
Exhaust Emissions Control for Off-Road SI Engines

Manufacturers of Emission Controls
Association

May 2000



Outline

- >25 hp Off-Road SI Engines
 - Past Experience
 - Systems for Various Fuels
 - Product Lines
 - Performance
- Marine Stern Drive SI Engines
- Lawn and Garden SI Engines
- Conclusions



>25 hp Off-Road SI Engines



A Large Number of Engines Have Been Equipped with Emission Control Technology Over the Last 35 Years

- First Installation – Ballentine Brewery – 1964
 - Oxidation Catalysts – Eliminate Warehouse Carbon Monoxide (CO)
 - Meet OSHA Workplace Standards
 - Product Quality – Food and Product Spoilage
- To Date, Over 150,000 Systems Installed
- Three-Way Catalyst (TWC) Closed-Loop with LPG Fuel Systems Marketed for Over 8 Years
- Most OE Manufacturers Now Offer TWC Systems as Optional Equipment

After 40 Years, Regulations Have Finally Taken Hold



Advantages Beyond Emissions Control and Worker Health

- Productivity Improvements
- Operator Alertness – Accident Avoidance

***The Local Environment as well as the
Regional Environment Is Improved***



Systems Designed for Various Fuels

- Forklift Trucks
 - Gasoline – 25%
 - LPG – 75%
 - CNG -- Special
- Industrial Engines
 - Gasoline – 25%
 - LPG – 75%
 - CNG – Special
- Annual Unit Sales
 - Gasoline – 17,000
 - LPG – 34,000
 - CNG -- Varies



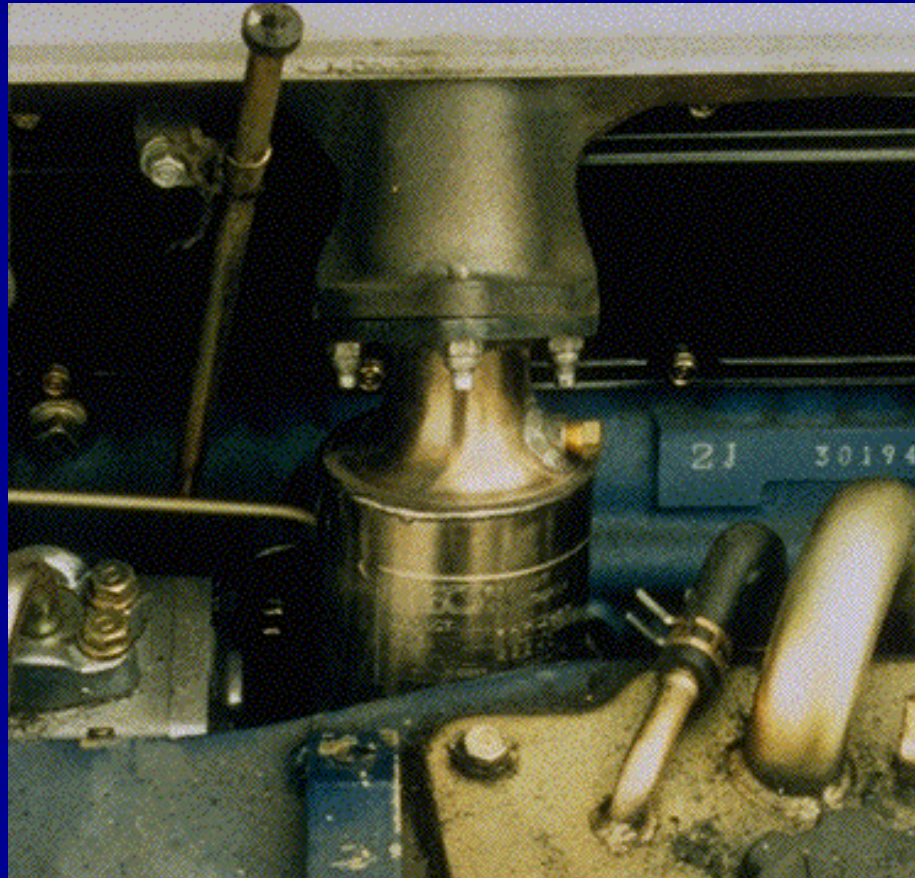
Typical Product Lines

- Catalytic Converters
 - Oxidation Catalysts
 - TWC
- Close Coupled, In-Line, Integrated Converter Mufflers
- Complete Closed-Loop Fuel Management Systems

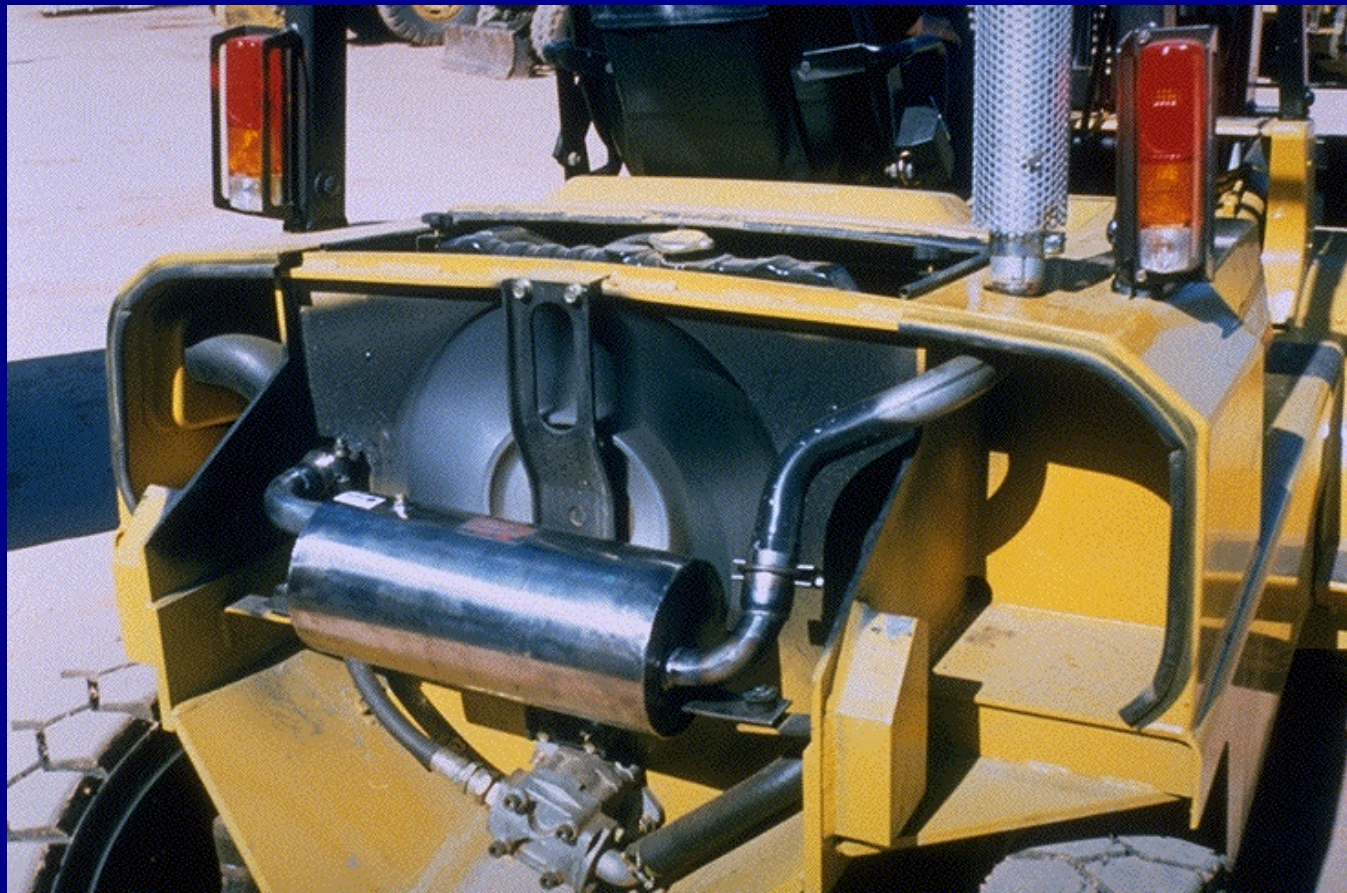
A Wide Range of Products for The Different Applications



Close Coupled Converter



Integrated Converter Muffler



Closed-Loop LPG/CNG Emissions Control Systems



Closed-Loop Performance: LPG

45 hp, 2l Engine ISO 8 Mode (g/bhp-hr)	CO	HC	NOx
Baseline - open-loop, lean	109	3.11	8.75
Standard ECM - closed-loop	14	1.99	18.57
Optimized w/ Catalyst	0.78	0.04	1.1

Testing at SwRI Has Shown Excellent Catalyst Durability for Over 4000 Operating Hours

Marine Stern-Drive SI Engines



Emissions from Marine Stern-Drive Engines Can Be Significantly Reduced

- Automotive Fuel Metering Systems Can Be Utilized
- TWC Catalyst Technology Can Be Applied
- Engineered Solutions Can Be Developed for:
 - Integration into the Boats (Space and Heat)
 - Water Contacting the Catalyst
- With an Engineered System, It Is Expected That Emissions Reductions in Excess of 90% for CO, HC, and NO_x
- Joint ARB/U.S. EPA/MECA Test Program Underway



Lawn and Garden SI Engines



Catalyst Technology Has Been Successfully Applied To Lawn and Garden SI Engines

- Handheld Engines

- NOx+HC Reductions -- 40 to 60+%
- Over 500,000 Husqvarna Engines Have Been Equipped
- U.S. Forest Service Requirements Have Been Met
- Field Experience – Reported Very Good
- All-Day Workers Appreciate

- Non-Handheld Engines

- NOx+HC Reductions -- 40 to 80+%
- Over 250,000 Lawn Mowers Have Been Equipped in the U.S.
- Easy to Apply Catalytic Emission Control Technology



Summary

- Off-Road >25 hp SI Engines – Catalytic Emission Control Is Proven for Over 35 years
- Closed-Loop Fuel Metering and TWC Systems – In-Use for Over 8 years to Control CO, HC and NOx Emissions
- Marine Sterndrive SI Engine – Automotive-Type Systems, with Engineered Modifications, Appear Ideal for This Application
- Catalyst Technology Systems Have Dramatically Improved the Exhaust Emissions of Handheld 2-Stroke SI Engines and Non-Handheld 4-Stroke SI Engines

