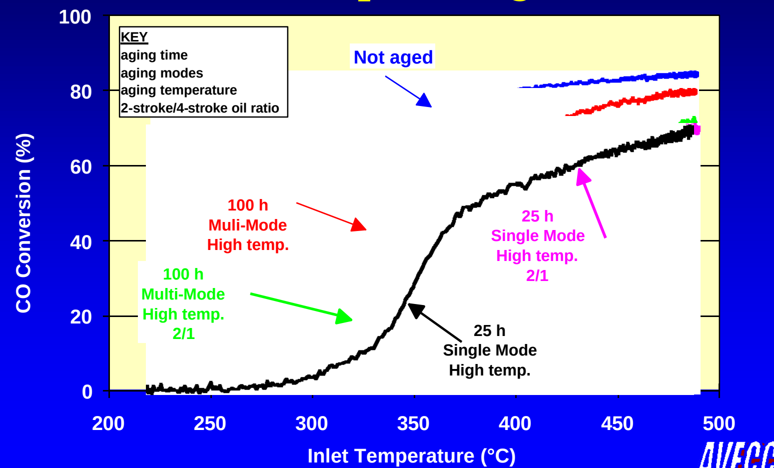
Impact of Aging Environment on HC and CO Conversions During Temperature Sweep Testing



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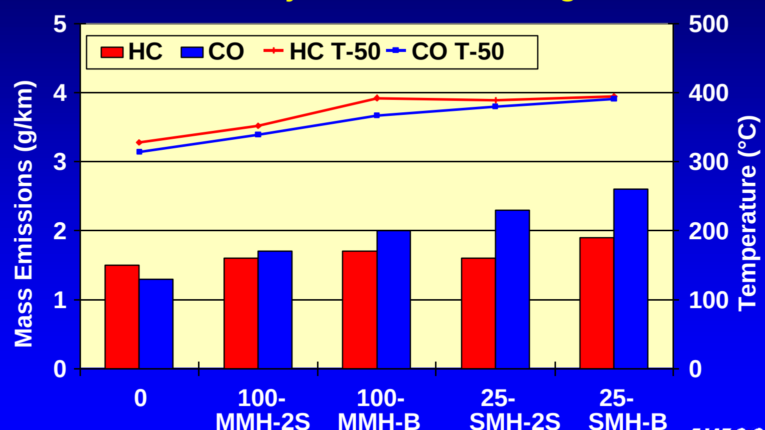
Post-catalyst HC and CO Mass Emissions During 50 cc 2-stroke Vehicle Testing and the Corresponding HC and CO T-50 During Stoichiometric Stand Dynamometer Testing



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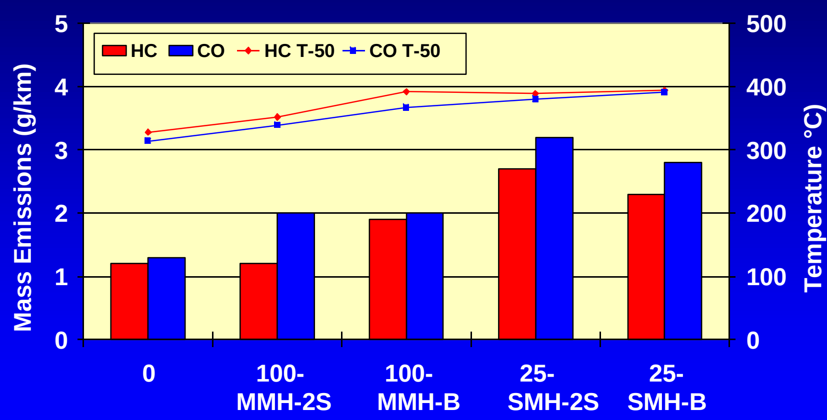
Post-catalyst HC and CO Mass Emissions During 50 cc 2-stroke Vehicle Testing and the Corresponding HC and CO T-50 During Stoichiometric Stand Dynamometer Testing



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Surface Areas of Aged Parts

Catalyst	Surface Area (m^2/g)	Area Loss (%)
Fresh	54.4	---
100-MMH-2S	40.0	26
100-MMH-B	35.0	36
25-SMH-2S	22.8	58
25-SMH-B	18.8	65

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Significant Changes in Catalyst Composition Due to Aging Conditions are Indicated

Aging	CeO_2	$CeAlO_3$ or $LaAlO_3$
Fresh	Major	---
100-MMH-2S & MMH-B	Major	Minor
25-SMH-2S & SMH-B	Minor	Major

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The Exhaust Stream Environment Has a Clear Impact on Catalyst Surfaces

	Surface Composition (atomic %)						
	C	Ca	P	S	Pt	Rh	Al
Unaged	25.3	0.0	0.9	1.3	5.5	0.8	8.8
100-MMY-2S	23.5	5.1	1.7	1.2	1.7	0.0	6.0
100-MMH-B	27.3	2.0	7.6	0.5	0.5	0.0	2.8
25-SMH-2S	30.2	1.3	1.5	1.3	1.8	0.7	5.1
25-SMH-B	28.6	0.9	4.6	0.6	0.7	0.2	2.4

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Catalyst Deactivation Processes Are A Function of the Power Plant

	Thermal	Poisons
2-stroke	+	-
4-stroke	-	+

Conclusions

- **Thermal and poisoning modes of catalyst deactivation can both significantly impact catalyst performance**
- **Analysis of aged parts indicated major changes in physicochemical properties due to thermal and poisoning processes. These changes correlated with deteriorated catalytic performance**
- **Reducing exposure of the catalyst to exhaust-borne poisons can maximize long-term performance. Particularly for 4-stroke applications**
- **Effective heat management is important for maintaining long-term performance**

Conclusions

- **Temperatures need to be high enough to initiate catalytic activity, but not promote thermal deactivation processes**
- **Delayed catalyst light-off is the primary cause of reduced catalyst efficiency (higher mass emissions)**
- **Catalysts should be formulated and designed for maximum *tolerance* to catalyst poisons and elevated temperatures**
- **Vehicle specific factors are also important to long-term effectiveness of catalytic aftertreatment**

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