

2 / 3 Wheeler Catalyst Technologies


AVECC Conference 2004
China World Hotel
Beijing

G Chandler

ENVIRONMENTAL CATALYSTS AND TECHNOLOGIES



Asian Market overview and Motorcycle catalyst

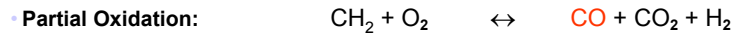
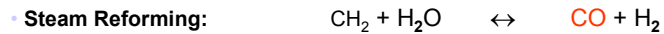
- Manufacturers in China tend to tune rich tune for enhanced power, but the future legislation must be met requiring possible calibration changes:
 - Vehicles must be tuned leaner to facilitate greater conversion of CO and suppress the CO forming reactions over catalyst.
 - Catalysts must be formulated that operate better under rich conditions by promoting CO and HC conversion
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Asian Market over view and Motorcycle catalyst

- Manufacturers in India generally tune vehicles leaner, and may also use SAI. They are also facing tough new legislation.
 - Increasing the catalyst size may increase HC conversion, but can generate CO if the catalyst formulation is not optimised.
 - Catalyst formulation can be optimised to improve CO and HC conversion, allowing a catalyst to be used to meet the regulations.

CO and HC are more difficult to convert under rich conditions

CO can be generated over the catalyst under rich conditions by



Catalyst Development



General Catalyst Development Objectives

- Good hydrocarbon conversion without generating CO
- Good CO conversion without affecting hydrocarbon activity
- NOx conversion if the vehicle calibration is suitable
- High thermal durability (2-stroke) (Tubes)
 - Large exotherm generated over catalyst due to high hydrocarbon content of exhaust gas
 - Temperature rise can be $>400^{\circ}\text{C}$ across catalyst
 - Catalyst location
- Poisoning resistance
- Ability to thrift metal from formulation to reduce cost



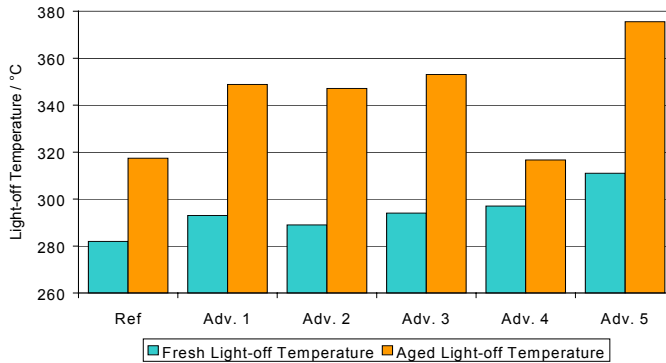
2-Stroke Catalyst Development Program

- Five potential new washcoat formulations all with superior fresh CO activity (ADV1 to ADV5) were compared against the reference catalyst (REF).
- First, the catalysts were compared for light-off temperature on a European moped using a WOT test.
- Then the catalysts were aged on a 2-stroke bench engine to simulate 30,000 km durability, and tested for aged light-off activity.
- Finally, the most durable advanced CO catalyst was compared with the reference catalyst for emissions on vehicles.
- Vehicles from both Indian and Chinese markets were used to assess overall CO conversion over two different drive cycles.



2-Stroke Catalyst Development

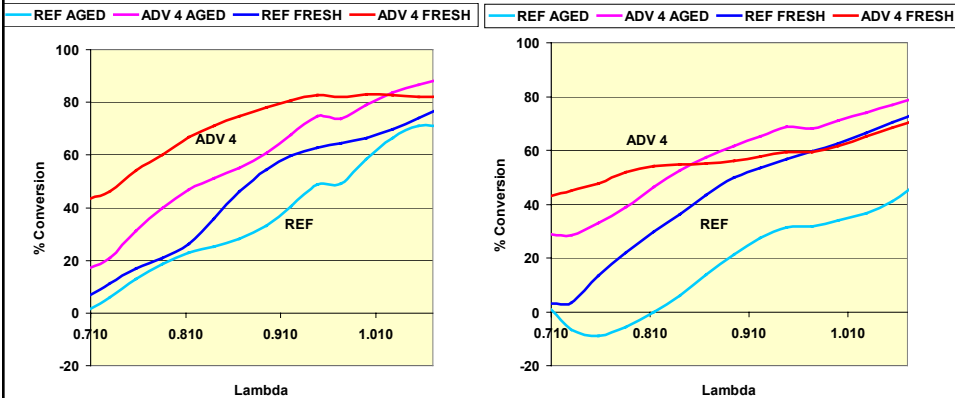
- Aged light-off temperature indicates formulation durability.
- New formulations must be as durable as the reference catalyst.
- Only Adv.4 shows equivalent durability to the reference catalyst after ageing for lightoff performance.



2-Stroke - SCAT CO Performance Fresh and Aged

450 °C Evaluation

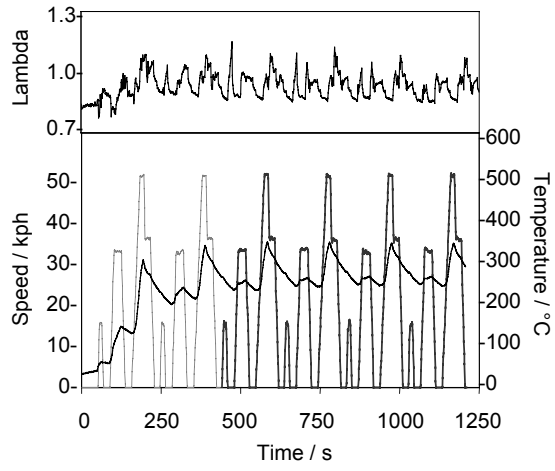
600 °C Evaluation



2-Stroke Applications



Chinese 2-Stroke



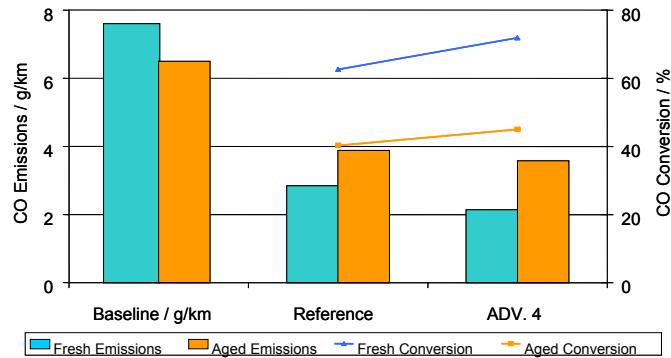
Low catalyst inlet temperature due to R40 drive cycle, rich tune, and catalyst position.

Temperature rise is fairly rapid, but peak temperature is low.

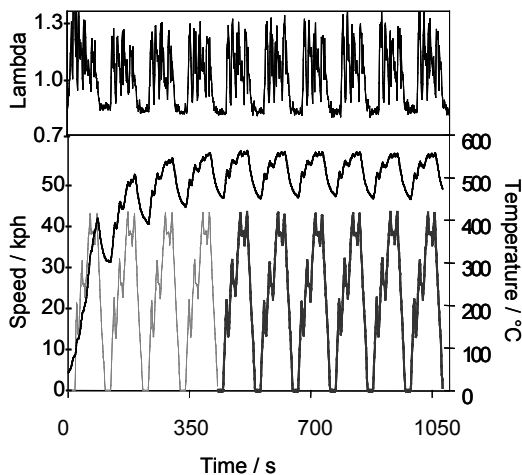


Chinese 2-Stroke

- ADV. 4 fresh and aged CO conversions are significantly better than the reference catalyst
- Fresh CO conversion is 10% improvement on reference
- Aged CO conversion is 5% improvement on reference
- Needs a catalyst to meet Stage 1 4.5 g/km CO



Indian 2-Stroke



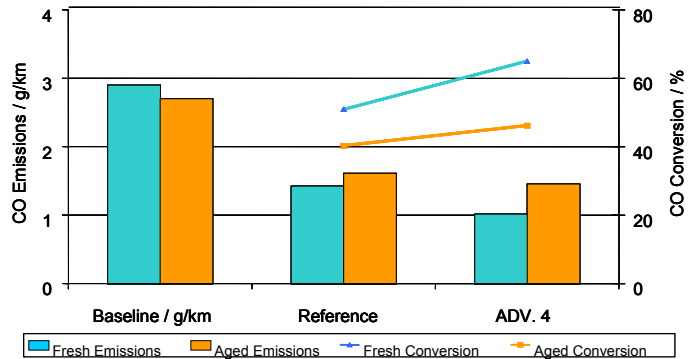
High catalyst inlet temperature due to relatively close coupled position in exhaust. Very fast warm-up.

Generally lean exhaust to promote fuel economy. Idle is rich.

Lambda is highly transient

Indian 2-Stroke

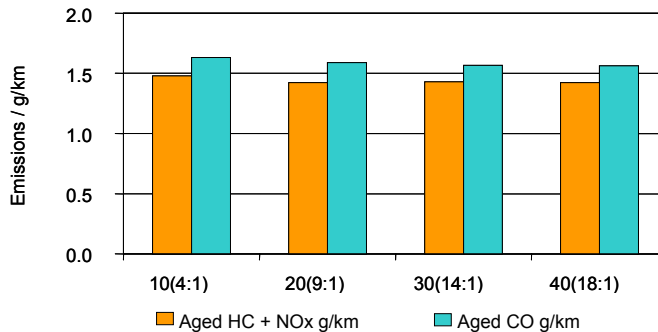
- ADV. 4 fresh and aged CO conversions are significantly better than the reference catalyst
- Fresh CO conversion is 15% improvement on reference
- Aged CO conversion is 5% improvement on reference
- Catalyst required to meet CO limit of 2.0 g/km



2-stroke Monolith Catalysts loading g/ft³

Aged catalyst activity after 30,000 km (simulated) 2-stroke motorcycle, 40 X 40 / 100 cpsi IDC

- All PGM loadings met the aged emissions target
- The difference between the performance of the 40 g/ft³ and the 10 g/ft³ formulations was very small
- Hot test



Conclusions

- ADV 4 meets all the development objectives
 - Improved fresh and aged CO conversion, allowing vehicle manufacturers a greater margin for tuning the engine and controlling emissions with larger converters
- ADV 4 is an improvement on the reference catalyst over a wide range of operating conditions
 - On Indian vehicles, the CO improvement is 15%, and on the Chinese vehicle the improvement is 10%
 - Equivalent light-off after ageing ensures product durability
- More durable catalysts with superior CO activity offer the potential for substantial PGM savings



DI 2-Stroke Moped Vehicle Study



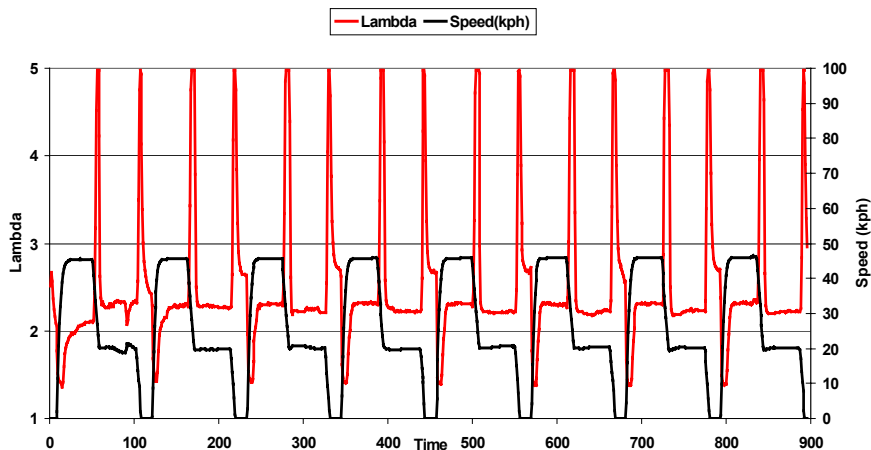
DI 2-Stroke Characteristics

- New engine design
 - Fuel is injected directly into the cylinder so short-circuiting of unburned charge is eliminated, giving better fuel control
 - Low HC and CO concentrations, but may be higher NO_x depending on the calibration
- Catalyst issues
 - Vehicle tune is sensitive to exhaust obstructions so catalyst placement is critical
 - Lower exotherm over the catalyst, typically 150°C
 - Very lean exhaust, so HC and CO conversions are high, but NO_x conversion is minimal
 - **New optimised catalyst formulation required**

DI 2-Stroke Characteristics

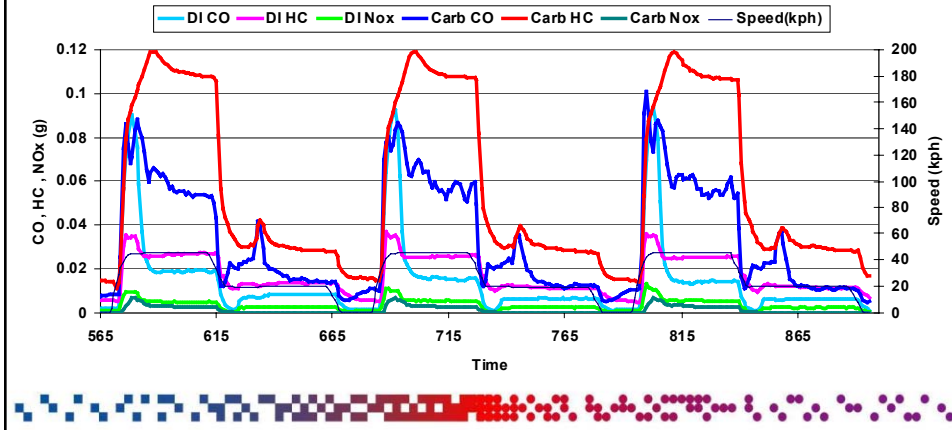
Low catalyst inlet temperature over R47 drive cycle (350 °C), due to catalyst position and calibration.

Lean running 100% of the cycle.



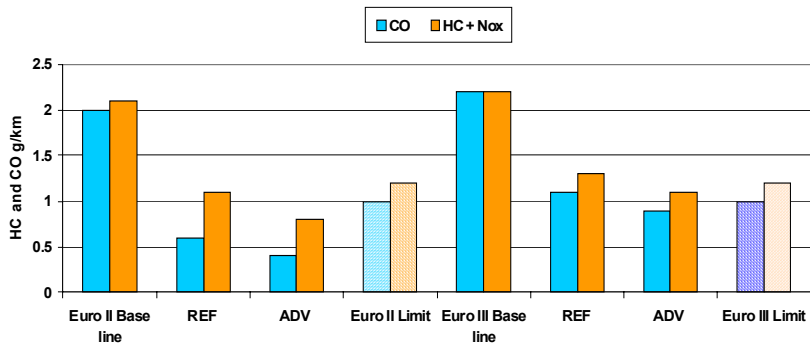
2-Stroke DI vs. 2-Stroke Carburetted Engine

- The DI has significantly lower HC emissions over all sections of the test cycle
- CO with the DI is lower during steady state cruising and decelerations
- NOx levels are lower on the Carburetted vehicle



New DI 2-Stroke Catalyst developments

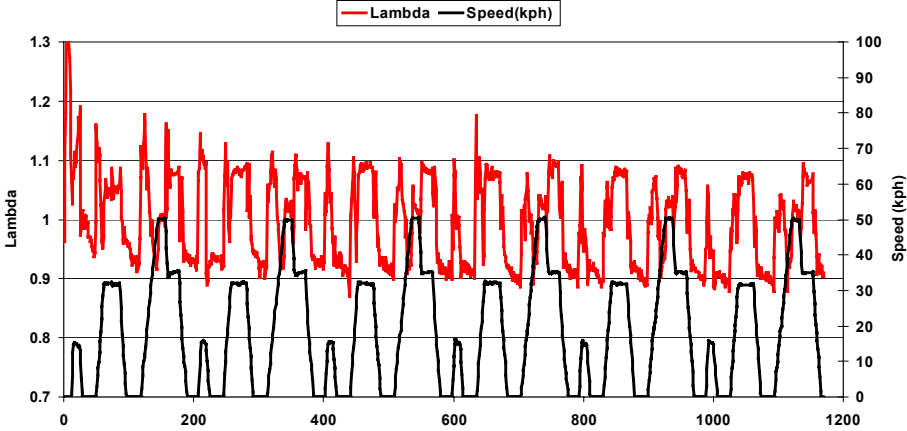
- New DI formulation has better aged CO conversions and is significantly better than the reference catalyst
- Aged CO conversion is 30% better over the Stage II test and 20% better on the Stage III test
- The vehicle requires a catalyst to meet Euro II
- Advanced formulation meets the Euro III cold test limits



4-Stroke Applications

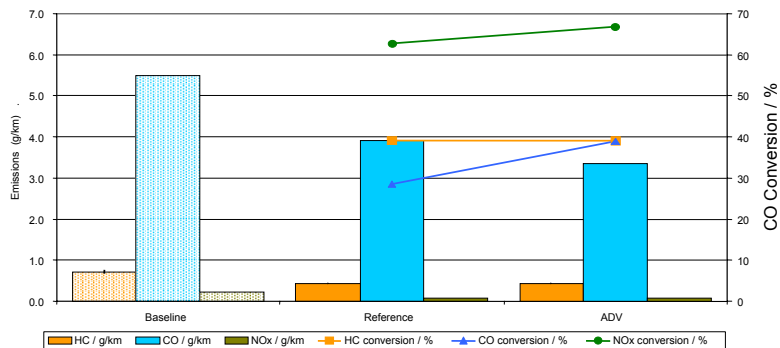


Chinese 125cc 4-Stroke Motorcycle Lambda trace



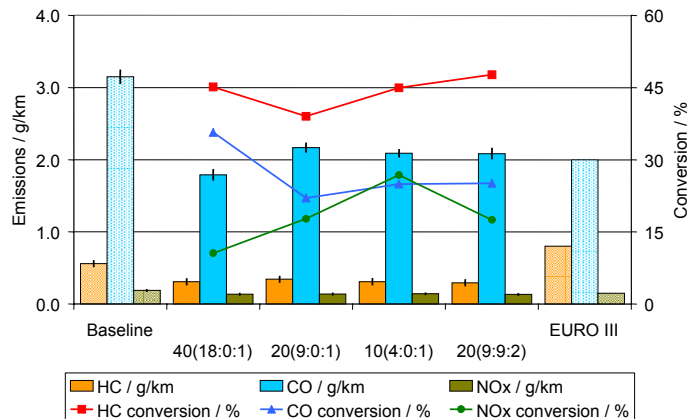
Chinese 125cc 4-Stroke Motorcycle emission results

- New FS formulations offer significant improvements over the reference catalyst
- Aged CO conversion shows a 12% improvement over the reference
- A Catalyst is required to meet the Stage 1 CO limit of 4.5 g/km



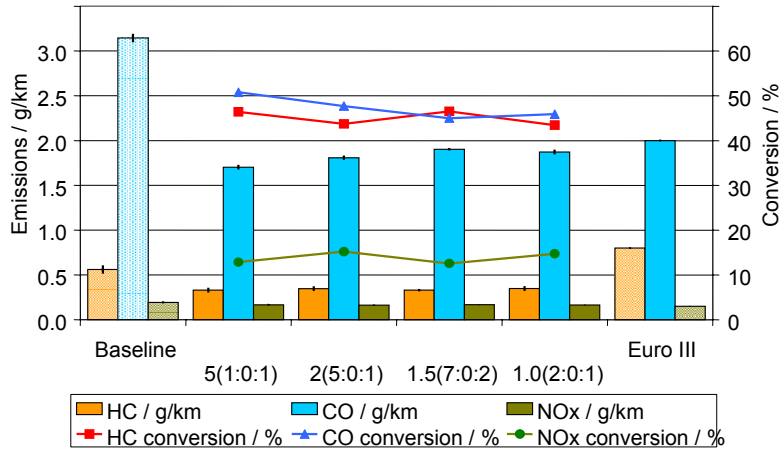
4-Stroke Monolith Catalysts loading g/ft³

Aged catalyst activity after 30,000 km (simulated)
 Chinese 125cc 4-stroke motorcycle, 33x60 / 100 cpsi (R-40)
 Stage II Limit 3.5 (g/km) CO



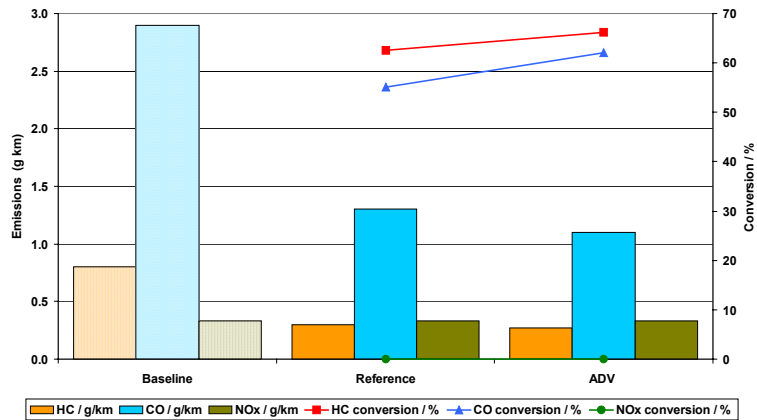
Coated Perforated Tubes 28x266 mm loading g/m²

Fresh CT tube catalyst activity
Chinese 150 cc 4-stroke motorcycle with SAI, (R-40)



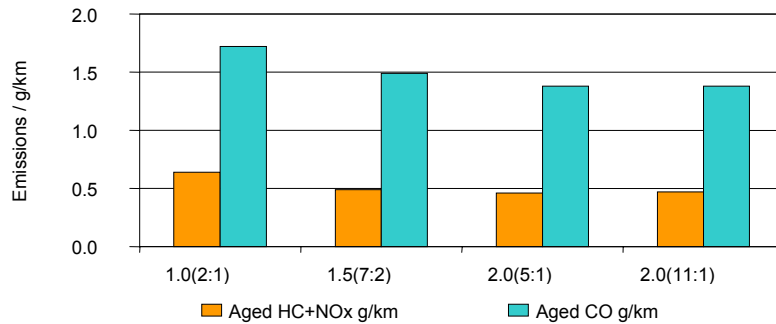
Indian 160 cc 4 Stroke with SAI Emission results

- FS formulation has significantly better HC and CO than the reference catalyst under lean running conditions
- Aged CO / HC conversions are a 10% improvement on reference
- Catalyst required to meet CO limit of 2.0 g / km

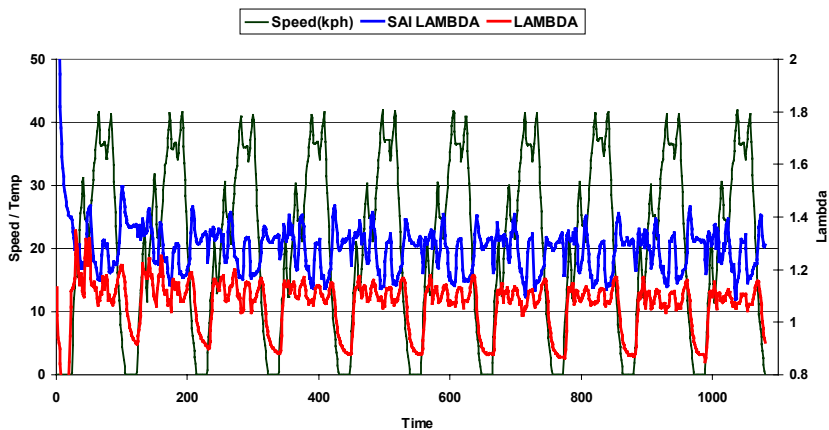


4-stroke Indian Motorcycle Coated Tube Catalysts

- New CT catalysts may also be used on tubes where slightly lower % conversions are required to meet the limits
- The difference between the performance of 1.0g m² and 2g m² formulations is very small.

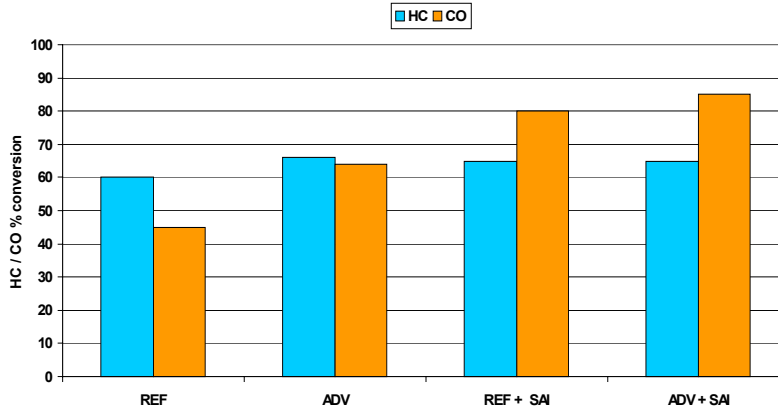


Indian 4-Stroke with / without SAI Lambda

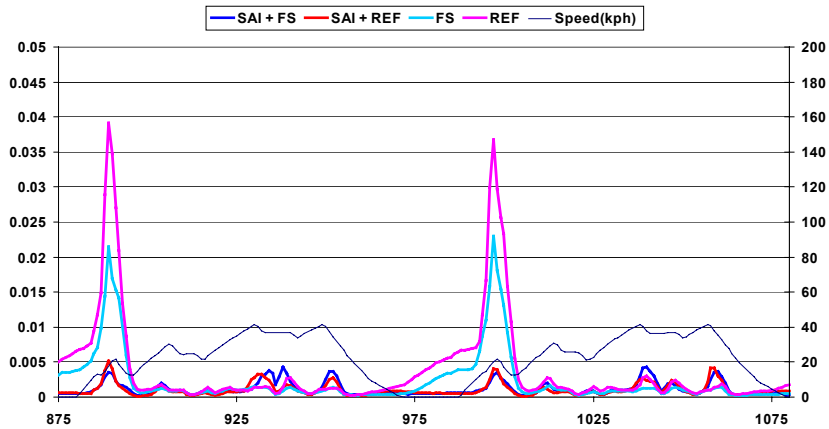


HC and CO % conversions with / without SAI

- FS formulation has significantly better HC and CO than the reference catalyst under both running conditions
- SAI has a large effect on CO

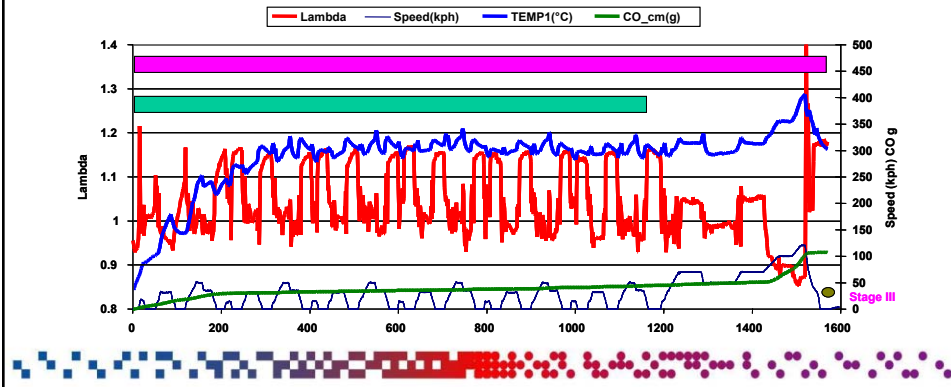


CO break through



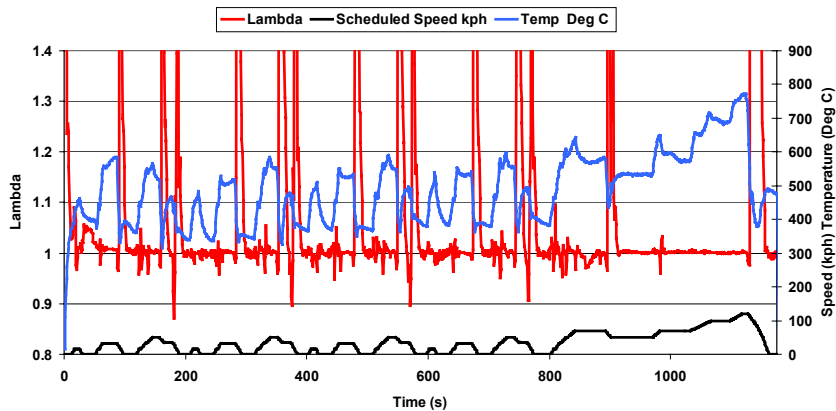
Looking Ahead to Euro III

- Emissions measured from Key On
- < 150 cc 6 x UDC
 - > 150 cc 6 x UDC + EUDC (clipped low power)
 - PM emissions* OBD* Durability*
- Catalyst needs to operate effectively early in the test and at high space velocities :
 - (Low lightoff temperature, Fast kinetics, Thermally durable)



1.3 Gasoline Vehicle Temperature / Lambda

Stage III Car Limits HC = 0.2 , CO = 2.3 , NOx = 0.15
 2006 >= 150cc Motorcycle Limits HC = 0.3 , CO = 2.0 , NOx = 0.15



Summary

- There are a large number of products for motorcycle applications for a large and diverse market
- Products need to be integrated with the application, and where possible developed in conjunction with the manufacturer, considering:
 - Final emissions targets
 - Carburettor tune
 - Position inside muffler
 - Effect on vehicle performance and rideability
 - Overall Cost
 - System durability
- New Catalyst developments are constantly pushing up conversion enabling cost effective solutions to be engineered.

