TITLE 13. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC HEARING TO CONSIDER THE ADOPTION OF EXHAUST AND EVAPORATIVE EMISSION CONTROL REQUIREMENTS FOR SMALL OFF-ROAD ENGINES LESS THAN OR EQUAL TO 19 KILOWATTS AND EQUIPMENT THAT USE SUCH ENGINES

The Air Resources Board (the Board or ARB) will conduct a public hearing at the time and place noted below to consider amendments to the small off-road engine regulations and test procedures, and adoption of evaporative emission standards, certification procedures, and evaporative test procedures for small off-road engines.

DATE: September 25, 2003

TIME: 9:00 a.m.

PLACE: South Coast Air Quality Management District
Auditorium
21865 East Copley Drive
Diamond Bar, CA 91765-4182

This item will be considered at a two-day meeting of the Board, which will commence at 9:00 a.m., September 25, 2003, and may continue at 8:30 a.m., September 26, 2003. This item may not be considered until September 26, 2003. Please consult the agenda for the meeting, which will be available at least 10 days before September 25, 2003, to determine the day on which this item will be considered.

If you have special accommodation or language needs, please contact the ARB's Clerk of the Board at (916) 322-5594 or sdorais@arb.ca.gov as soon as possible. TTY/TDD/Speech-to-Speech users may dial 7-1-1 for the California Relay Service.

INFORMATIVE DIGEST OF PROPOSED ACTION AND POLICY STATEMENT OVERVIEW

Sections Affected: Proposed adoption of sections 2405.1, 2405.2, and 2405.3, 2750, 2751, 2752, 2753, 2754, 2755, 2756, 2757, 2758, 2759, 2760, 2761, 2762, 2763, 2764, 2765, 2766, 2767, 2768, 2769, 2770, 2771, 2772, and 2773, title 13, California Code of Regulations (CCR). Proposed adoption of the incorporated "California Exhaust Emission Standards and Test Procedures for 2005 and Later Small Off-Road Engines," and the incorporated "Small Off-Road Engine Evaporative Emission Test Procedures, TP-901 and TP-902" and "Small Off-Road Engine Evaporative Emissions Control System Certification Procedures, CP-901 and CP-902." Proposed amendments to sections 2400, 2401, 2403, 2404, 2405, 2407, 2408, and 2409, title 13, CCR. Proposed amendments to the incorporated "California Exhaust Emission Standards and Test Procedures for 1995 and later Small Off-Road Engines," as last amended January 28, 2000, title 13, CCR.

Background: Health and Safety Code sections 43013 and 43018 direct the ARB to set emission control requirements for off-road mobile source categories. These categories include marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. The small engine category is covered by this mandate.

Small off-road spark-ignition engines run on gasoline or an alternative fuel such as liquefied petroleum gas (LPG) or compressed natural gas (CNG), and are rated at or below 19 kilowatts (25 horsepower). Small off-road engines are used to power a broad range of lawn and garden equipment including lawn mowers, leaf blowers, and lawn tractors, as well as generators and other small industrial equipment.

In December 1990, the Board approved exhaust emission control regulations for small off-road engines. (See title 13, CCR, sections 2400-2409 and the documents incorporated therein). The small off-road engine category was the first off-road category subject to emission control regulations because its emissions impact was significant and because a court order required Board action on the category by January 1991. The small off-road engine regulations apply to engines produced on or after January 1, 1995. On July 5, 1995, the United States Environmental Protection Agency (U.S. EPA) approved California's authorization request; approval allows the state to enforce the regulations.

The current small off-road engine regulations include exhaust emission standards, test procedures, and provisions for warranty and production engine compliance programs. Since its initial adoption the small off-road engine regulations have been amended several times, with the most recent amendment occurring in 1998. The current regulations consist of two tiers of emission standards. Tier 1 standards became effective in 1995, and Tier 2 standards began implementation with the 2000 model year. Exhaust emission standards have been established for hydrocarbons (HC), oxides of nitrogen (NOx), carbon monoxide (CO), and particulate matter (PM) (for two-stroke engines only). Additionally, the regulations separate small engines into three displacement categories: up to and including 65 cubic centimeters (cc), >65 to <225 cc, and 225 cc and above. Engines 65 cc and below are typically used in handheld applications, such as chainsaws and trimmers. Because of their unique operation, engine weight and size limitations, these engines are allowed to comply with a less stringent set of emission standards. Engines above 65 cc are typically used in nonhandheld applications, such as lawn mowers and portable generators. These engines meet more stringent emission levels due to the engine designs and available emission control systems.

Proposed Actions: Staff is proposing to amend the existing California exhaust emission regulations for small off-road spark-ignition engines to include more stringent exhaust standards as well as proposing new regulations to control evaporative emissions from small engine equipment.

Currently the small off-road engine regulations apply to engines below 25 horsepower (hp). The staff proposes to revise the regulations to harmonize with the U.S. EPA unit power designation and adopt the use of kilowatt (kW) as the unit of power for small off-road engines. The result is that the small off-road engine regulations would apply to engines that produce a gross power at or below 19 kW.

The original 65 cc engine class cut point was based upon the product line and market demands for handheld engines at the time the displacement categories were proposed (i.e., 1998). However, the natural progression of the product for handheld engines is moving toward larger displacement handheld engines. To address this market shift, staff proposes to modify the upper boundary of this smaller engine class to include engines up to and including 80 cc, beginning in 2005.

Staff proposes a new set of exhaust emission standards (Tier 3) for new small off-road spark-ignition engines. The Tier 3 standards would further limit exhaust emissions and are based on available engine designs and the most technologically feasible and cost-effective control strategies.

In March 2000, the U.S. EPA finalized new federal exhaust emission standards for handheld small off-road engines. The federal rule for handheld small engines includes a HC+NOx emission standard for engines below 50 cc that becomes more stringent over several years and, beginning with the 2005 model year, is more stringent than the current California HC+NOx emission standard for these same engines. Staff thus recommends adopting the federal HC+NOx exhaust emission standard for engines below 50 cc.

The staff also proposes to adopt new Tier 3 standards for engines above 80 cc. These new exhaust emission standards are based on reductions achievable with the use of a catalyst that would reduce HC+NOx by 50 percent at the end of useful life. Staff proposes to implement the new catalyst-based standards with the 2007 model year for engines >80 - <225 cc, and with the 2008 model year for engines 225 cc and above.

The proposed exhaust emissions standards are presented in Table 1, as are the existing standards for comparative purposes.

Table 1
Adopted & Proposed Exhaust Emissions Standards for Small Off-Road Engines

Year	Displacement	Standards g/kW-hr [g/bhp-hr]		
		HC+NOx	CO	PM*
Adopted Tier 2	≤ 65 cc	72 [54]	536 [400]	2.0 [1.5]
Adopted Tier 2	> 65 to < 225 cc	16.1** [12.0]	549 [410]	N/A
	≥ 225 cc	12.1 [9.0]	549 [410]	N/A
2005 and later (Proposed Tier 3)	≤ 50 cc	50 [37]	536 [400]	2.0 [1.5]
	> 50 to ≤ 80 cc	72 [54]	536 [400]	2.0 [1.5]
2007 and later (Proposed Tier 3)	> 80 to < 225 cc	8.0 [6.0]	549 [410]	N/A
2008 and later (Proposed Tier 3)	≥ 225 cc	6.0 [4.5]	549 [410]	N/A

*Applicable to two-stroke engines only.
**For 2002-2005 model years, vertical shaft engines are allowed to meet 16.1 g/kW-hr HC+NOx and 467 g/kW-hr CO emission standards without a durability demonstration.

In addition to new exhaust emission requirements, staff is proposing new regulations to control evaporative emissions from small off-road equipment less than or equal to 19 kW. Currently, there are no regulations that control evaporative emissions from small off-road equipment. If left uncontrolled, it is estimated that the statewide evaporative emissions from all small engine equipment will be 52 tons per day of HC in 2010.

The proposed evaporative emission standards are presented in Table 2 below.

Table 2
Proposed Evaporative Emission Standards for Small Off-Road Engine Equipment

Year	Displacement	Standard(s)
2007 and later	Small Engine Equipment ≤ 80 cc	Fuel tank permeation emissions shall not exceed 2.0 grams per square meter per day. Equipment that uses a structurally integrated nylon tank is exempt.
2007 and later	All Walk-Behind Mowers > 80 cc to < 225 cc	Diurnal emissions shall not exceed 1.0 gram hydrocarbons per day.
2007 and later	All Small Engine Equipment > 80 cc to < 225 cc	Diurnal emissions shall not exceed 0.21*Tank Volume+0.95 grams hydrocarbons per day.
2008 and later	All Small Engine Equipment ≥ 225 cc	Diurnal emissions shall not exceed 2.0 grams hydrocarbons per day.

The staff proposal establishes performance standards for engines and equipment. Staff is proposing to set one permeation performance standard applicable to fuel tanks on all small off-road engine equipment less than or equal to 80 cc. Staff is also proposing three diurnal evaporative emission performance standards for small off-road engine equipment with displacements greater than 80 cc. The proposed evaporative regulations also include:

- options that allow engine or equipment manufacturers to certify evaporative emission control systems;
- labeling requirements to allow for the quick identification of equipment subject to the proposed regulations; and
- test methods that ARB and industry would use to determine compliance with the permeation and diurnal evaporative emission performance standards.

To continue support of incentive programs that encourage the use of engines that go beyond mandatory emission standards, the staff proposes to implement voluntary optional low exhaust emission standards for small engines. An engine certified to these standards will be classified as a "Blue Sky Series" Engine. The optional standards represent a reduction of approximately 50 percent below the proposed Tier 3 levels for HC+NOx.

The ARB and U.S. EPA each have exhaust emissions test procedures in place which manufacturers must adhere to when certifying to the applicable State or federal exhaust emission standards for small engines. In order to ease the burden of certifying engine families with multiple units to both the federal and California emission standards, staff proposes to more fully harmonize with the federal small engine test procedures (40 Code of Federal Regulations, part 90, subparts A, B, D, and E and corresponding appendices) to be used for 2005 and later model year engines when certifying to California's exhaust emission standards. The current small engine exhaust emission regulations require that manufacturers conduct a durability demonstration as part of the certification process. For each engine family manufacturers are able to choose an emissions durability period of either 125, 250, or 500 hours for the larger (nonhandheld) engines. The federal rule also includes a 1000 hour durability option for nonhandheld engines greater than or equal to 225 cc, and in the spirit of alignment, staff proposes to adopt the 1000 hour durability option. Also, the federal rule requires manufacturers to report emission-related defects. Staff proposes a similar requirement such that a manufacturer must report to ARB emission-related defects affecting a given class or category of engines. If ARB determines that a substantial number of any class or category of engines do not conform to the regulations when in actual use, ARB will notify the manufacturer and require the manufacturer to submit a plan to resolve the nonconformity of the engines.

The staff also proposes to make other non-substantive modifications to the regulations and test procedures to clarify or simplify existing language.

COMPARABLE FEDERAL REGULATIONS

The U.S. EPA has exhaust emission control regulations for small off-road engines (Title 40, Code of Federal Regulations, Part 90). Those regulations are similar to the California regulations that predated them. The staff has made every effort to minimize conflicts with the current U.S. EPA rule, while retaining specific features needed by California. Those efforts include aligning the structure of the exhaust emission test procedures wherever justifiable. However, the proposal includes several differences from the current U.S. EPA regulations, including more stringent exhaust emissions standards, and evaporative emission standards.

The staff analysis of the proposed regulations indicates that they will reduce emissions from ozone precursors in a cost-effective manner, beyond what would be accomplished by the existing federal regulations. Thus, the cost of the separate California program is justified by the benefit to human health, public welfare, and the environment. In addition, Health and Safety Code sections 43013 and 43018 authorize the differences from the federal program.

BENEFITS OF THE PROPOSAL

The intent of the proposed regulations is to reduce emissions from small engines and equipment utilizing technologies that are technologically feasible and cost-effective. By 2010, it is estimated that the proposed emission standards will result in statewide emission reductions of 3.2 tons per day of NOx emissions and 18.5 tons per day of HC emissions. In 2020, the estimated reductions increase to 7.5 and 42.0 for NOx and HC, respectively. Staff estimates that a 2010 South Coast Air Basin HC+NOx reduction of 9.0 tons per day will be realized.

AVAILABILITY OF DOCUMENTS AND CONTACT PERSONS

The Board staff has prepared a Staff Report: Initial Statement of Reasons (ISOR) for the Proposed Regulatory Action, which includes a summary of the environmental impacts of the proposal.

Copies of the Staff Report and the full text of the proposed regulatory language, in underline and strikeout format to allow for comparison with the existing regulations, may be accessed on the ARB's web site listed below, or may be obtained from the Public Information Office, Air Resources Board, 1001 I Street, Environmental Resources Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990 at least 45 days prior to the scheduled hearing September 25, 2003.

Upon its completion, the Final Statement of Reasons (FSOR) will be available and copies may be requested from the agency contact persons in this notice, or may be accessed on the ARB's web site listed below.

Inquiries concerning the substance of the proposed regulation may be directed to the designated agency contact persons, Mr. Manjit Ahuja, at (916) 327-8528 or mahuja@arb.ca.gov, or Ms. Jackie Lourenco, at (626) 575-6676 or jlourenc@arb.ca.gov.

Further, the agency representative and designated back-up contact persons to who nonsubstantive inquiries concerning the proposed administrative action may be directed are Artavia Edwards, Manager, Board Administration & Regulatory Coordination Unit, (916) 322-6070, or Amy Whiting, Regulations Coordinator, (916) 322-6533. The Board has compiled a record for this rulemaking action, which includes all the information upon which the proposal is based. This material is available for inspection upon request to the contact persons.

If you are a person with a disability and desire to obtain this document in an alternative format, please contact the Air Resources Board ADA Coordinator at (916) 323-4916, or TDD (916) 324-9531, or (800) 700-8326 for TDD calls outside the Sacramento area.

This notice, the ISOR and all subsequent regulatory documents, including the FSOR, when completed, are available on the ARB Internet site for this rulemaking at www.arb.ca.gov/regact/sore03/sore03.htm.

COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred by public agencies and private persons and businesses in reasonable compliance with the proposed regulations are presented below.

Pursuant to Government Code sections 11346.5(a)(5) and 11346.5(a)(6), the Executive Officer has determined that the proposed regulatory action will not create costs or savings to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the state pursuant to Part 7 (commencing with section 17500), Division 4, Title 2 of the Government Code, or other nondiscretionary savings to state or local agencies.

In developing this regulatory proposal, the ARB staff evaluated the potential economic impacts on representative private persons or businesses. The ARB is not aware of any cost impacts that a representative private person or business would necessarily incur in reasonable compliance with the proposed action.

The Executive Officer has made an initial determination that the proposed regulatory action will not have a significant statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states, or on representative private persons.

In accordance with Government Code section 11346.3, the Executive Officer has determined that the proposed regulatory action will not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within the State of California, or the expansion of businesses currently doing business within the State of California. A detailed assessment of the economic impacts of the proposed regulatory action can be found in the Staff Report (ISOR).

The Executive Officer has also determined, pursuant to title 1, CCR, section 4, that the proposed regulatory action will have some impact, although not significant, on small businesses that buy and sell lawn and garden equipment. During the initial years of implementation, the increased cost of equipment may lead to a slight drop in demand that could result in lower profits for small businesses.

In accordance with Government Code sections 11346.3(c) and 11346.5(a)(11), the ARB's Executive Officer has found that the reporting requirements of the regulation which apply to businesses are necessary for the health, safety, and welfare of the people of the State of California.

Before taking final action on the proposed regulatory action, the Board must determine that no alternative considered by the agency or that has otherwise been identified and brought to the attention of the agency would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions not physically submitted at the hearing must be received **no later than 12:00 noon, September 24, 2003**, and addressed to the following:

Postal mail is to be sent to:

Clerk of the Board
Air Resources Board
1001 "I" Street, 23rd Floor
Sacramento, California 95814

Electronic mail is to be sent to: SORE03@listserv.arb.ca.gov, and received at the ARB **no later than 12:00 noon, September 24, 2003.**

Facsimile transmissions are to be transmitted to the Clerk of the Board at (916) 322-3928 and received at the ARB **no later than 12:00 noon, September 24, 2003.**

The Board requests but does not require that 30 copies of any written statement be submitted and that all written statements be filed at least 10 days prior to the hearing so that ARB staff and Board Members have time to fully consider each comment. The ARB encourages members of the public to bring to the attention of staff in advance of the hearing any suggestions for modification of the proposed regulatory action.

STATUTORY AUTHORITY AND REFERENCES

This regulatory action is proposed under that authority granted in Health and Safety Code Sections 39600, 39601, 43013, 43018, 43101, 43102, and 43104. This action is proposed to implement, interpret, and make specific Health and Safety Code Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212.

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, Title 2, Division 3, Part 1, Chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory language as originally proposed, or with non substantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text as modified is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language as modified could result from the proposed regulatory action; in such event the full regulatory text, with the modifications clearly indicated, will be made available to the public, for written comment, at least 15 days before it is adopted.

The public may request a copy of the modified regulatory text from the ARB's Public Information Office, Air Resources Board, 1001 "I" Street, Environmental Services Center, 1st Floor, Public Information Office, Sacramento, CA 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

Catherine Witherspoon
Executive Officer

Date: July 29, 2003

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs see our Web –site at www.arb.ca.gov.

California Environmental Protection Agency

Air Resources Board

STAFF REPORT
INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING
PUBLIC HEARING TO CONSIDER THE ADOPTION OF EXHAUST AND EVAPORATIVE EMISSION CONTROL REQUIREMENTS FOR SMALL OFF-ROAD EQUIPMENT AND ENGINES LESS THAN OR EQUAL TO 19 KILOWATTS

Date of Release: August 8, 2003
Scheduled for Consideration: September 25, 2003

Location:
South Coast Air Quality Management District
21865 East Copley Dr.
Diamond Bar, California 91765-4182

Air Resources Board
P.O. Box 2815
Sacramento, CA 95812

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EXECUTIVE SUMMARY

To address California's acute air quality problems, the federal Clean Air Act granted California the unique authority to adopt and enforce rules to control mobile source emissions within California. The California Clean Air Act requires the Air Resources Board (ARB or Board) to achieve the maximum degree of emission reductions possible from vehicular and other mobile sources in order to attain the State ambient air quality standards by the earliest practicable date. The Proposed 2003 State and Federal Strategy for the California State Implementation Plan (SIP) contains specific control measures aimed at reducing emissions from off-road equipment. To follow through with the commitments proposed in the SIP, staff is proposing to amend the existing California exhaust emission regulations for small off-road spark-ignition engines to include more stringent standards as well as proposing new regulations to control evaporative emissions from off-road equipment, which utilize engines less than or equal to 19 kilowatts (kW). This category includes handheld and nonhandheld lawn and garden and industrial equipment such as string trimmers, leaf blowers, walk-behind lawn mowers, generators, and lawn tractors.

Staff is proposing a new set of exhaust emission standards for new small off-road spark-ignition engines. The standards would further limit exhaust emissions of oxides of nitrogen (NOx) and hydrocarbons (HC). Rather than a single standard and implementation date for all sizes of engines, the proposal consists of different standards partitioned by the displacement of the engine. Engine displacement is defined in terms of cubic centimeters (cc).

The Board initially adopted exhaust emission standards for these engines in 1990. The existing small off-road engine regulations include exhaust emission standards, emissions test procedures, and provisions for warranty and production compliance programs. The first exhaust emission standards were implemented in 1995, with a second tier of standards being implemented with the 2000 model year engines. In addition to the State standards, the United States Environmental Protection Agency (U.S. EPA) has also established federal exhaust emission standards for these same engines.

In March 2000 the U.S. EPA finalized federal Phase 2 exhaust emission standards for handheld small off-road engines. The federal Phase 2 hydrocarbon plus oxides of nitrogen (HC+NOx) emission standard for handheld engines under 50 cc increases in stringency over several years and, beginning with the 2005 model year, is more stringent than the current California Tier 2 HC+NOx emission standard for those same engines. Therefore, staff proposes to adopt a 50 g/kW-hr (37 g/bhp-hr) HC+NOx emission standard, consistent with the federal standard, for engines less than 50 cc, beginning with the 2005 model year. The current HC+NOx emission standard of 72 g/kW-hr (54 g/bhp-hr) will be unaffected for engines 50 - 65 cc, and will also apply to engines up to 80 cc, inclusive, beginning with the 2005 model year.

The staff also proposes to adopt new Tier 3 exhaust emission standards for engines above 80 cc. This size engine is generally used in nonhandheld equipment such as lawn mowers and generators. These new standards are based on reductions achievable with the use of a catalyst. Staff proposes to implement the new catalyst-based standards with the 2007 model year for engines between 80 and 225 cc, and with the 2008 model year for engines 225 cc and above. Overall, these catalyst-based standards represent an additional 50 percent reduction in engine out exhaust emissions from the current adopted HC+NOx emission standards.

With regard to evaporative emissions, staff is proposing new regulations to control evaporative emissions from small off-road equipment less than or equal to 19 kilowatts. Currently, there is no regulation that controls evaporative emissions from small off-road equipment. If left uncontrolled, it is estimated that the evaporative emissions from preempt and nonpreempt small off-road equipment will be 52 tons per day (TPD) of HC in 2010. ("Preempt" refers to new small engines used primarily in farm and construction equipment. Federal law prohibits California from regulating exhaust emissions from preempt engines.)

The sources of evaporative emissions from off-road equipment are fuel system components (fuel tanks, fuel lines, and carburetors). Evaporative emissions occur while equipment is being operated (running loss), immediately after shutdown (hot soak), and while stored (diurnal). Diurnal emissions account for most evaporative emissions. Diurnal emissions occur because users typically do not drain fuel from equipment before storage.

The proposed regulations reduce evaporative emissions by establishing performance standards for evaporative emission control systems on engines and equipment. Staff is proposing to set one permeation performance standard applicable to fuel tanks on off-road equipment utilizing engines with displacements less than or equal to 80 cc. Staff is also proposing diurnal evaporative emission performance standards for off-road equipment utilizing engines less than or equal to 19 kilowatts with displacements greater than 80 cc. The technologies for meeting the permeation and diurnal performance standards include low permeation fuel tanks and lines, carbon canisters, and sealed systems. These technologies have a proven track record in on-road vehicles and can be applied to this category. The proposed regulations also include:

- options that allow engine or equipment manufacturers to certify evaporative emission control systems;
- labeling requirements to allow for the quick identification of equipment subject to the proposed regulations; and
- test methods that ARB and industry would use to determine compliance with the permeation and diurnal evaporative emission performance standards.

Staff has determined that the proposed regulations, exhaust and evaporative, will cost California consumers about $85 million per year over a seven-year period. This would amount to an increase of $2.16 to $179.35 per unit. Staff estimates that the added retail price of emission controls for equipment with displacements at or below 80 cc will range from $2.16 to $4.84 per unit. For equipment greater than 80 cc but less than 225 cc, staff estimates that the added retail price of emission controls will range from $37.39 to $52.13 per unit. Finally, staff estimates that the added retail price of emission controls for all equipment with displacements at or above 225 cc will range from $71.30 to $179.35 per unit. Although the percent price increase may persuade a consumer to delay the purchase of a new piece of equipment in the short term, it is not expected to significantly impact the long-term demand because equipment such as lawn mowers are necessary for lawn care and wear out.

Cost-effectiveness estimates were calculated for various applications in order to determine a range. For equipment 80 cc and below, the cost-effectiveness ranged from $1.71 to $6.21 per pound of HC reduced. For equipment above 80 cc, a rear-engine mower was determined to have the highest cost per pound of HC+NOx reduced, at $4.30. Conversely, staff identified equipment in the generator category as the most cost-effective with an estimate of $0.20 per pound of HC+NOx reduced. This compares favorably with other adopted emission reduction measures, which have a typical cost effectiveness of $5.00 per pound of HC+NOx reduced. Staff's proposal is very cost effective when compared with recently adopted control measures.

Staff held four public workshops to allow for continuing public involvement and input throughout the development of the proposed regulations. In addition staff considered alternatives to the proposal, including no action, setting zero-emission/electric equipment standards, setting more stringent standards, and the current proposal. Staff determined that adopting the proposal is both technologically feasible and cost effective.

1. INTRODUCTION

Small off-road spark-ignition engines (SORE) run on gasoline or an alternative fuel such as liquefied petroleum gas (LPG) or compressed natural gas (CNG), and are rated at or below 19 kilowatts (25 horsepower). The vast majority of these engines use gasoline. Small off-road engines are used to power a broad range of lawn and garden equipment including lawn mowers, leaf blowers, and lawn tractors, as well as generators and small industrial equipment. Exhaust and evaporative emissions from off-road equipment are a significant source of hydrocarbon (HC) emissions in California. Exhaust emissions are also a source of oxides of nitrogen (NOx). Both NOx and HC contribute to the formation of ozone. The small engine emissions (exhaust and evaporative) contribute to the State's current ozone problem, and without further control, it is estimated that nonpreempt[1] small off-road engines and equipment will emit 111 tons per day of HC+NOx into California's air by 2010. This is equivalent to the amount of emissions emitted by four million cars in 2010.

This report presents the proposed exhaust and evaporative emission requirements for small off-road engines and equipment. The proposed rule includes more stringent exhaust emission standards and new evaporative emission regulations for new engines and equipment less than or equal to 19 kilowatts. Compliance with the emission standards will substantially reduce HC and NOx emissions from new 2005 and later small off-road equipment.

This document addresses the need for the proposed regulations, provides a summary of the proposed regulations, presents environmental and economic impacts of the proposal, and discusses alternatives along with staff's proposal. Appendix A contains the Proposed Amendments to the Small Off-Road Engine Exhaust Emission Control Regulations, and Appendix B contains amendments to the exhaust emission test procedures for incorporation by reference in the regulations. Appendix C contains the Proposed Small Off-Road Engine Evaporative Emission Control Regulations, and Appendix D contains the evaporative emission test methods for incorporation by reference in the regulations. Appendix E contains the Proposed Small Off-Road Engine Evaporative Emission Certification Procedures.

1 The federal Clean Air Act Amendments of 1990 preempt California control of emissions from new engines used in farm and construction equipment under 175 horsepower. Engines that do not fall under this preemption are termed "nonpreempt." (See Appendix F.)

2. BACKGROUND

2.1 Legal Authority

In 1988, the Legislature enacted the California Clean Air Act (CCAA), which declared that attainment of state ambient air quality standards is necessary to promote and protect public health, particularly the health of children, older people, and those with respiratory diseases. The Legislature also directed that these standards be attained by the earliest practicable date.

Health and Safety Code (HSC) sections 43013 and 43018 directs ARB to achieve the maximum feasible and cost effective emission reductions from all mobile source categories, which includes off-road.

2.2 Regulatory History

2.2.1 Exhaust Emissions

In December 1990, the Board approved exhaust emission control regulations for new small off-road engines. Small off-road engines are equal to or less than 19 kilowatts and include both handheld equipment (such as string trimmers and chain saws) and nonhandheld equipment (such as lawn mowers and generators, as well as industrial equipment).

The small off-road engine regulations include exhaust emission standards, emissions test procedures, and provisions for warranty and production compliance programs (See Title 13, California Code of Regulations, sections 2400-2409 and the documents incorporated therein). The small off-road engine category was the first off-road category subject to emission control regulations because its emissions impact was significant. A settlement required Board action on the category by January 1991. The small off-road engine regulations applied to engines produced on or after January 1, 1995. On July 5, 1995, the United States Environmental Protection Agency (U.S. EPA) approved California's waiver request, which made the small off-road engine regulations the first enforceable California off-road emission control regulations. The adopted regulations consisted of two tiers. The first tier began in 1995, while the Tier 2 standards were to become effective with the 1999 model year.

Subsequent to a 1996 status report to the Board, staff proposed revisions to the 1999 Tier 2 standards. Staff used information from its own efforts and from industry input to evaluate the industry's ability to meet the 1999 standards. On March 26, 1998, the Board revised the Tier 2 standards and delayed their implementation slightly, but required manufacturers to meet the emission standards for the life of the engine instead of just when the engines are new. In addition, the Board approved an alternative to the proposed Tier 3 nonhandheld catalyst based standards that provided similar benefits by

2010, while allowing individual manufacturers the flexibility of choosing their own means to achieve the goals.

The current 2000 and later model year exhaust emission standards for small engines are shown in Table 2.1. Rather than a single standard and implementation date for all sizes of engines, the standards are partitioned by the displacement of the engine.

Table 2.1
2000 and Later Exhaust Emission Standards (Tier 2)
for Small Off-Road Engines

Model Year	Engine Displacement	Durability Periods (hours)	HC+NOx	CO	Particulate*
			grams per kilowatt-hour [grams per brake horsepower-hour]		
2000 and subsequent	0-65 cc, inclusive	50/125/300	72 [54]	536 [400]	2.0 [1.5]
2000 – 2001	>65 cc - <225 cc	N/A	16.1 [12.0]	467 [350]	N/A
	≥225 cc	N/A	13.4 [10.0]	467 [350]	N/A
2002 – 2005	>65 cc - <225 cc Horizontal	125/250/500	16.1 [12.0]	549 [410]	N/A
	>65 cc - <225 cc Vertical	N/A	16.1 [12.0]	467 [350]	N/A
	≥225 cc	125/250/500	12.0 [9.0]	549 [410]	N/A
2006 and subsequent	>65 cc - <225 cc	125/250/500	16.1 [12.0]	549 [410]	N/A
	≥225 cc	125/250/500	12.0 [9.0]	549 [410]	N/A

* The PM standard is applicable to all two-stroke engines.

2.2.2 Evaporative Emissions

In the late 1990s, portable fuel containers or "gas cans" that are used to refuel a broad range of small off-road engines and equipment were identified as a significant source of HC emissions. The 1998 statewide estimate of HC emissions from all containers was almost 87 tons per day. The HC emissions from fuel containers were attributable to spillage, evaporation and permeation. Subsequently, staff developed a regulatory proposal to control emissions from portable fuel containers. This effort culminated with the Board adopting, at its public hearing on September 23, 1999, the "Portable Fuel Container Spillage Control Regulations." By establishing a set of performance standards for portable fuel containers, the regulations have led to a significant reduction of a previously uncontrolled source of HC emissions.

With the success of the Portable Fuel Container Spillage Control Regulations, ARB's focus has turned to the evaporative emissions from small off-road engines. Evaporative and permeation emissions from small off-road engines are also a major source of uncontrolled HC emissions. The 2000 statewide estimate of evaporative HC emissions from preempt and nonpreempt small off-road engines was 47 tons per day. Beginning in early 2000, ARB staff began developing a proposal to control emissions from this category of equipment. This report describes staff's proposal to regulate evaporative and permeation emissions from small off-road engines.

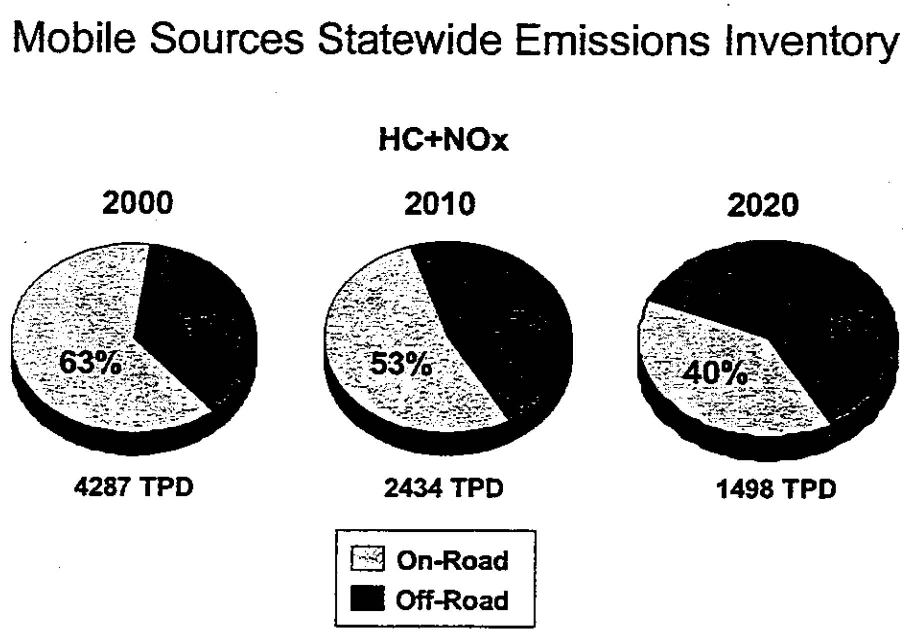
2.3 Emissions Inventory

2.3.1 Mobile Source Emissions

As shown in Figure 2.1 below, all off-road engines in 2000 emitted roughly 37 percent of the statewide mobile source HC+NOx exhaust and evaporative emissions. Although both the on-road and off-road mobile source emissions inventories are decreasing overall as a result of State and federal regulations, the off-road contribution to the total is increasing. Without any further control, the off-road percentage is expected to increase to 60 percent, in 2020. This increase is due to both the projected growth of off-road engine usage and the more stringent control of on-road sources such as cars and heavy trucks.

The proposed rule is one of several measures that ARB and U.S. EPA are pursuing to reduce emissions from the off-road category.

Figure 2.1



2.3.2 Small Engine Exhaust Emissions

Figures 2.2 and 2.3 illustrate the total statewide small engine population and HC+NOx exhaust emissions inventory, respectively for 2000, 2010 and 2020. Since the implementation of exhaust emission standards for small engines, substantial reductions have been observed in the small engine emissions inventory. The emissions contribution from small engines will decline over the next decade as a result of the current regulations. However, between 2010 and 2020 the emission contribution from small engines will begin to rise as a result of population growth with no corresponding decrease in tailpipe emissions.

Figure 2.2

SORE Equipment Statewide Population Estimates

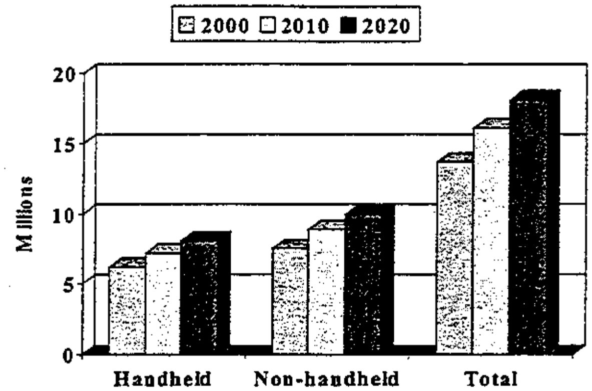
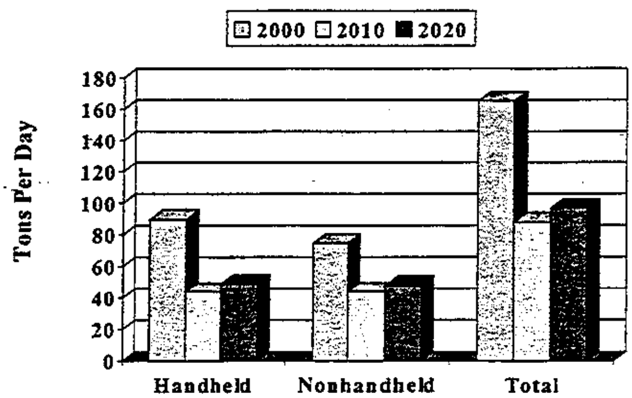


Figure 2.3

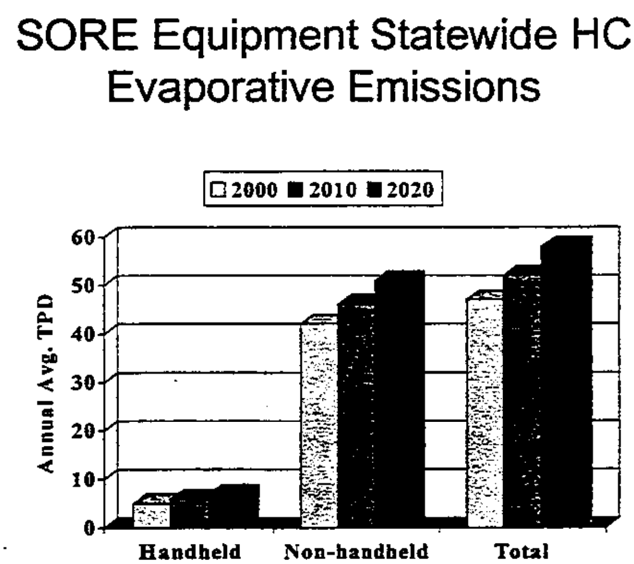
SORE HC+NOx Statewide Exhaust Emissions Inventory



2.3.3 Small Engine Evaporative Emissions

In 2000, the statewide evaporative HC emissions from all preempt and nonpreempt small off-road engines were estimated at 47 tons per day. If left uncontrolled, the emissions will increase to 58 tons per day in 2020, due to population growth. Walk-behind lawn mowers account for 31 percent of the emissions from this category. Clearly, evaporative emissions are a significant source of HC. Controlling these emissions is an essential part of California's plan to attain federal and state ambient air quality standards for ozone. Figure 2.4 shows the small engine HC evaporative emissions for 2000, 2010 and 2020.

Figure 2.4



2.4 Related Federal Regulations

In March 1999, the U.S. EPA finalized its Phase 2 rule for nonhandheld engines, which is similar to the existing California standards. In April 2000, the U.S. EPA finalized its Phase 2 rule for handheld engines. The Phase 2 rule includes an HC+NOx emission standard for engines below 50 cc that will be more stringent than the existing Tier 2 ARB standard, beginning in 2005.

Recently, the U.S. EPA also adopted rules to control permeation emissions from all terrain vehicles, off-road motorcycles, snowmobiles, and large off-road spark-ignition engines. The U.S. EPA has also proposed regulations that control evaporative and permeation emissions from marine vessels. However, the U.S. EPA has not proposed evaporative control regulations for small off-road equipment.

2.5 Public Process

The proposed regulations incorporate many comments and suggestions from off-road engine and equipment manufacturers and representatives, environmental consultants, and the U.S. EPA.

Public information concerning the development of this proposal was made available on ARB's website at www.arb.ca.gov/msprog/sore/sore.htm. In addition, announcements regarding workshops and the release of regulatory documents were provided via e-mail by ARB's Mobile Source list server.

2.5.1 Workshops

Staff conducted public workshops on November 9, 2000, April 25, 2002, November 13, 2002, and July 2, 2003 to aid in developing the proposed regulations and emissions inventory. Workshop notices were sent to almost 1000 affected stakeholders comprised of environmental organizations, engine manufacturers, equipment manufacturers, and trade associations, as well as other interested parties. Staff considered all oral and written comments received. As a result of these comments, staff made significant changes to the proposed regulations and test and certification procedures, which are reflected in the staff's proposal.

2.5.2 Meetings

Meetings have been held with a number of stakeholders as summarized in Table 2.2 below.

Table 2.2
List of Meetings

Stakeholder	Date(s)
Engine Manufacturers Association	12/13/00, 06/07/01, 12/18/01, 03/27/02, 04/08/02, 04/24/02, 06/11/02, 09/11/02, 10/16/02, 11/13/02, 11/14/02, 01/16/03, 02/20/03, 02/26/03, 03/13/03, 04/03/03, 04/10/03, 05/12/03, 06/02/03
Outdoor Power Equipment Institute	01/09/01, 12/04/01, 04/04/02, 04/12/02, 04/24/02, 06/11/02, 09/11/02, 10/16/02, 11/13/02, 11/14/02, 01/16/03, 02/20/03, 02/26/03, 03/13/03, 04/03/03, 04/10/03, 05/12/03, 06/02/03
Portable Power Equipment Manf. Assoc.	01/10/01
American Honda Co.	10/30/02, 10/31/02, 04/16/03, 07/09/03, 07/10/03
Komatsu Zenoah Co./RedMax	05/22/02
Shindaiwa Inc.	12/04/02
Tecumseh Products Co.	02/27/03
Briggs & Stratton Corp.	02/27/03
Kawasaki Motors Corp.	12/17/02
Kohler Co.	02/20/03
Kubota Corp.	02/26/03
Onan Corp.	01/29/03
Andreas Stihl AG & Co.	11/14/02

3. NEED FOR EMISSION CONTROL

3.1 Background

In 1994, ARB adopted a comprehensive Ozone State Implementation Plan (SIP). Under the federal Clean Air Act, all nonattainment areas must submit SIPs that detail how they plan to improve air quality to meet federal ambient air quality standards. The 1994 Ozone SIP described an ambitious 16-year strategy to dramatically reduce emissions and meet federally required attainment dates for the 1-hour ozone standards. Since 1994, most of the existing near-term SIP measures have been adopted by the responsible agency, along with additional controls (that had not been identified in 1994) to reduce emissions. For the South Coast ozone nonattainment area, the SIP also described a long-term strategy – allowed under Section 182(e)(5) of the federal Clean Air Act – to identify and develop additional control measures needed to attain the federal 1-hour ozone standard by the 2010 deadline.

In 1999, ARB entered into a settlement agreement with three Los Angeles-based environmental groups who filed a lawsuit regarding the 1994 Ozone SIP. Under the terms of that agreement, ARB must adopt measures to secure additional near-term reductions of HC and NOx in the South Coast in 2010. The settlement was amended in 2003, and includes a commitment by ARB to propose a measure in 2003 to reduce emissions from small off-road engines.

3.2 2003 SIP Update

ARB staff is currently developing the next phase of its emission reduction strategy to meet ongoing legal obligations under federal law and the settlement agreement. This proposed strategy includes both defined measures and a long-term strategy composed of emission reduction concepts. In ARB's Draft Proposed State and Federal State Implementation Plan Measures ("Proposed SIP Measures"), staff describes measures that will reduce emissions to help many areas of the state attain the federal ambient air quality standards by the applicable attainment dates. The Board will consider the Proposed SIP Measures in the fall of 2003.

The small off-road engine standards proposed in this staff report represent two of the defined measures in the Proposed SIP – SMALL OFF-RD-1 and SMALL OFF-RD-2. The staff's proposal contained in this staff report provides critical emission reductions to meet ARB's aggregate emission reduction obligations.

4. SUMMARY OF PROPOSAL

4.1 Introduction

This chapter discusses staff's proposed emission requirements for small off-road engines and equipment. Staff will identify the major requirements of the regulations, explain the rationale for each provision, and discuss its feasibility. The proposed regulations would apply to new off-road spark-ignition engines less than or equal to 19 kilowatts (25 horsepower) (see "Unit Power Designation" discussion below), and equipment utilizing such engines, manufactured for sale and use in California. The proposed regulation excludes farm and construction equipment engines, consistent with the preemption provisions of the 1990 federal Clean Air Act Amendments. It also excludes marine propulsion engines, engines used in devices that operate on rails or tracks, recreational vehicles, snowmobiles, and gas turbines. This is in accord with the current small off-road engine regulations (See Title 13, California Code of Regulations, sections 2400-2401).

4.2 Exhaust Emission Requirements (Engines $\leq$ 80 cc)

The small off-road engine regulations previously drew a distinction between handheld (e.g., chain saws and string trimmers) and nonhandheld (e.g., lawn mowers and portable generators) equipment applications.

Although the distinction largely succeeded in allowing handheld applications to use lighter, two-stroke engines, the staff and industry encountered a number of difficulties with the definitions. Staff and industry agreed that setting an engine standard based on the equipment application complicated the certification process. A review of certification data available in 1998 revealed a natural displacement break between engines used in most handheld applications and engines used in most nonhandheld applications. As such, at the March 1998 hearing the Board revised the small off-road engine regulations to establish three distinct engine categories based solely upon engine displacement. Those categories are engines 65 cubic centimeters (cc) and less, engines between 65 cc and 225 cc, and engines at or above 225 cc. Engines 65 cc and less are typically used in "handheld" equipment while those engines greater than 65 cc are typically used in "nonhandheld" equipment.

Since the 1998 Board hearing, however, it has been brought to staff's attention that market demand is moving toward larger sized handheld equipment, and that the natural break between engines used in handheld applications versus those used in nonhandheld applications is approaching 80 cc. For instance, the backpack blower market is infringing on the 65 cc upper limit for the largest of the smaller engines. In addition, switching from a two-stroke engine design to a cleaner emission four-stroke design could require an increase in engine displacement to generate comparable power. The original 65 cc upper boundary was based upon the product line and market demands for handheld engines at the time. Manufacturers have requested extending the smaller engine class limit to allow for the natural progression of the product demand for higher-powered handheld engines. The 2002 federal list of small engine families certified indicates that only 16 engine families between 65 cc and 80 cc were federally certified, and all of those families were certified for preempt applications. Therefore, staff has determined that the population that such a change would affect is minimal. The staff therefore, proposes to modify the upper boundary of the smaller engine class to include engines up to and including 80 cc, beginning with the 2005 model year, to adjust for the change in market demand.

4.2.1 Standards

In March 2000, the U.S. EPA finalized federal Phase 2 exhaust emission standards for handheld small off-road engines. The federal Phase 2 HC+NOx emission standard for handheld engines under 50 cc becomes more stringent over several years and, beginning with the 2005 model year, is more stringent than the current California HC+NOx emission standard for those same engines. Therefore, staff proposes to adopt a 50 g/kW-hr (37 g/bhp-hr) HC+NOx emission standard, identical to the federal standard, for engines less than 50 cc, beginning with the 2005 model year. The current HC+NOx emission standard of 72 g/kW-hr (54 g/bhp-hr) will be unaffected for engines 50 - 65 cc, and will also apply to engines up to 80 cc, inclusive, beginning with the 2005 model year. The proposed standards are shown in Table 4.1.

Table 4.1
Adopted & Proposed
0 - ≤ 80 cc Emissions Standards

Year	Displacement	Standards g/kW-hr [g/bhp-hr]		
		HC+NOx	CO	PM*
Tier 2 2000 and later (Adopted)	≤ 65 cc	72 [54]	536 [400]	2.0 [1.5]
Tier 3 2005 and later (Proposed)	< 50 cc	50 [37]	536 [400]	2.0 [1.5]
	≥ 50 to ≤ 80 cc	72 [54]	536 [400]	2.0 [1.5]

*Applicable to two-stroke engines only.

4.2.2 Technology

Manufacturers have pursued a variety of technologies to comply with the current handheld engine emission requirements. Most manufacturers have sought to improve the basic two-stroke engine design, while others have also incorporated the use of low efficiency catalysts. Some manufacturers have introduced new four-stroke engine designs to replace their two-stroke counterparts. These technologies have allowed manufacturers to comply with the current emission requirements as well as confirm the feasibility of the proposed emission requirements.

Table 4.2 shows the 2003 model year HC+NOx emission certification levels of engines less than 50 cc that have already met the proposed 2005 emission standards. Specifically, 25 engine families have certification emission levels well below the proposed 50 g/kW-hr HC+NOx emission standard. These engines incorporate the technologies mentioned above as well as other improved designs, which will be discussed further below.

The U.S. EPA's Phase 2 rulemaking for handheld engines in 2000 documents the review and testing of advanced emission control technologies in the EPA Final Regulatory Impact Analysis, Chapter 3: Technologies and Standards. These advanced technologies included stratified scavenging with lean combustion (with and without catalysts), improved two-stroke engines with a catalyst, and four-stroke engines. U.S. EPA reviewed other advanced technologies, but the technologies listed above either have been or are currently used by manufacturers and will likely be used in the future to comply with the proposed standards. These technologies are discussed further below.

Table 4.2
Current Emission Control Technologies and Emission Levels of Handheld Engines below the Proposed 2005 Standards

Manufacturer and Technology	Engine Size (cc)	Durability Period (hours)	HC+NOx level (g/kW-hr)
Andreas Stihl – Four-stroke with the 4-MIX Technology™	31	300	32.2
Andreas Stihl – Two-stroke with oxidation catalytic converter	32	50	46.9
Briggs & Stratton – Four-stroke with Fource™ side valve technology	34	50	33.5
Electrolux Home Products – Two-stroke with three way catalytic Converter	25	50	42.9
	25	50	42.9
	25	50	48.3
Fuji Robin – Four-stroke	24.5	300	18.8
	33.5	300	16.1
Honda – Mini Four-stroke technology	25	300	32.2
	31	300	41.6
Kioritz (Echo) – Two-stroke with Power Boost Tornado Technology™ and three way catalytic converter	21	300	29.5
	21	300	41.6
	21	300	41.6
	23	300	38.9
	23	300	48.3
	25	300	37.5
Komatsu Zenoah – Four-stroke	26	300	32.2
Maruyama – Two-stroke with HERE™ recirculator technology and oxidation catalytic converter	30.1	300	33.5
Mitsubishi – Two-stroke with stratified scavenging	42.7	300	40.2
MTD Southwest (Ryobi)– Four-stroke	26	50	14.8
	26	300	21.5
	26	50	37.5
MTD Southwest – Two-stroke with dual three way catalytic converter	31	50	38.9
Shindaiwa – Four-stroke with the C4 Technology™	25	300	34.9
Tanaka – Two-stroke with PureFire™ stratified scavenging technology and three way catalytic converter	24	300	37.5

4.2.2.1 Two-Stroke Engines

Stratified Scavenging Two-Stroke (With and Without Catalyst)

The inherent design of a two-stroke engine allows a portion of unburned fuel that enters the combustion chamber to escape to the atmosphere. This process, known as scavenging, results in excessive exhaust HC emissions. Komatsu Zenoah, Mitsubishi, and Tanaka are using stratified scavenging technology to meet current California standards. The stratified scavenged engine design by Komatsu Zenoah uses air as the scavenging component instead of unburned fuel. An "air head" creates a barrier between the fuel charge and the exhaust port, minimizing scavenging losses. It also effectively leans out the air-fuel mixture in the combustion chamber, improving combustion efficiency. Potential downsides of this approach include lower power. However, advantages include lower fuel consumption and lower engine out emissions, and thus will likely continue to be used and improved upon in the future. To date, one manufacturer (Mitsubishi) has certified one of its 2003 model year stratified scavenging engines (without a catalyst) that meets the proposed 2005 standards. In addition, Tanaka combined a three-way catalyst with stratified scavenging technology. The 2003 model year Tanaka engine family is certified at 37.5 g/kW-hr HC+NOx (also well below the proposed 50 g/kW-hr standard).

Two-Strokes with Catalysts

In order to meet the more stringent emission standards, some manufacturers are expected to incorporate internal engine redesign coupled with the use of a catalyst. The catalyst may consist of various formulations and substrate configurations. For handheld equipment applications, the cost of a catalyst is minimal and its additional weight is negligible. In addition, modified two-stroke engines designed to reduce scavenging will minimize the deterioration of the catalyst by significantly reducing the catalyst's exposure to "escaping" fuel and oil. Thus, staff expects widespread use of catalysts in the future for these applications.

There are a number of two-stroke engines with catalysts that have already been certified to levels below the proposed 2005 emission standards. For example, Maruyama's 30.1 cc two-stroke engine design has been shown to reach an HC+NOx level as low as 33.5 g/kW-hr using an oxidation catalyst.

Other Advanced Design

Echo recently introduced an advanced two-stroke engine technology. The Echo engine design is such that the air-fuel mixture is pressurized prior to entering the combustion chamber, and enters the combustion chamber in a "vortex-like" motion, resulting in a thorough mix of the air and fuel. The result is a more complete combustion process and a reduction in scavenging losses. For the 2003 model year, Echo's new engine design equipped with a three-way catalyst is certified to 29.5 g/kW-hr HC+NOx.

4.2.2.2 Four-Stroke Engines

Current Four-Stroke Designs

The four-stroke engine is the primary internal combustion engine design used in personal transportation and nonhandheld equipment applications. In contrast, the handheld equipment market continues to be dominated by the two-stroke engine, because of its high power-to-weight ratios, multi-positional operation, simple construction, lower manufacturing costs, and low maintenance requirements.

Compared to a typical two-stroke engine, a four-stroke engine can achieve as much as a 30 percent improvement in fuel economy and emit significantly less HC emissions. Another benefit of the four-stroke engine design is that consumers do not need to pre-mix fuel with oil. Although four-stroke engines require periodic oil changes, and are thought to be "too heavy" when used with larger sized handheld equipment, recent advances in small four-stroke engine design has allowed the four-stroke engine to be an attractive alternative to its two-stroke counterpart.

A significant number of handheld equipment manufacturers already certify engines using four-stroke technology. Ryobi Outdoor Power Products, was the first manufacturer (in 1995) to meet the stringent 2000 emission levels with a multi-positional four-stroke trimmer. In 1997, Honda also provided a mini four-stroke engine capable of meeting the 2000 standards. For the 2003 model year, ARB has certified handheld four-stroke engines manufactured by MTD Southwest, Fuji Robin, Andreas Stihl, Briggs & Stratton, Honda, Shindaiwa, Komatsu Zenoah, and Yamaha, as shown in Table 4.3. Note that they all easily meet the proposed 2005 HC+NOx standard. The equipment using these four-stroke engines include line trimmers, blower, edgers, hedge trimmers, pumps, and generator sets.

Table 4.3
2003 Model Year Four-Stroke Handheld Engines Certified in California

Manufacturer	Disp. (cc)	Durability periods (hours)	HC+NOx Level (g/kW-hr)
Yamaha Motor Co., Ltd.	50	300	10.7
MTD Southwest Inc	26	50	14.8
Fuji Robin Industries, Ltd.	33.5	300	16.1
Fuji Robin Industries, Ltd.	24.5	300	18.8
MTD Southwest Inc	26	300	21.5
Honda Motor Co., Ltd.	57	300	25.5
Andreas Stihl	31	300	32.2
Honda Motor Co., Ltd.	25	300	32.2
Komatsu Zenoah Company	26	300	32.2
Briggs & Stratton Corporation	34	50	33.5
Shindaiwa Kogyo Co., Ltd.	25	300	34.9
MTD Southwest Inc	26	50	37.5
Honda Motor Co., Ltd.	31	300	41.6

Four-Stroke Engines Using a Fuel-Oil Mix

Recently, Stihl and Shindaiwa developed new advanced designs that not only meet current emission standards but also the proposed standards. The advanced technologies have the benefits of two-stroke and four-stroke engines combined, which means they continue to use a fuel-oil mixture while incorporating intake and exhaust valves and valve train to optimize emission control. For example, the Stihl 4-MIX™ engine runs on a standard 50:1 fuel-oil mix, which eliminates the need for a separate oil chamber. Thus, this engine does not require either a supply of oil in the crankcase or a lubricating oil pump. This permits operation in all positions. Neither oil checks nor oil changes are required. In addition, because it is a four-stroke engine design, scavenging is not a concern and therefore the exhaust emissions reportably contain minimal unburned residues. Stihl's 2003 model year engine was recently certified at 32.2 g/kW-hr HC+NOx. According to Stihl, this engine can provide 5 percent more power, 17 percent more torque and 15 percent less vibration than its two-stroke counterpart.

Shindaiwa also has a patented advanced design four-stroke engine equipped with a pressurized pre-mix chamber. This chamber not only provides for increased power and torque, it also enables the use of a standard fuel-oil mix for engine lubrication. For the 2003 model year, Shindaiwa certified its four-stroke engine at 34.9 g/kW-hr HC+NOx.

4.2.2.3 Electric Powered Equipment

Many types of handheld equipment have electric-powered counterparts. Electric powered equipment does not use fuel and has no exhaust emissions stemming from the unit. Staff inspection of retail stores and web sites has revealed that electric powered handheld equipment is readily available for the residential user's market, including blowers, trimmers, and chain saws. However, most of the electric units currently available are the small, lower weight and lower cost units.

Commercial uses of handheld equipment typically require greater mobility than afforded by corded equipment and greater length of operation than provided by battery-powered units. Therefore, commercial use does not lend itself as readily to the operation of electric-powered handheld equipment compared to residential use.

However, electric equipment does remain as a viable option when consumer usage is limited to residential applications. The demographic shift toward smaller residential lots could result in an increase in the use of electric handheld equipment.

4.3 Exhaust Emission Requirements (Engines > 80 cc)

4.3.1 Standards

Staff proposes new Tier 3 standards for engines above 80 cc. The proposed standards are based on the use of a catalyst that would reduce HC+NOx by 50 percent at the end of useful life. As shown in Table 4.4, for engines >80 cc - <225 cc, the proposed Tier 3 standard is 8 g/kW-hr HC+NOx at the end of useful life. For engines 225 cc or above, the proposed Tier 3 standard is 6 g/kW-hr HC+NOx at the end of useful life. Although staff expects that carbon monoxide (CO) emission reductions may occur concurrently with HC+NOx emission reductions, staff is not proposing a change to the current CO emission standard. In previous documents released to the public staff initially proposed an implementation date of 2006 for the proposed Tier 3 standards. However, based on comments received from industry stating that more time would be needed in order to address design issues associated with adding a catalyst system to small engines, staff modified the proposal to provide manufacturers additional lead time. Staff proposes to implement the new catalyst-based standards with the 2007 model year for engines between 80 and 225 cc, and with the 2008 model year for engines 225 cc and above.

The proposed Tier 3 emissions standards for engines above 80 cc are presented in Table 4.4 below, as are the existing standards for comparative purposes.

Table 4.4
Adopted & Proposed Emissions Standards for Engines Greater Than 80 cc

Year	Displacement	Standards g/kW-hr [g/bhp-hr]	
		HC+NOx	CO
2002 – 2005	> 65 to < 225 cc Horizontal Shaft	16.1 [12.0]	549 [410]
	> 65 to < 225 cc Vertical Shaft*	16.1 [12.0]	467 [350]
	≥ 225 cc	12.1 [9.0]	549 [410]
2006 and later	> 65 to < 225 cc	16.1 [12.0]	549 [410]
	≥ 225 cc	12.1 [9.0]	549 [410]
2007 and later *(Proposed)*	> 80 to < 225 cc	8.0 [6.0]	549 [410]
2008 and later *(Proposed)*	≥ 225 cc	6.0 [4.5]	549 [410]

*For 2002-2005 model years, vertical shaft engines are not required to certify to a durability period.

Overall, the staff proposal represents an additional 50% reduction in exhaust emissions from the current adopted HC+NOx emission standards. Although, staff assumes that manufacturers will utilize catalyst technology to meet the proposed standards, the standards remain performance based, and thus manufacturers will be able to use any technology that accomplishes the ultimate goals. ARB has contracted with Southwest Research Institute (SwRI) to demonstrate compliance with the proposal using catalysts. The following discussion provides more detail regarding the technologies likely to be used along with the results of the SwRI study.

4.3.2 Technology

As noted above, staff assumes that manufactures will utilize catalyst technology to meet the proposed standards. For some engines this could require a systems approach, in which the engine, catalyst, and exhaust are integrated into one system. A compliant engine will require a well designed clean engine, in addition to a catalyst that is appropriately sized and formulated for the application. It will require good fuel management in order for the catalyst to operate at its optimal efficiency, but will not necessarily require a closed loop system or fuel injection.

4.3.2.1 Enleanment

The HC emissions may be reduced by leaning out the air-fuel mixture, which increases the proportion of air to fuel. Many small engines are operated rich of stochiometric. Engines are operated rich in order to assure good performance under a variety of conditions. Rich operation of the engine also assists in keeping the engine cool. Enleaning the mixture means that less fuel is entering the combustion chamber during a cycle. This results in a more complete combustion and thus lower HC emissions in the exhaust. Unfortunately, enleanment also results in increased combustion temperatures. The impact on performance and durability of the engine can be severe and places a practical limit on how far the air-fuel ratio of the engine can be enleaned, and how much HC emission reduction can be achieved through this method. But properly managed, modest air-fuel ratio enleanment is an effective and inexpensive HC emission control strategy, and was one of the major control strategies utilized to meet previous emission standards. By reducing the amount of HC emissions required to be oxidized by the catalyst, and increasing the amount of oxygen available for the oxidation process, enleanment can also play a major role in emission reductions when also utilized with a catalyst.

4.3.2.2 Catalytic Converters

The catalytic converter is the primary technology responsible for the remarkable improvements in automotive emission control over the past three decades. Indeed, due largely to the catalytic converter, ozone-forming emissions from a modern automobile are less than one percent of the levels of an uncontrolled vehicle of the 1960s, with improved operability and fuel economy as an added bonus. The typical modern automotive catalytic converter consists of an active catalytic material (usually one or more noble metals such as platinum, palladium or rhodium) applied as a washcoat to a substrate (usually ceramic or metal), surrounded by a mat and placed in a housing ("can") which also acts to direct the exhaust flow over the active material so as to maximize surface exposure.

In addition to their common use to reduce emissions from on-road vehicles, catalysts have long been used to reduce emissions from large off-road spark-ignition engines (i.e. engines 25 horsepower and above) in special operating environments such as mines and indoor warehousing applications. The ARB and U.S. EPA have both recently adopted standards for these large engines that are based on the use of a catalytic converter. Research test efforts and certification data show that the HC+NOx levels from these engines can be reduced more than 80 percent below uncontrolled levels by utilizing a catalyst. In addition, many manufacturers have met the current emission standards for small engines below 65 cc by utilizing a catalyst on a two-stroke engine.

There have been and continue to be small engine equipment equipped with catalytic converters (primarily in Europe), including tillers and lawn mowers. Some manufacturers used catalysts to meet the original Tier 1 emission standards. Low efficiency catalysts have been incorporated onto Briggs & Stratton lawn mower engines in Europe. Kohler has an engine certified in California for use in riding mowers and industrial equipment that is equipped with a three-way catalytic converter, along with an oxygen sensor, and an electronic control module. Onan has two engines certified in California for use in floorcare and burnisher equipment, both of which are equipped with a three-way catalytic converter, throttle body injection, an oxygen sensor, and electronic control module. The Kohler and Onan engines certified to 500 hours are operated on LPG and are designed for CO emissions control.

Staff expects that manufacturers will apply catalyst technology to meet the proposed exhaust emission standards for engines above 80cc. As discussed below, testing completed at SwRI has shown that catalyst equipped small engines can meet the proposed standards over the lifetime of the engine.

4.3.2.3 Secondary Air Injection

A catalytic converter can be designed to oxidize HC and CO and also reduce NOx. To more efficiently oxidize HC (and CO), excess oxygen must be present in the exhaust. Since these engines are required to operate rich of stochiometric for load response and durability reasons, even after substantial enleanment, it may be necessary to introduce a secondary source of air in the exhaust stream in front of the catalyst. This can be achieved mechanically by using an air pump, but the pump may be relatively costly and could result in a loss of engine power. However, air injection can also be achieved passively by using a pulse valve or a simple venturi system, and this is a less expensive alternative. The amount of air added will be required to be optimized for engine operation to get the necessary emission reductions while keeping the exhaust temperatures at a minimum.

Several engine manufacturers have expressed concerns regarding the technical challenges of utilizing catalytic converters on small engines above 80cc. These include heat management, deactivation by poisoning from lubricating oil, space available for the catalyst, and the physical location of the catalyst relative to the engine. These concerns are discussed later in this report.

4.3.3 Testing

Under a 1998 ARB-sponsored contract, SwRI demonstrated that (then current) 1996 model year small off-road engines under 25 hp could be brought into compliance with the then existing 1999 4.3 g/kW-hr (3.2 g/bhp-hr) HC+NOx emission standard. Two engines were tested; a 5.5 horsepower Honda overhead-valve engine (163 cc) and a 2.8 horsepower Briggs & Stratton side-valve engine (148 cc). The emission test results are shown in tables 4.5 and 4.6. SwRI utilized carburetor enleanment of the existing engines with the addition of a catalyst system to achieve the controlled emission results.

The engines were allowed to run rich during the high-load test modes to reduce cylinder temperatures and ensure engine durability.

Table 4.5
Summary of Emission Test Results of Honda Overhead Valve 163 cc Engine

Test	Emissions, g/kW-hr			
	HC	CO	NOx	HC+NOx
Baseline	8.0	268	2.0	10.1
Controlled	3.8	87.9	0.3	4.0
Reduction %	54	67	84	60

Source: Southwest Research Institute, ARB Contract No. 96-603.

Table 4.6
Summary of Emission Test Results of Briggs & Stratton Side Valve 148 cc Engine

Test	Emissions, g/kW-hr			
	HC	CO	NOx	HC+NOx
Baseline	13.8	479	2.3	16.1
Controlled	3.0	86.1	1.2	4.2
Reduction %	78	82	49	74

Source: Southwest Research Institute, ARB Contract No. 96-603.

Although these tests show that engines can be designed to comply with a 4.3 g/kW-hr HC+NOx emission level on a zero-hour emission test basis, engines and catalyst systems can deteriorate over time, resulting in increased emissions. Engine vibration and extreme temperatures, as well as poisoning can cause catalyst degradation, and emission control development needs to account for this. However, catalyst manufacturers have continued to perform research and develop better and more durable catalytic converters to overcome these problems, and much progress has been made in recent years.

The ARB contract currently underway with SwRI is aimed at addressing issues related to engine and catalyst deterioration and to quantify the potential for emission reductions over the life of the small engine using a catalyst system. Though the study is still ongoing, SwRI has provided staff with results of the test program's progress [see Appendix G].

The current SwRI study calls for testing six small engines to measure the "as-received" zero-hour baseline emission levels and determine the end-of-useful life emission levels achievable using a catalytic converter. The engines chosen for the test program are listed in Table 4.7. The engines were selected based on size, certification emission levels, sales volumes, equipment application, and other factors, including suitability for modification. All engines are versions that are currently available to the public and meet California's current Tier 2 exhaust standard. Four engines were between 80 cc and 225 cc, and were produced for use in walk behind lawn mowers, which is the largest application of small engines. Two engines were above 225 cc. One of these was produced for use primarily in a riding mower, while the other was produced for use primarily in a portable generator. These engines may be used in other applications as well. Mowers and generators overwhelmingly represent the majority of small engine nonhandheld applications. Lawn mowers in particular represent over 65% of the small engine nonhandheld population. All engines were designed for use with gasoline, were air cooled, carbureted, and equipped with an overhead valve design.

Table 4.7
Test Engines

Engine No.	Disp. (cc)	Mfc.	App.	Engine Family and Model	kW [hp]	Cert Hours	Shaft
1	190	Briggs & Stratton	WBM	YBSXS.1901VE Intek	4.8 [6.5]	125	Vert.
2	190	Briggs & Stratton	WBM	YBSXS.1901VE Intek	4.8 [6.5]	125	Vert.
3	195	Tecumseh	WBM	YTPXS.1951AA Magna Torque	4.8 [6.5]	125	Vert.
4	161	Honda	WBM	2HNXS.1611AK GCV-160	4.1 [5.5]	125	Vert.
5	675	Kawasaki	RIDING MOWER	2KAXS.6752CA FH601V	14.2 [19]	500	Vert.
6	338	Honda	GEN	2HNXS.3892AK GX-340QA2	8.2 [11]	500	Horiz.

As part of the test program each engine was emission tested in the "as-received" configuration. Engines were tested according to the California Test Procedures for small engines. The engines were then modified to a "low-emission" configuration by outfitting them with a three-way catalyst and retested. The Manufacturers of Emission Controls Association (MECA) supplied the catalysts. Catalyst information for the catalysts used in the test program is listed in Table 4.8. The engine manufacturers also supplied additional engine and development data. In many cases representatives of the engine manufacturers were present during the "low-emission" configuration development work at SwRI.

Table 4.8
Catalyst Information

Catalyst ID	Diameter (mm)	Length (mm)	Cell Density (cpsi)
C	60.5	50.8	200
E	118	115	400
J	60.0	50.8	400
L	39.2	50.0	400

In some cases it was necessary to modify the engines to run leaner than the original "as-received" calibration in order to lower the engine out HC concentration, while still attempting to stay within the not-to-exceed engine operating limits supplied by the engine manufacturers. In order to lean out the air-fuel ratio of the engines, variable-needle jets were installed in the stock carburetor. SwRI used the variable jet carburetors to optimize the air-fuel ratio for emission reduction and engine durability. SwRI then fabricated a fixed jet and incorporated it into the carburetor. For the Kawasaki engine, the manufacturer supplied SwRI a carburetor designed to run lean, which was originally intended for use at higher elevations. The Tecumseh, Honda GCV-160, and the second Briggs & Stratton engines were not enleaned. The second Briggs & Stratton engine is still undergoing testing, however the Tecumseh and Honda engines were able to meet the desired reduction without enleanment.

In addition, it was also decided to include a passive secondary air injection system. An air induction system for the Briggs & Stratton Engine 1 utilized a 4-hole venturi and check valve. For the other engines in the program, SwRI designed a system to capture air circulated above the engine from the flywheel impeller, and direct it into the exhaust pipe through the use of a transfer tube and dampening chamber. The dampening chamber traps exhaust that escapes the induction system orifices, and allows it to be mixed with fresh air from the flywheel impeller, thereby redirecting it into the exhaust. To reduce exhaust scavenging through the orifices, a venturi is designed into the pipe to create a low pressure region.

The engines were run over the service accumulation cycle to accumulate hours, and subsequently emission tested at specified intervals. All engines were scheduled to be tested at 125 hours and 250 hours. Engines above 225 cc were also scheduled to be tested at 500 hours. Full or partial service accumulation emissions test results are available for the first and second Briggs & Stratton engines (Engine 1 and 2), the Tecumseh engine (Engine 3), the Honda GCV-160 engine (Engine 4), and the Kawasaki engine (Engine 5). Tables 4.9 - 4.13 show the average test results for the baseline ("as-received") emissions, initial zero-hour "low-emission" configuration engine-out and after-catalyst emissions, and 125, 250, and 500-hour "low-emission" configuration engine-out and after-catalyst emissions for these engines, as applicable.

Using catalyst C, passive air injection, and air-fuel ratio enleanment, SwRI was able to obtain a 72 percent reduction in HC+NOx emissions from Engine 1 at the zero-hour (see Table 4.9). Engine 1 is certified in California to a durability period of 125 hours. Engine-out emissions increased substantially during the 125-hour service accumulation. The engine-out emissions increased by 38 percent. However, the catalyst was still approximately 58 percent effective in reducing HC+NOx emissions. SwRI speculated that a portion of the decrease in HC+NOx conversion efficiency might be due to the increase of engine-out emissions and a lack of sufficient oxygen to completely oxidize the HC emissions. The engine also suffered from misfire and engine shutdown episodes during service accumulation, which may have caused some loss in catalyst efficiency. After a review of the test data, staff decided to remove Engine 1 from further testing because of the severe engine deterioration observed.

Table 4.9
Test Engine 1 Emissions
190 cc - Proposed HC+NOx Standard of 8 g/kW-hr

		Average Emissions, g/kw-hr			
		HC	CO	NOx	HC+NOx
"As-received"		10.7	406.2	2.7	13.4
"Low-Emission" Config. Zero-Hour	Engine-out	13.8	300.3	6	19.8
	After Catalyst	4.9	122	0.6	**5.6**
	% Reduction	64	59	89	72
"Low-Emission" Config. 125-Hour	Engine-out	21	315	6.3	27.3
	After Catalyst	9.9	194.4	1.2	**11.1**
	% Reduction	53	38	81	59

Engine 2 is the same make and model as Engine 1. Using catalyst L and passive air injection, with no modification to the air-fuel ratio, SwRI was able to obtain a 57 percent reduction in HC+NOx emissions from Engine 2 at the zero-hour (see Table 4.10). Engine 2 is currently undergoing service accumulation, and is scheduled to be emissions tested again after 125 and 250 hours of service accumulation.

Table 4.10
Test Engine 2 Emissions
190 cc - Proposed HC+NOx Standard of 8 g/kW-hr

		Average Emissions, g/kW-hr			
		HC	CO	NOx	HC+NOx
"As-received"		10.3	411.5	2.4	12.7
"Low-Emission" Config. Zero-Hour	Engine-out	10.3	411.5	2.4	12.7
	After Catalyst	5.0	293.6	0.5	**5.5**
	% Reduction	52	29	78	57

Using catalyst C, and passive air injection, SwRI was able to obtain a 63 percent reduction in HC+NOx emissions from Engine 3 at the zero-hour (see Table 4.11). No enleanment of the air-fuel ratio was necessary to achieve the desired emission levels. Engine 3 is certified in California to a durability period of 125 hours. At the end of the 125-hour service accumulation the catalyst was still 50 percent effective in reducing HC+NOx emissions. SwRI continued service accumulation of this engine out to 250 hours. Engine-out HC+NOx emissions increased by an average of 5 percent from the 125-hour results. However after-catalyst HC+NOx emissions decreased as compared to the 125-hour results. This is mainly the result of the engine operating leaner at high loads, which resulted in higher exhaust gas oxygen concentrations and increased catalyst activity. The 250-hour HC+NOx exhaust emission levels were below the proposed standard of 8 g/kW-hr.

Table 4.11
Test Engine 3 Emissions
195 cc - Proposed HC+NOx Standard of 8 g/kW-hr

		Average Emissions, g/kw-hr			
		HC	CO	NOx	HC+NOx
"As-received"		8	485.3	2.1	10.2
"Low-Emission" Config. Zero-Hour	Engine-out	8	485.3	2.1	10.2
	After Catalyst	3.4	226.5	0.4	**3.7**
	% Reduction	58	53	84	63
"Low-Emission" Config. 125-Hour	Engine-out	11.7	526.8	1.9	13.5
	After Catalyst	6.3	339.1	0.5	**6.8**
	% Reduction	46	36	73	50
"Low-Emission" Config. 250-Hour	Engine-out	12.1	572.4	2.1	14.2
	After Catalyst	4.7	341.8	0.5	**5.1**
	% Reduction	61	40	78	64

Using catalyst J, and passive air injection, SwRI was able to obtain a 71 percent reduction in HC+NOx emissions from Engine 4 at the zero-hour (see Table 4.12). No enleanment of the air-fuel ratio was necessary to achieve the desired emission levels. Engine 4 is certified in California to a durability period of 125 hours. At the end of the 125-hour service accumulation the engine-out emission levels increased by approximately 22 percent. The engine began to run leaner than observed at zero-hour, and the majority of the increase in engine-out HC+NOx emissions was due to approximately a 50 percent increase in NOx emissions. However, the catalyst system was able to accommodate the increase in HC+NOx emissions. Catalyst efficiency increased and after 125-hours the catalyst proved to be 81 percent effective in reducing HC+NOx emissions. At the end of the 250-hour service accumulation engine-out NOx continued to increase, while HC stayed relatively stable. The HC+NOx combined efficiency of the catalyst system was 76%. The 250-hour HC+NOx exhaust emission levels were below the proposed standard of 8 g/kW-hr.

Table 4.12
Test Engine 4 Emissions
161 cc - Proposed HC+NOx Standard of 8 g/kW-hr

		Average Emissions, g/kw-hr			
		HC	CO	NOx	HC+NOx
"As-received"		8.7	392.8	3.1	11.8
"Low-Emission" Config. Zero-Hour	Engine-out	8.7	392.8	3.1	11.8
	After Catalyst	3.0	144.8	0.4	**3.4**
	% Reduction	66	63	87	71
"Low-Emission" Config. 125-Hour	Engine-out	7.1	213.1	7.3	14.4
	After Catalyst	2.0	85.8	0.7	**2.8**
	% Reduction	71	60	90	81
"Low-Emission" Config. 250-Hour	Engine-out	7.1	195.2	8.1	15.2
	After Catalyst	3.0	100.5	0.5	**3.6**
	% Reduction	57	48	93	76

Using catalyst E, passive air injection, and air-fuel ratio enleanment, SwRI was able to obtain approximately an 81 percent reduction in HC+NOx emissions from Engine 5 at the zero-hour (see Table 4.13). Engine 5 is certified in California to a durability period of 500 hours. At the end of the 125-hour service accumulation the engine-out emission levels increased by approximately 7 percent. The catalyst was still approximately 79 percent effective in reducing HC+NOx emissions. The engine was tested after 250 and 500 hours of service accumulation. Engine out HC and NOx continued to increase slightly at each test point, with a final engine-out HC+NOx level of 12.0 g/kW-hr after 500 hours. The catalyst reduced this level to 3.2 g/kW-hr.

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Table 4.13
Test Engine 5 Emissions
675 cc - Proposed HC+NOx Standard of 6 g/kW-hr

		Average Emissions, g/kw-hr			
		HC	CO	NOx	HC+NOx
"As-received"		7.4	509.4	2.6	10.0
"Low-Emission" Config. Zero-Hour	Engine-out	4.8	303.0	5.2	10.0
	After Catalyst	1.9	142.1	0.1	**1.9**
	% Reduction	61	53	98	81
"Low-Emission" Config. 125-Hour	Engine-out	5.1	266.8	5.6	10.6
	After Catalyst	2.1	166.2	0.1	**2.3**
	% Reduction	58	38	98	79
"Low-Emission" Config. 250-Hour	Engine-out	5.6	252.3	6.1	11.7
	After Catalyst	2.4	166.2	0.1	**2.6**
	% Reduction	57	34	98	78
"Low-Emission" Config. 500-Hour	Engine-out	5.8	239.7	6.3	12.0
	After Catalyst	3.0	182.3	0.1	**3.2**
	% Reduction	48	24	98	73

Figures 4.1 and 4.2, respectively summarize the emission levels and catalyst HC+NOx reducing efficiencies achieved during the SwRI test program.

Figure 4.1

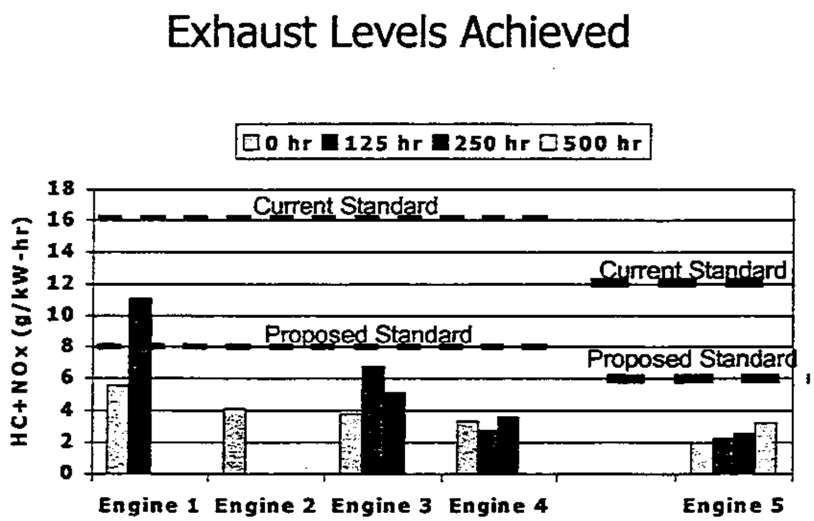
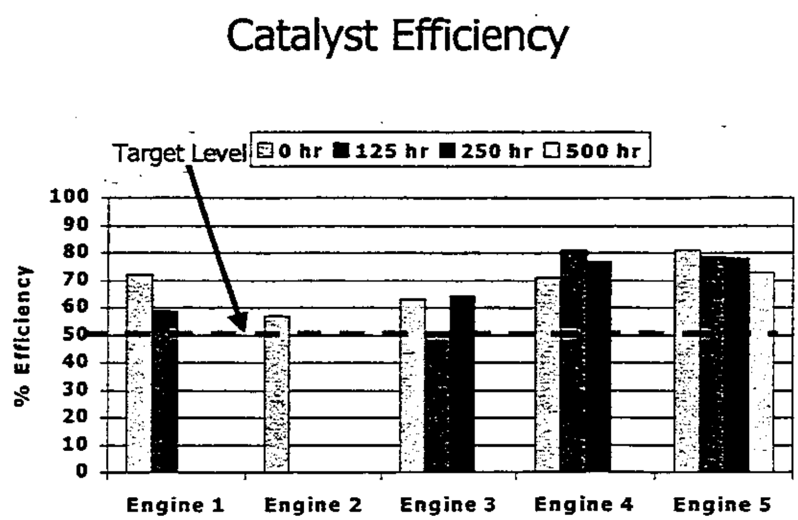


Figure 4.2



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Staff acknowledges that there are some issues (as discussed below) that must be addressed when applying catalytic converters to small engines, and that the test program did not resolve all of the issues or apply catalysts to all small engine applications. The intent of the program was to show "proof-of-concept". The SwRI test program has revealed that catalyst systems can be incorporated onto small engines, are durable, and reduce the engine out emissions by 50 percent over the useful life of the engine. As a result, staff has concluded that the use of catalytic converters properly engineered and applied, can reduce small engine emissions sufficiently to meet the proposed standards and be durable for the life of the engines and equipment. Staff has provided time within the implementation schedule for manufacturers to address design and engineering issues associated with catalyst/engine integration.

4.4 Other Exhaust Emissions Changes

4.4.1 Optional Low Emission Exhaust Standards ("Blue Sky Series")

To encourage the use of engines that go beyond mandatory emission standards, the staff proposes to implement voluntary optional low exhaust emission standards for small engines. An engine certified to these standards will be classified as a "Blue Sky Series" Engine. The optional standards are presented in Table 4.14 below. The standards represent a reduction of approximately 50 percent below the proposed Tier 3 levels for HC+NOx. Engines certified to these voluntary standards would be eligible for marketable credit programs. The manufacturers must declare at the time of certification whether it is certifying an engine family to an optional reduced-emission standard. Engines certified to these voluntary standards would not be eligible to participate in the corporate averaging programs allowed in the small engine exhaust emission regulations (See Title 13, California Code of Regulations, sections 2400-2409 and the documents incorporated therein).

Table 4.14
"Blue Sky Series" Engine Emission Standards
g/kW-hr
[g/bhp-hr]

Model Year	Displacement	HC+NOx	CO	PM*
2005 and later	< 50 cc	25 [18.5]	536 [400]	2.0 [1.5]
2005 and later	≥50 to ≤ 80 cc	36 [26.9]	536 [400]	2.0 [1.5]
2007 and later	>80 - <225cc	4.0 [3]	549 [410]	N/A
2008 and later	≥225cc	3.0 [2.3]	549 [410]	N/A

* The PM standard is applicable to all two-stroke engines.

4.4.2 Unit Power Designation (hp vs. kW)

The existing California small off-road engine regulations define a small engine as one that produces a gross power of less than 25 horsepower (See Title 13, California Code of Regulations, section 2401), and the emission standards are stated in terms of grams per brake horsepower-hour (g/bhp-hr). In contrast, the U.S. EPA uses kilowatt as the unit of power for these same engines, and the federal standards are expressed in terms of grams per kilowatt-hour (g/kW-hr). In order to ease the burden of certifying engine families with multiple units to both the federal and California emission standards manufacturers have expressed a desire to have harmonization between State and federal unit power designation. Staff, therefore, proposes to harmonize with the U.S. EPA, and adopt the use of kilowatt as the unit of power for small off-road engines. The result is that the small off-road engine regulations (See Title 13, California Code of Regulations, sections 2400-2409) would apply to engines that produce a gross power at or below 19kW.

In addition, the ARB defines a large spark-ignition engine as one that produces a gross power of 25 horsepower or greater (See Title 13, California Code of Regulations, sections 2430-2431). A change in the current unit power designation for small engines would cause a temporary overlap in the California regulatory definition of large versus small engines that could affect engines with a gross power that lies on the cusp of the power break. Staff intends to return to the Board in the near future to amend the large spark-ignition engine definition to address the overlap. In the meantime, it is staff's intent that engines that could fall under either the small or large engine definition, based upon the unit power designation, be allowed to certify under the small engine regulations.

4.4.3 Exhaust Emissions Test Procedures

The ARB and U.S. EPA each have exhaust emissions test procedures in place that manufacturers must adhere to when certifying to the applicable State or federal exhaust emission standards for small engines. For the most part the state and federal test procedures are aligned, but there are some non-substantive differences between the two procedures. Manufacturers have expressed a desire to have harmonization between State and federal exhaust emissions test procedures. To eliminate non-substantive differences staff proposes to incorporate the federal small engine test procedures (40 Code of Federal Regulations, part 90, subparts A, B, D, and E and corresponding appendices) beginning with the 2005 model year.

4.4.4 Durability Period

The current small engine exhaust emission regulations require that manufacturers conduct a durability demonstration as part of the certification process. For each engine family manufacturers are able to choose an emissions durability period of either 50, 125, or 300 hours for the smaller (handheld) engines, and 125, 250, or 500 hours for the larger (nonhandheld) engines. The U.S. EPA uses a similar methodology. However, the federal program also includes a 1000 hour durability option for nonhandheld engines greater than or equal to 225 cc. Staff, therefore, proposes to align with the U.S. EPA, and adopt a durability period option of 1000 hours for engines greater than or equal to 225 cc.

4.4.5 Other Non-Substantive Modifications

Staff also proposes to make other non-substantive modifications to the regulations and test procedures to clarify or simplify existing language.

4.5 Permeation Emission Requirements (SORE Equipment ≤80 cc)

4.5.1 Standards and Implementation Schedule

Staff is proposing to establish a permeation performance standard for fuel tanks on small off-road engines with displacements less than or equal to 80 cc, except for engines with structurally integrated nylon tanks. Staff proposes to exempt structurally integrated nylon tanks because there is no cost-effective material substitute for nylon that has acceptable thermal properties and because emissions from this type of tank are already below the proposed standard. Structurally integrated nylon tanks are found on approximately 40 percent of the handheld equipment less than or equal to 80 cc.

Staff is not proposing a permeation standard for fuel tanks used with >80 cc engines because staff's proposal contains a diurnal standard (discussed in Section 4.6), which implicitly controls permeation emissions from tanks.

Table 4.15 describes the proposed fuel tank permeation performance standards. The proposed permeation standard corresponds to an 84 percent reduction in permeation emissions from small handheld equipment tanks.

Table 4.15
Proposed Fuel Tank Permeation Emissions Performance Standards

Model Year	Applicability	Permeation Limit Grams/square meter/day as per TP-901
2007 and Later	SORE Equipment* ≤ 80 cc	2.0
2007 and Later	SORE Equipment > 80 cc	None (included in diurnal standard)

* Except equipment that use structurally integrated nylon tanks. The proposal exempts structurally integrated nylon tanks because they already have permeation emissions below 2.0 gram/m^2/day.

As discussed in the following sections, existing technology (alternative materials, co-extrusion, and barrier treatments) is available to control permeation emissions from fuel tanks used on all SORE equipment. Staff has determined that an 84 percent reduction in permeation emissions is both feasible and cost effective for all SORE equipment.

4.5.2 Source of Permeation Emissions

Approximately 90 percent of the fuel tanks used on all off-road equipment are made from High Density Polyethylene (HDPE). The polymer structure of HDPE allows gasoline molecules to saturate the material. After becoming saturated with gasoline, molecules can diffuse through the walls of a HDPE tank or container and evaporate on the outer surfaces. This process is called permeation. Saturation times are dependent upon concentration gradient (the difference between a concentration of a substance in two different areas), temperature, and container wall thickness and can occur in as little as 15 days for thin walled tanks. Because the process of permeation involves the evaporation of gasoline, it is considered to be a component of diurnal evaporative emissions.

4.5.3 Testing to Quantify Permeation Emissions

In order to develop the emissions inventory, staff tested 53 untreated HDPE tanks to determine average permeation rates for a variety of off-road equipment fuel tanks. The testing subjected sealed tanks to multiple diurnal temperature profiles and emissions were quantified using gravimetric analysis.

Test results were grouped into four tank categories based on tank volume and material type as follows:

Table 4.16
Uncontrolled Fuel Tank Permeation Emissions

Off-Road Equipment Tank Category	Tank Volume (quarts)	Tank Wall Thickness (inches)	Average Permeation Rate (grams per square meter per day)
Handheld Tanks (HDPE)	< 1	>0.125	6.39
*Handheld Tanks (Nylon)	1.5	>0.125	0.66*
Small Nonhandheld (HDPE)	> 1 and ≤ 2 quarts	0.110 to 0.125	10.60
Large Nonhandheld (HDPE)	> 2	>0.125 in	5.92

* Note: The proposal exempts structurally integrated nylon tanks because they already have permeation emissions below 2.0 gram/m^2/day.

The wall thickness of HDPE fuel tanks is an important factor in the permeation rate. As indicated above, the thinner walls of small nonhandheld tanks have a much higher permeation rate than the other two categories.

Permeation emissions from plastic fuel tanks account for more than one third of the total diurnal emissions from off-road equipment. If left uncontrolled, it is estimated that permeation emissions from plastic off-road equipment fuel tanks will emit 13 tons per day of HC emissions statewide in 2010. Extensive testing by ARB staff during the development of the Portable Fuel Container Spillage Control Measure and testing by the automotive industry supports staff's findings.

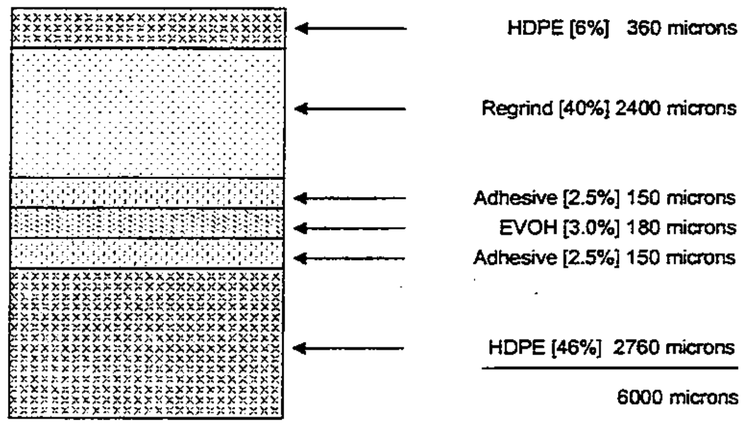
4.5.4 Technology to Control Permeation Emissions

Several control approaches were identified as options to reduce permeation emissions. Those deemed most applicable for SORE fuel tanks are discussed in this section and include multi-layer co-extrusion, special polymers, and barrier surface treatments.

4.5.4.1 Multi-Layer Co-Extrusion

The majority of SORE fuel tanks are constructed using a single layer of HDPE (monolayer HDPE). Typically, these fuel tanks are either blow or injection molded. In the late 1980s, as a result of U.S. EPA and CARB emission regulations, and the increased oxygen content of fuels, multilayer technology using ethylene vinyl alcohol (EVOH) as a barrier layer was developed for manufacturing plastic automobile fuel tanks. Portable fuel container manufacturers are also considering this technology for adoption. It is likely that off-road equipment manufacturers will design tanks using coextrusion technology because of its durability and permeation characteristics. Figure 4.3 shows the basic structure of a coextruded multilayer fuel tank with a 180 micron EVOH layer.

Figure 4.3
Basic Structure of a Coextruded Multilayer Fuel Tank



Note: Information provided by Eval Company of America.

Compared to other technologies, coextruded plastic fuel tanks have superior durability and permeation characteristics. Table 4.17 compares the permeation properties of a coextruded material (Multilayer F Series) with nylon and virgin HDPE. The coextruded material has superior permeation properties even when tested with fuel containing 15 percent methanol (CM15) at a temperature of 40°C.

Table 4.17
Permeation Properties Comparison
(Grams per 20 µm/ m²/day@ 40°C, 65% RH)

Fuel	Multilayer F Series	Nylon	HDPE
ASTM Ref C	0.018	0.30	4100
CM15	12.0	98.4	3300
MTBE 15	0.014	0.24	3300

Note: Data provided by Eval Company of America.

In 1994, the first commercial coextruded multilayer HDPE fuel tank was installed on the Jeep Grand Cherokee. Currently, more than 65 percent of the automobile tanks in North America use multilayer plastic fuel tanks. Automobile manufacturers have almost universally selected this approach for fuel tank construction due to strict evaporative emission standards and differences in fuel specifications. Switching from a monolayer blow or injection molded tank to a coextruded tank is one potential way to meet the permeation standard. Although the cost of switching to a multilayer tank is initially higher than the other alternatives, staff believes that the cost effectiveness may approach that of other alternatives for mass-produced tanks.

4.5.4.2 Special Polymers and Resins

Permeation may also be controlled by modifying or substituting polymers and resins. Thermoplastic materials such as nylon and acetal copolymers have inherent permeation resistance characteristics superior to that of HDPE. Nylon was developed in the 1930s. Nylon 6 and Nylon 66 were the first commercial nylons. Their properties are characterized by a combination of high strength, toughness, and chemical resistance. Glass reinforced nylons have even better resistance to fuel. In general, the highly crystalline nylon structures provide the best permeation barrier. Highly crystalline nylons only cost slightly more per pound than less crystalline plastics.

Acetal copolymers were developed in the 1950s that have properties similar to nylon. The tight bonding of the molecules in these polymers does not allow gasoline molecules to freely permeate through them. Acetal copolymer is currently used to manufacture automobile fuel system components such as fuel vapor vent valves mounted in automobile gas tanks and gas caps. These materials can potentially replace HDPE in the tank manufacturing process.

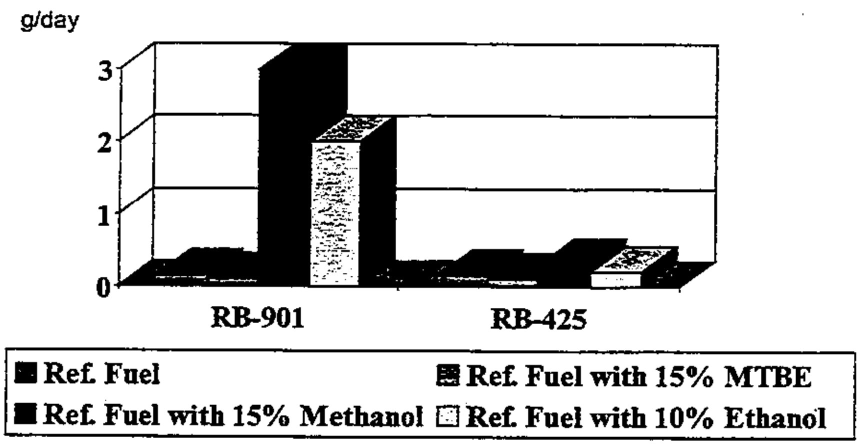
Barrier resins such as DuPont's Selar® RB Series are designed for use in pellet blends of nylon copolymers and proprietary adhesives for nylon and polyethylene. These resins can be processed into packaging structures using conventional equipment for monolayer, multilayer, or laminar technologies.

Selar® RB 901 is one of the original grades of Selar developed. It has been in use in Europe for many years. More recently, Selar® RB 425 was developed. It has improved resistance to permeation by fuel containing alcohols. Figure 4.4 contains permeation data for Selar® RB 901 and Selar® RB 425 collected using a Sealed Housing for Evaporative Determination (SHED) test method. This data is important because it clearly shows that tanks manufactured with both types of Selar® resins can meet our proposed 2.0 gram/day permeation standard when tested with Certification fuel that does not contain alcohol. Tanks manufactured with Selar® RB 425 can meet our proposed standard even when tested with fuel containing 15 percent methanol.

Figure 4.4

SHED TEST RESULTS

Selar® RB-901 and RB-425



Note: The reference fuel is a mixture of 50% toluene and 50% isooctane. SHED results represent permeation emissions from sealed tanks. Data provided by Dupont USA.

4.5.4.3 Barrier Surface Treatments

Another alternative that can be used to control permeation emissions from engine fuel tanks is the use of barrier surface treatments. It is possible to apply a barrier surface treatment on plastic fuel tanks to substantially mitigate the effects of permeation. Staff tested two such post production barrier surface treatments, fluorination and sulfonation. Fluorination and sulfonation each exposes the post-molded plastic fuel tank to a specific concentration of treatment gas while controlling pressure and length of exposure. Fluorination exposes the fuel tank to fluorine gas, while sulfonation uses sulfur trioxide gas. Each treatment replaces hydrogen atoms with atoms of the treatment gas on the exposed polyethylene surface. The atoms of the treatment gas 'block' the path that hydrocarbon molecules would normally take through the polyethylene, thereby mitigating the effects of permeation.

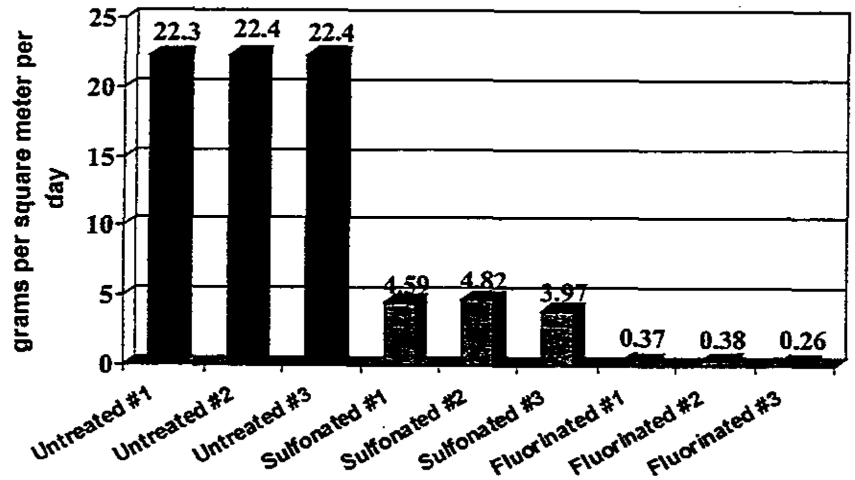
To work effectively however, barrier treatments must be optimized. At one time this was thought to be solely a component of material composition of the fuel tank. Society of Automotive Engineers Technical Paper 920164, Permeation of Gasoline-Alcohol Fuel Blends Through High-Density Polyethylene Fuel Tanks with Different Barrier Technologies, cites how significant reductions in average fuel tank permeation rates can be achieved when the treatment process is optimized. Optimization of the treatment process requires the use of specific resins, blow-molding gases, and strict limits on the amount of regrind, additives, and light stabilizers that can be used when manufacturing an HDPE fuel tank. By controlling these factors, an effective barrier can be created on the surface of a fuel tank to resist the effects of permeation.

To assess the effectiveness of barrier treatments, staff performed tests on several different types of small off-road engine fuel tanks. These initial tests were performed on existing, non-optimized engine fuel tanks and the results were made available to the public in the report entitled Durability Testing of Barrier Treated High-Density Polyethylene Small Off-Road Engine Fuel Tanks, (June 2002). Following these initial tests, it was determined that the results were biased due to the addition of an UV inhibitor during the manufacturing process. Therefore, CARB staff elected to repeat these tests with fuel tanks that did not contain an UV inhibitor. In March 2003 staff performed testing on nine HDPE tanks that contained an optimized resin and additive package supplied by American Honda Motor Company (Honda). The testing was performed on three super fluorinated, three sulfonated, and three untreated tanks. Staff measured the average permeation rates of the nine fuel tanks while exposed to variable and constant temperature profiles. The results of the testing were made available to the public in a report entitled Durability Testing Of Barrier Treated High - Density Polyethylene Small Off-Road Engine Fuel Tanks, (March 2003), and report addendum.

Figure 4.5 compares the permeation rates of the nine tanks tested at a constant 40°C. The data indicates that the super fluorinated tanks have permeation rates well below the proposed 2.0 gram/m^2/day permeation performance standard.

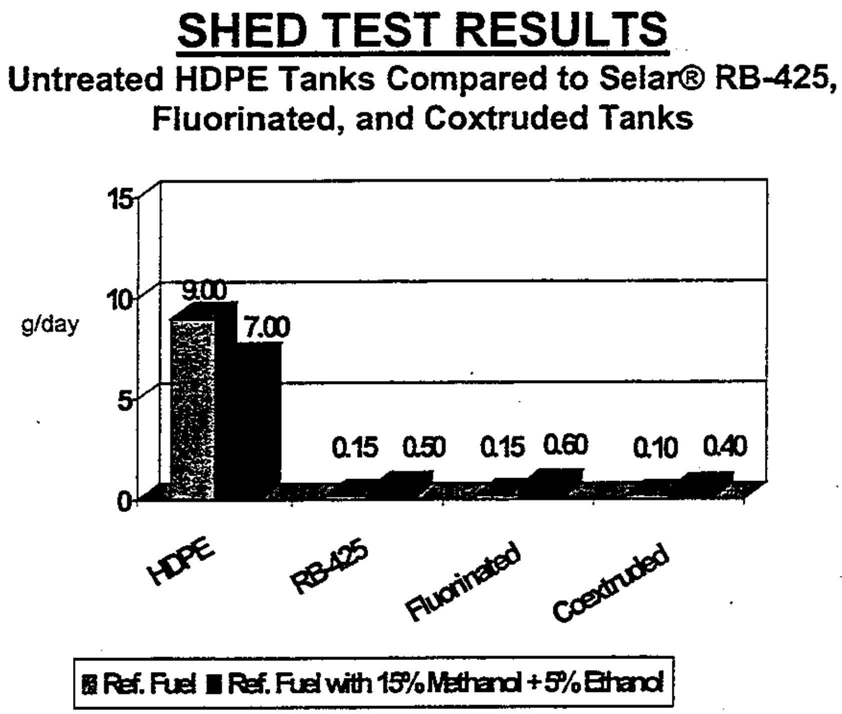
Figure 4.5

Permeation Rate Comparison of Optimized HDPE Fuel Tanks



In conclusion, staff has identified several proven technologies that could be used to control permeation emissions from HDPE tanks. Figure 4.6 shows a comparison of average permeation rates from untreated HDPE fuel tanks to tanks made with Selar® RB 425, HDPE tanks that have been fluorinated, and coextruded tanks. The data clearly shows that effectiveness of the various permeation control technologies. All three technologies could potentially be used to meet staff's proposed permeation standard, even when tested with an aggressive fuel containing 15 percent methanol and 5 percent ethanol.

Figure 4.6



Note: The reference fuel is a mixture of 50% toluene and 50% isooctane. SHED results represent permeation emissions from sealed tanks. Data provided by Dupont USA.

4.5.5 Permeation Test Procedure

Equipment manufacturers electing to certify plastic fuel tanks to the proposed performance standard will be required to use Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks "TP-901". TP-901 is included in Appendix D.

4.6 Diurnal Evaporative Emission Performance Requirements (SORE Equipment > 80 cc)

4.6.1 Standards and Implementation Schedule

In addition to the proposed permeation requirements, staff is proposing regulations to establish three diurnal evaporative emission standards. In order to allow manufacturers sufficient lead-time to incorporate evaporative controls into their designs, staff proposes to phase-in the diurnal evaporative emission standards. There are no diurnal standards for equipment with displacements ≤ 80 cc, only the permeation standard applies. Beginning in 2007, walk-behind mowers with displacements > 80 cc to < 225 cc would need to meet a 1.0-gram/day HC diurnal standard. In 2007, all equipment using small off-road engines with displacements (excluding walk-behind mowers) >80 cc and <225 cc would need to meet a sliding scale diurnal standard based on tank volume. Typical equipment using engines with displacements > 80 cc and < 225 cc would include lawn mowers, pressure washers, high wheel string trimmers, and small generators. Beginning in 2008, equipment with engine displacements ≥ 225 cc would need to meet a 2.0-gram/day HC diurnal standard. Typical equipment that use engines with ≥ 225 cc displacements are commercial turf equipment and large generators. Table 4.18 outlines the proposed diurnal evaporative emission performance standards and implementation schedule.

Table 4.18
Proposed Diurnal Emissions Performance Standards

Model Year	Applicability	Diurnal Emission Limit Grams HC/day
2007 and Later	All Walk-Behind Mowers > 80 cc to < 225 cc	1.0
2007 and Later	SORE Equipment > 80 cc to < 225 cc Excluding Walk-Behind Mowers	(0.21/gallons)*Tank Volume (gallons)+0.95
2008 and Later	All SORE Equipment ≥ 225 cc	2.0

Because SORE equipment ≥ 225 typically have higher permeation and evaporative emission characteristics due to larger internal tank surface areas and tank volumes, staff is proposing to hold equipment in this category to a less stringent diurnal emissions standard. Since SORE equipment < 225 cc typically have lower permeation and evaporative emissions characteristics, staff proposes setting a more stringent diurnal emissions standard for this category.

4.6.2 Sources of Diurnal Evaporative Emissions

Evaporative emissions from SORE equipment are characterized by the following:

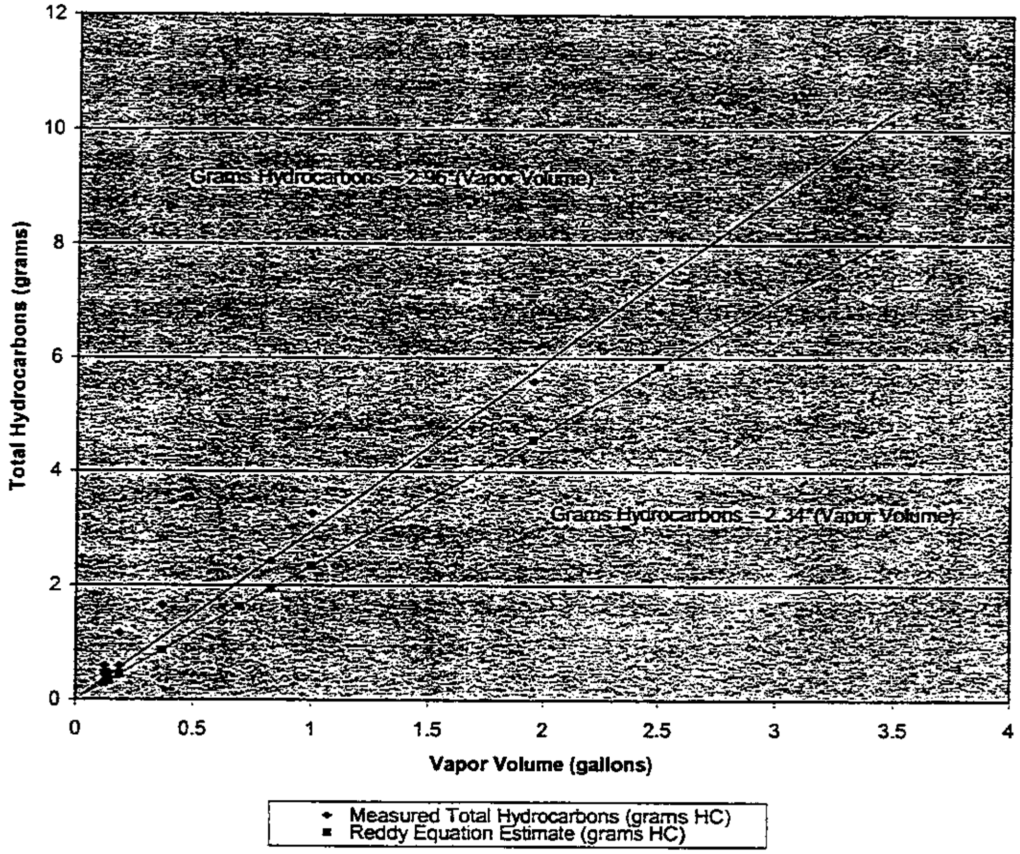
Background Emissions
Running Loss Emissions
Hot Soak Emissions
Diurnal Emissions (including permeation emissions)

Background emissions are a result of HC emissions from new plastic components. Although measurable immediately after equipment is manufactured, they are not a constant source of emissions. Running loss emissions occur as a result of engine heat being transferred to the fuel system during equipment operation. Engine vibration also agitates fuel within the tank and contributes to running loss emissions. Hot soak emissions result from latent heat causing an increase in evaporative emissions from fuel system components immediately after equipment is operated. The majority of hot soak emissions occur during a one-hour period after equipment is shut down. Diurnal emissions are evaporative emissions from the fuel system components such as fuel tanks, fuel lines, and carburetors. Diurnal emissions result from daily temperature variations. Diurnal emissions include permeation emissions that are caused by fuel diffusing through plastic fuel system components.

Characteristics of Existing Diurnal Evaporative Emissions

Effective control technologies for diurnal emissions should target the fuel system components, which are the primary contributors to these emissions. In an effort to gauge the emissions generated by fuel tanks over a diurnal cycle, staff evaluated the vapor generation from 14 new HDPE off-road equipment fuel tanks. Diurnal emissions were measured in a SHED using a variable (65°F – 105°F –65°F) temperature profile. In order to limit permeation effects, the new tanks were fluorinated and tested without pre-soaking them with fuel. All tanks were tested at 50 percent of nominal capacity. Figure 4.7 on the following page plots the diurnal emissions versus vapor volume for all the tanks tested:

Figure 4.7
Diurnal Emissions from Vented HDPE Off-Road Equipment Fuel Tanks



The measured results were very predictable and linear. The empirical data closely approximates the Reddy equation, which was developed by S. Raghuma Reddy (SAE 892089) for General Motors to predict diurnal emissions from automotive fuel tanks. The data clearly documents that vapors generated from vented tanks are a significant source of emissions, especially for large volume fuel tanks. A five-gallon fuel tank filled to 50 percent capacity with 7 RVP fuel will generate over 6 grams HC over a one-day summer diurnal cycle.

To further identify the sources of diurnal evaporative emissions from new equipment, staff isolated and tested various fuel system components on new walk-behind mowers. Staff also used known permeation and vapor generation rates to estimate the sources of diurnal emissions for a typical generator. Figures 4.8 and 4.9 summarize staff's findings regarding the sources of diurnal evaporative emissions. For equipment with small fuel tanks, like walk-behind mowers, the major source of emissions are from fuel tank and fuel line permeation. Only 20 percent of the emissions are vented through the fuel cap. However, for equipment with large fuel tanks, such as generators, the vented emissions from the fuel tank are the primary source of emissions. This data is important in that it shows that diurnal emissions can be significantly reduced by controlling fuel tank vented emissions and fuel tank and fuel line permeation emissions.

Figure 4.8
Sources of Diurnal Evaporative Emissions
(Typical Walk-Behind Mower)

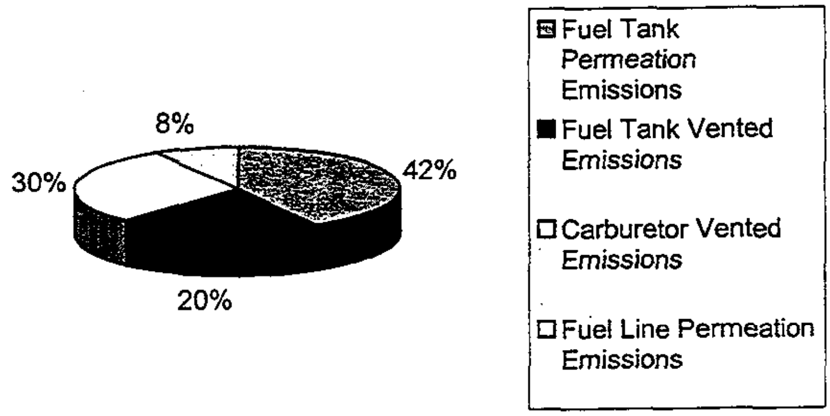
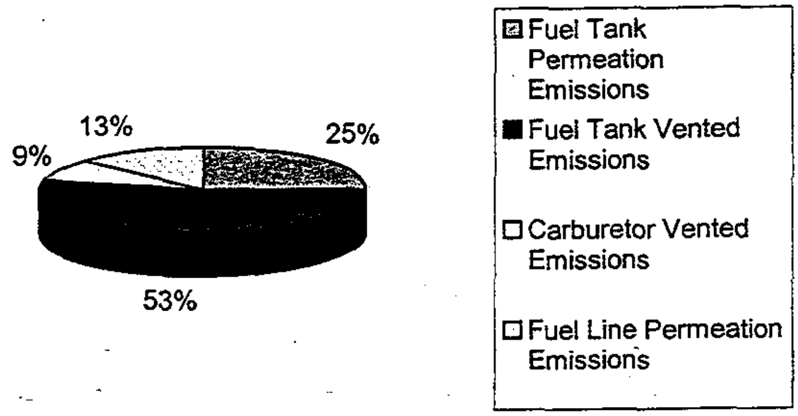


Figure 4.9
Sources of Diurnal Evaporative Emissions
(Typical Generator)



4.6.3 Technology to Control Diurnal Evaporative Emissions

As discussed above, fuel tank vented emissions constitute a significant percentage of the total diurnal evaporative emissions. Two technologies to control fuel vent emissions, sealed fuel tanks and carbon canisters, are discussed here.

4.6.3.1 Sealed Fuel Tanks

For many years, handheld SORE equipment has used technologies to contain gasoline vapors within the fuel tank that limit diurnal emissions. The technology consists of one-way fuel caps and diaphragm type carburetors that do not vent to the atmosphere. Currently, nonhandheld equipment uses vented fuel caps and gravity fed carburetors. Handheld technology cannot be directly adapted to most nonhandheld equipment because diaphragm carburetors cannot deliver an adequate fuel supply to the engine and one-way caps could result in carburetor flooding. Carburetor flooding would occur when the vapor pressure within a sealed tank rises above the carburetor needle valve cracking pressure. However, it is possible to seal a fuel tank during storage and avoid carburetor flooding. One way to do this would be to use a one-way cap in conjunction with a fuel shutoff valve or pressure-reducing orifice. The system could be passively actuated during the engine shutdown procedure.

Currently, there are four models of nonhandheld SORE equipment that can be placed in a mode that seals the fuel tank. None are passively actuated. Three models are generators and one model is a lawn tractor. The generators have levers in their caps that can be switched to contain vapors within the tank. The primary purpose of the levers is to control vapors when the generators are stored in confined spaces. The tractor has a screw in the cap that can be turned to contain vapors and prevent spillage when the equipment is turned on-end. There are clear emission benefits when the equipment's fuel tank is sealed, even though they may be unintended.

Existing regulations requiring sealed tanks allow venting when significant pressure build-up occurs in the fuel tank. In the U.S. EPA Final Regulatory Support Document: Control of Emissions from Unregulated Nonroad Engines[2], the EPA cites an Underwriters Laboratories specification that requires forklifts operating in certain high risk fire areas to use sealed or pressurized fuel tanks. Underwriters Laboratories also requires that industrial trucks use gasoline tanks with self-closing fuel caps that stay sealed to prevent evaporative losses; venting is allowed for positive pressures above 5 psi or for vacuum pressures of at least 1.5 psi[3]. These existing requirements are designed to prevent evaporative losses for safety reasons. This same approach for other types of engines would similarly reduce emissions for air-quality reasons.

To evaluate how much pressure could be safely maintained in SORE sealed tanks; staff performed destructive testing on four typical HDPE mower tanks. The tanks were pressurized until a leak or rupture occurred. Failures ranged from a low of 78 PSIG to a high of 132 PSIG. Staff has also received information from a major tank manufacturer that routinely tests their tanks to 100 PSIG as part of their quality assurance process.

To determine the maximum tank pressure during episodic (18° C to 40° C) and extreme (18° C to 50° C) temperature profiles, staff tested a mower tank using these profiles. The results of that testing were made available to the public in a report entitled Diurnal Testing Of Walk-Behind Mowers Configured With Fuel Tank Pressure Relief Valves (September 2002). The maximum pressure for the extreme temperature profile was just under 4.0 PSIG.

2 EPA 420-R-02-22, Section 3.3.2.1 – Sealed System with Pressure Relief, September 2002
3 UL558, paragraphs 26.1 through 26.4

In order to address safety concerns and give manufacturers a clear design objective, staff proposes allowing a pressure relief valve for use on all sealed SORE tanks.

4.6.3.2 Canister Technology

Canister technology has been successfully used on automobiles and motorcycles for many years. Large displacement small off-road engines and on-road motorcycles have similar emission characteristics. Because large SORE equipment is typically used on a daily basis, they are well suited for a carbon canister evaporative emission system. Vapors absorbed by a carbon canister over multiple diurnal cycles can be removed through daily purging for a properly sized canister. Because off-road equipment such as commercial turf equipment and construction generators has similar evaporative emission characteristics to on-road motorcycles, they too could easily meet a proposed 2.0-gram HC/day diurnal standard. On-road motorcycle evaporative emission certification data supports this contention. Staff believes that canister technology can be successfully adapted to off-road equipment.

Addition of a canister to SORE equipment is not expected to interfere with achievement of the SORE engine exhaust standards. During equipment storage, vapor generated in the tank is vented through a carbon canister. The canister temporarily collects and stores the hydrocarbon vapors. When the engine is operated, purge air is drawn through the canister and the hydrocarbons are burned in the engine. Adapting carbon canister technology to lawn and garden equipment requires a degree of effort to integrate evaporative and exhaust emission-control strategies. However, this has already been done in both automotive and motorcycle applications and should be easily transferred to these SORE categories. Engine manufacturers also often sell engines directly to equipment manufacturers, who would also need to integrate the new technology into equipment designs.

4.6.3.3 Hybrid Canister Technology

Canister technology can be incorporated into sealed systems with pressure relief valves to reduce the maximum pressure tanks must withstand when sealed. This technology vents a pressure relief valve to a carbon canister rather than the atmosphere. For most days the maximum pressure within a sealed fuel tank never exceeds 2.0 PSIG. However, on days that the pressure exceeds the set point of a pressure relief valve, emissions are vented to a carbon canister. Carbon canisters used in conjunction with sealed systems can be smaller and do not need as much working capacity as canister only systems. Overall, a hybrid design should be less costly to implement because it uses low cost carbon canisters, pressure relief valves, and fuel tanks.

4.6.4 Testing to Demonstrate the Feasibility of Proposed Diurnal Standard

This section describes testing conducted using the two identified control options, sealed tank and carbon canisters. Test results demonstrate that the proposed diurnal standards are achievable.

4.6.4.1 Evaporative Emission Control System Using a Sealed Tank Design

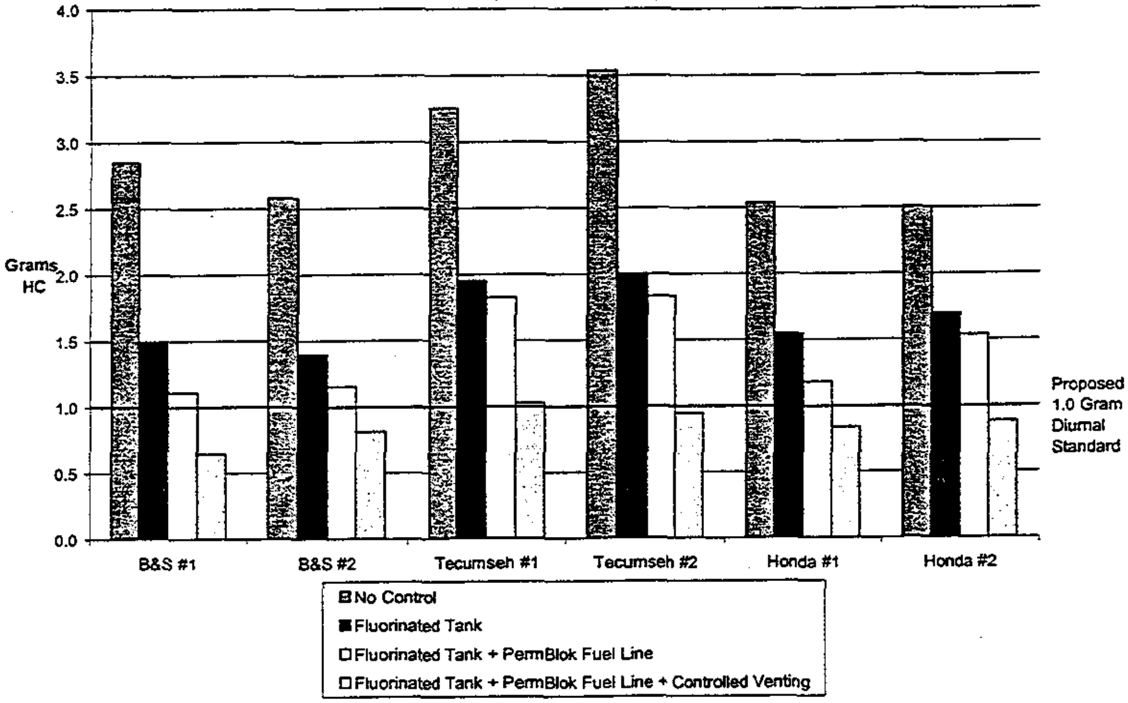
To evaluate likely emission reductions on walk-behind mowers, staff developed a control system that reduces fuel line and fuel tank permeation emissions and limits venting from the fuel tank. Staff focused on walk-behind mowers because they account for over 41 percent of the evaporative emissions from the SORE category. To limit vented tank emissions, staff successfully designed and built a controlled venting mechanism that contains vapors within a tank using a vent and fuel shutoff valve. An engine/blade-stop or similar cable controls the mechanism. To reduce permeation emissions, the control system used low permeation fuel lines and fluorinated HDPE fuel tanks. Staff retrofitted and tested three popular mower models outfitted with our venting mechanism, fluorinated tanks, and low permeation fuel lines to demonstrate the feasibility of such technology.

The testing was conducted in four phases.

- Phase I quantified baseline hot soak and diurnal emissions.
- Phase II quantified the benefit of replacing the HDPE fuel tank with one that had been fluorinated.
- Phase III quantified the benefit of a low permeation fuel line.
- Phase IV quantified the benefit of sealing the fuel when stored.

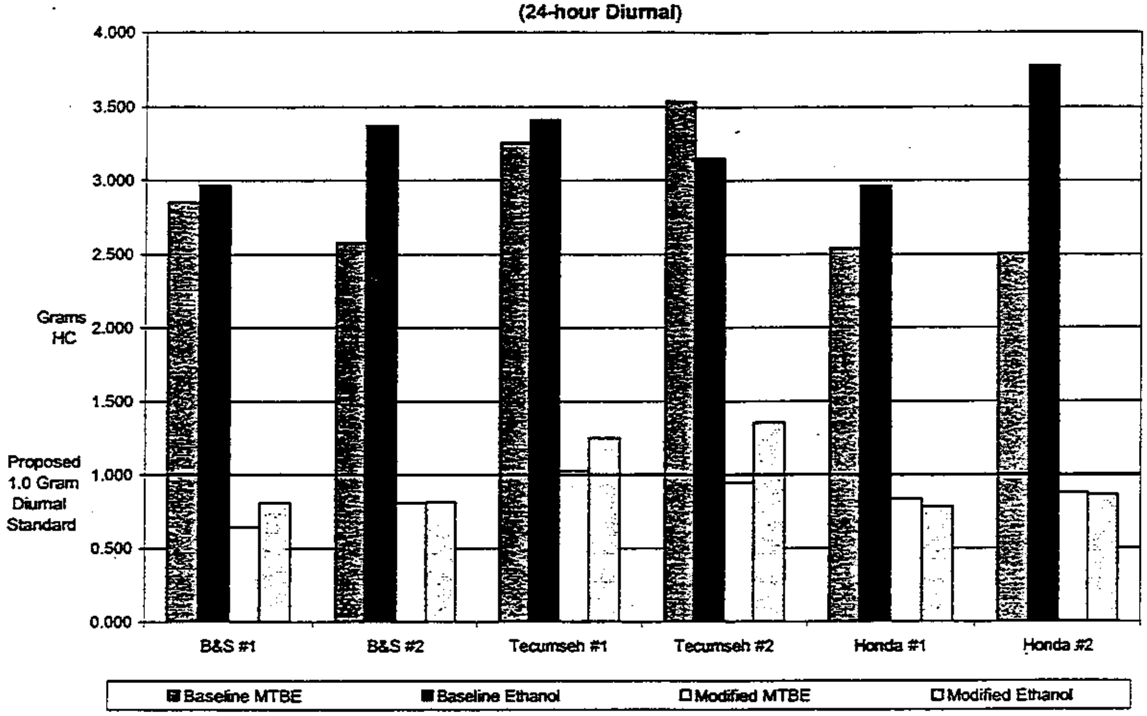
Figure 4.10 summarizes the results of the diurnal emission reduction testing with commercial pump fuel containing Methyl Tertiary Butyl Ether (MTBE) as an oxygenate. This figure compares three pairs of walk-behind mowers with systematically retrofitted control technology. Staff successfully controlled permeation and vented tank emissions on all equipment tested. Diurnal emissions were reduced by an average of 69 percent. On average, diurnal emissions dropped from 3.0 grams/day to below the proposed 1.0 gram/day diurnal standard. Based on these test results, control systems using sealed tanks and permeation control are a viable option for manufacturers to meet our proposed diurnal emission standard.

Figure 4.10
Mower Evaporative Emission Reduction Results
(24-Hour Diurnal)



Figures 4.11 summarizes the results of the diurnal emission reduction testing with commercial pump fuels containing ethanol and MTBE oxygenates. Staff successfully controlled permeation and vented tank emissions on the Briggs & Stratton and Honda engines with both types of fuels. However, the controlled results for the Tecumseh engine were higher for ethanol and non-ethanol fuel when compared to the other two engines. Staff suspects that fuel tank permeation was not controlled as effectively on the Tecumseh tank. Based on these test results, staff has shown the proposed diurnal standards can be met using the required test fuel (non-ethanol) and commercial fuel containing ethanol.

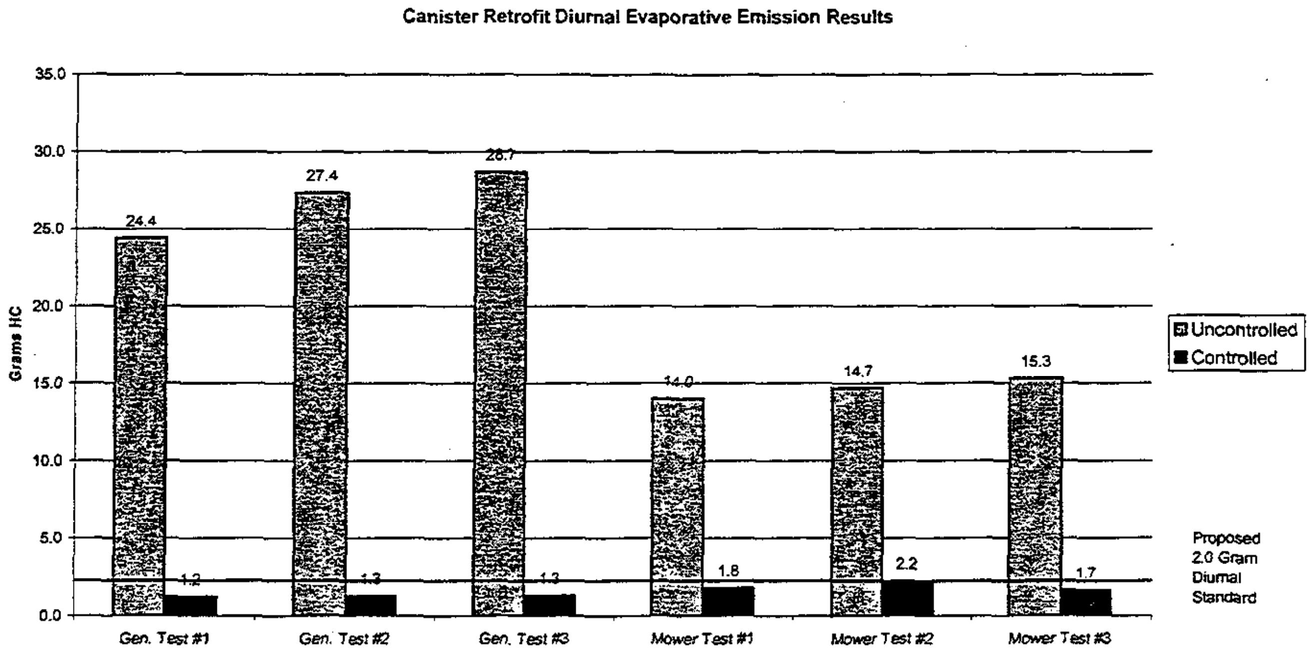
Figure 4.11
Mower Evaporative Emission Reduction Fuel Comparison Results
(24-hour Diurnal)



4.6.4.2 Carbon Canister Testing

To evaluate the feasibility of the proposed 2.0-gram HC/day diurnal evaporative emission standard for equipment ≥ 225 cc with large fuel tanks, staff worked with a canister supplier to test a commercial mower and generator retrofitted with a 670 cc canister system and low permeation fuel tanks and fuel lines. The results of the carbon canister testing were made available to the public in a report entitled Diurnal Testing Of Off-Road Equipment Retrofitted With Carbon Canister Evaporative Emission Control Systems (March 2003). Staff performed three baseline and three controlled SHED tests for each piece of equipment. Diurnal evaporative emissions were reduced from an average of 26.9 grams/day to 1.3 grams/day for the generator and from 14.7 grams/day to 1.9 grams/day for the lawn tractor. These results are below the proposed 2.0 gram/day diurnal emission standard for large equipment. The data clearly demonstrates that canister technology can be successfully adapted to off-road equipment to meet our proposed standard. Figure 4.12 details the results of the canister retrofit testing.

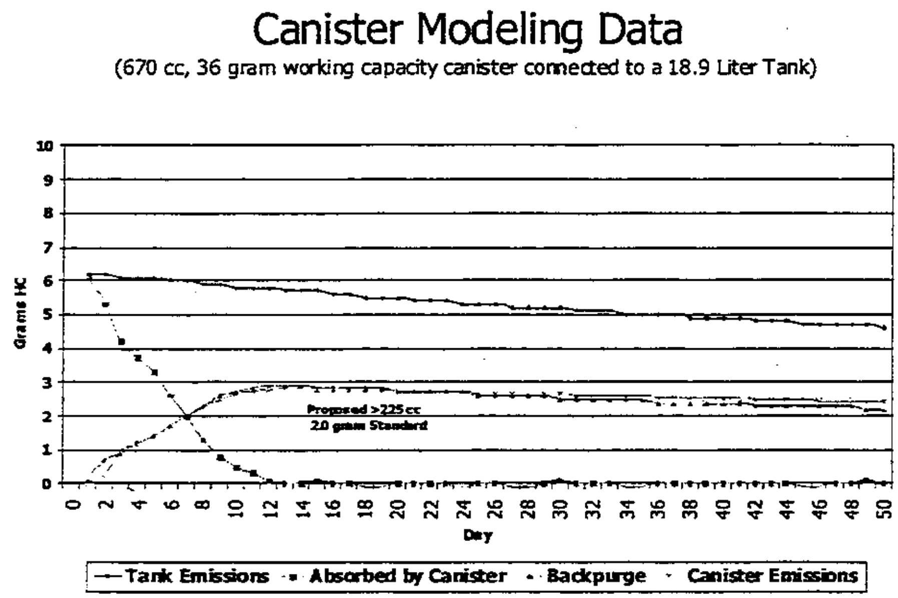
Figure 4.12



Staff also documented canister emission benefits over a 21-day storage period. Both models of equipment were able to meet the proposed standard through the 7th day.

Appropriately sizing a carbon canister has important long-term emission reduction implications. Staff used 670 cc carbon canisters with a 36 gram working capacity for the reduction testing. An automotive canister manufacturer modeled the canister's performance when connected to a five-gallon fuel tank filled to 50 percent capacity with 7 RVP fuel and subjected to repeated diurnal temperature over a 50-day period. The results of the modeling documented long-term canister efficiency at 48 percent. On the 50th day, canister emissions into the atmosphere were only 2.4 grams HC. Without the canister, emissions would have been 4.6 grams HC. Figure 4.13 details the results of the canister modeling. The effective working capacity of the modeled canister per liter of fuel tank volume was 1.9 grams/liter. Staff's proposal includes a requirement that carbon canisters for non-hybrid evaporative emission systems have a 2.0 grams working capacity per liter of fuel tank volume to ensure long-term emission reductions.

Figure 4.13



4.6.5 Diurnal Evaporative Emission Test Procedure

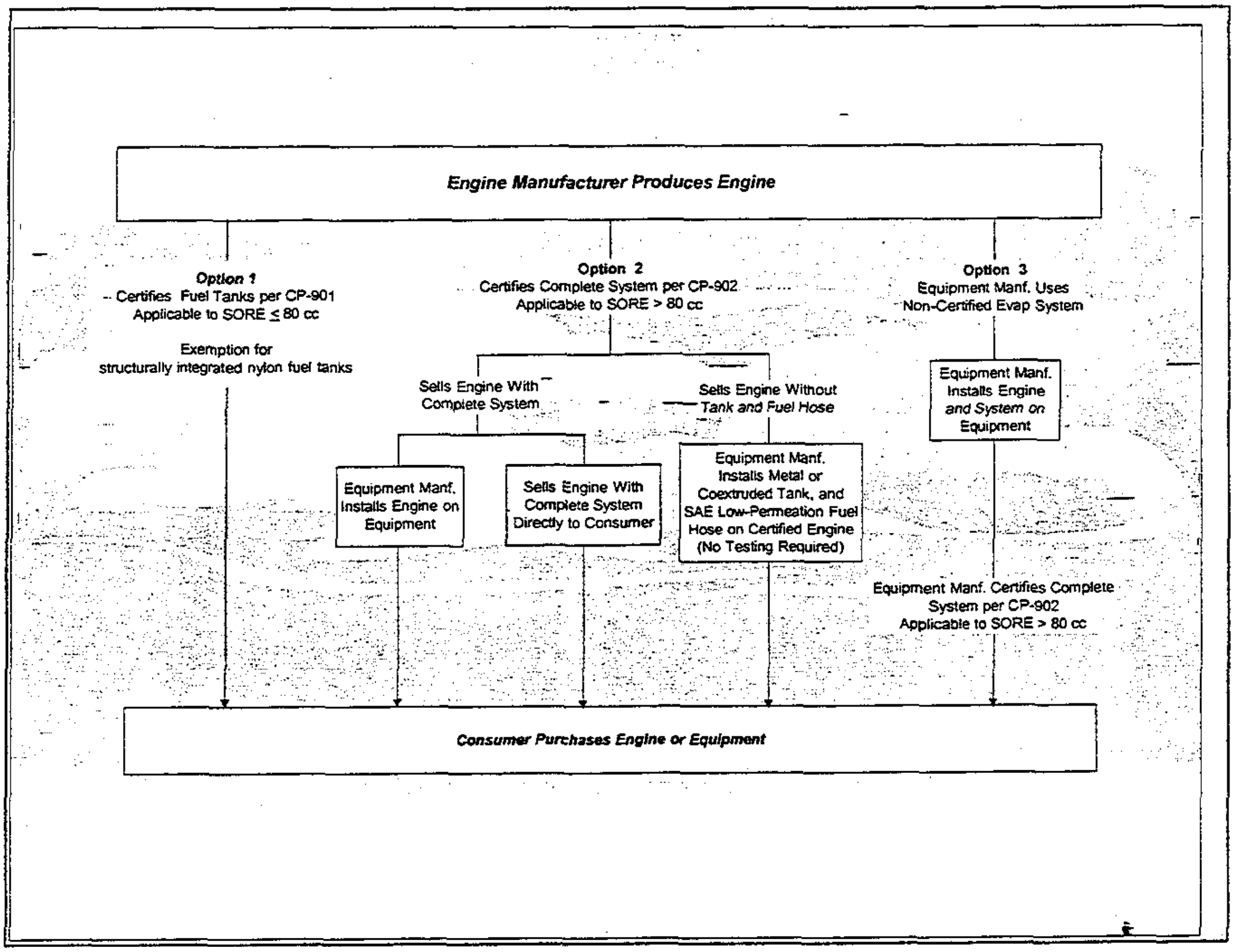
Equipment manufacturers electing to certify equipment to the proposed diurnal emission performance standards will be required to use Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines "TP-902." TP-902 is included in Appendix D.

4.7 General Evaporative Emission Certification Requirements

The proposed regulations require that evaporative emission control systems on small off-road engines or equipment that use small off-road engines be certified prior to being offered for sale or sold in California. The Small Off-Road Engine Evaporative Emissions Control System Certification Procedures "CP-901" and "CP-902" can be found in Appendix E. In general, the Certification Procedures describe the process to certify SORE equipment to evaporative emission performance standards. The procedures for evaluating and certifying small off-road engine fuel tanks are contained in CP-901. The procedures for evaluating and certifying evaporative emission control systems are contained in CP-902.

The proposal allows engine and equipment manufacturers to certify evaporative emission control systems on engines or equipment to specific performance standards. Figure 4.14 describes the certification options.

Figure 4.14
Options for Certifying Evaporative Emission Control Systems

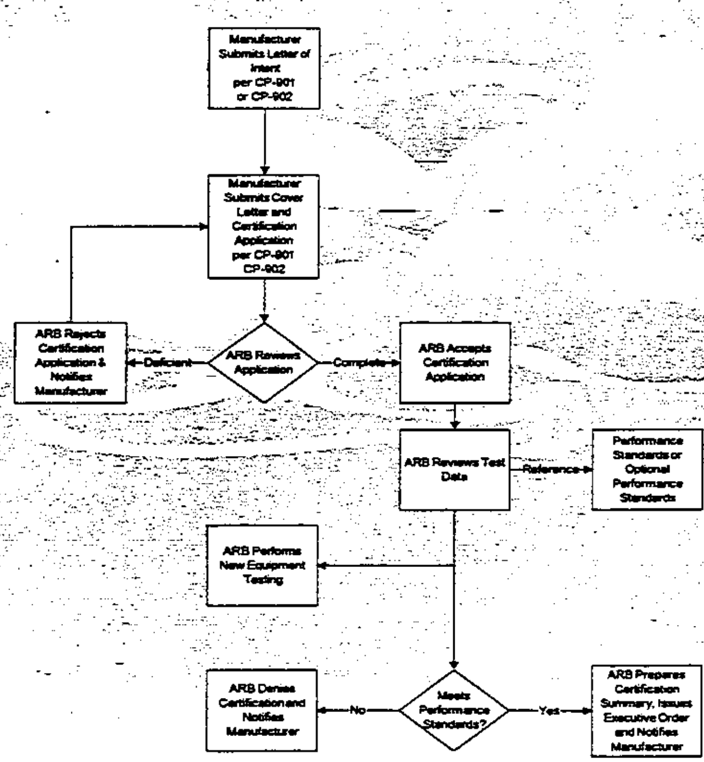


Staff expects most certifications to be conducted by engine manufacturers since a large majority of the small off-road engines are sold by engine manufacturers as complete systems to equipment manufacturers or directly to the consumer. Staff realizes the need by some equipment manufacturers to incorporate modified fuel tanks into the design of their equipment. For these situations, staff has incorporated an option to allow equipment manufacturers to install specified alternative fuel tanks and fuel hoses on certified systems without conducting further testing. Staff believes that the use of these alternative fuel tanks and hoses will not alter the emissions of the original system certification. Equipment manufacturers who install fuel tanks and fuel hoses other than those specified or modify the system from its original certification will need to certify the complete evaporative emission control system.

The certification process requires manufacturers to submit a formal application that includes test data that documents compliance. Testing must be performed on the highest emitting model of an evaporative family per the applicable Test Procedure. A CARB Executive Order certifying engines or equipment for sale in California will be issued if all of the applicable performance-based certification requirements are met. Figure 4.15 describes the performance-based certification process.

Figure 4.15

Off-Road Equipment Performance-Based Certification Process



4.8 Emissions Related Defects Reporting and Recall

Staff proposes a requirement that a manufacturer must report to ARB emission-related defects affecting a given class or category of engines. A manufacturer would be required to file a defect information report whenever the manufacturer determines, in accordance with procedures established by the manufacturer, either a safety-related or performance defect exists. A manufacturer must report the defect if the defect exists in 25 or more engines of a given engine family covered by the same Executive Order. This requirement is included in both the exhaust and evaporative emission regulations being proposed.

If ARB determines that a substantial number of any class or category of engines, although properly maintained and used, do not conform to the regulations when in actual use, ARB will notify the manufacturer and require the manufacturer to submit a plan to resolve the nonconformity of the engines. A resolution could be in the form of a recall of those engines. This requirement for defects reporting and recall is in alignment with the current federal program.

5. ENVIRONMENTAL AND ECONOMIC IMPACTS

5.1 Environmental Impact

5.1.1 Emission Reductions

The intent of the proposed regulations is to reduce emissions from small engines and equipment utilizing technologies that are technologically feasible and cost-effective. By 2010, on an annual average, it is estimated that the proposed emission standards would result in statewide emission reductions of 3.2 tons per day of NOx and 18.5 tons per day of HC. In 2020, the estimated reductions increase to 7.5 and 42.0 for NOx and HC, respectively. Estimated emission reductions are summarized below in Table 5.1. Staff estimates that an annual average 2010 South Coast Air Basin HC+NOx reduction of 9.0 tons per day would be realized, as highlighted in the table.

Table 5.1
Summary of Emissions Inventory and Reductions from the Proposed Regulations (Annual Average Tons Per Day for Nonpreempt Equipment)

Year	Pollutant	Emissions Inventory		
		Baseline	Controlled	Reductions
2010 Statewide	HC	98.9	80.4	18.5
	NOx	12.1	8.9	3.2
2020 Statewide	HC	107.2	65.2	42.0
	NOx	14.1	6.6	7.5
2010 South Coast	HC	40.9	33.2	**7.7**
	NOx	4.8	3.5	**1.3**
2020 South Coast	HC	44.9	27.4	17.5
	NOx	5.6	2.5	3.1

5.1.2 Toxic Air Pollutants

Benzene, a toxic air contaminant, is present in both exhaust and evaporative emissions from small off-road engines and equipment. Benzene in the exhaust, expressed as a percentage of total organic gases (TOG), varies depending on control technology (e.g., type of catalyst) and the levels of benzene and other aromatics in the fuel, but is generally about three to five percent. The benzene fraction of evaporative emissions depends on control technology and fuel composition and characteristics (e.g., benzene level and the evaporation rate), and is generally about one percent. Since the proposal will reduce HC emissions, an added benefit will be a reduction in public exposure to toxic compounds found in gasoline such as benzene.

5.1.3 Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code § 65040.12(c)). The Board recently established a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law. The policies developed apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, areawide, and other sources. Over the past twenty years, the ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Since the same ambient air quality standards apply to all regions of the State, all communities, including environmental justice communities, will benefit from the air quality benefits associated with the proposal. Alternatives to the proposed recommendations, such as recommending no change to the current exhaust emission standards, or not proposing revised exhaust emission standards or new evaporative emission standards, would adversely affect all communities. As additional relevant scientific evidence becomes available, the small off-road engine standards will be reviewed again to make certain that the health of the public is protected with an adequate margin of safety.

To ensure that everyone has an opportunity to stay informed and participate fully in the development of the small off-road engine standards, staff has held workshops in Sacramento and in El Monte and has distributed information by mail and through the internet, as described in section 2.5 of this report.

5.2 Cost and Cost-Effectiveness

Staff evaluated cost information supplied by engine and equipment manufacturers, MECA, and U.S. EPA to determine the economic impact of the proposed regulations.

For all cost-effectiveness figures, staff has estimated the increase in retail price due to the proposed emission controls. Those costs were then compared to the emissions reductions the proposed regulation would achieve beyond those achieved by the current California emission control programs.

5.2.1 Cost Estimates to Reduce Exhaust Emissions

5.2.1.1 Engines less than or equal to 80 cc

The cost of complying with the proposed emission standards in California for engines below 80 cc is not expected to be different from complying with the federal regulations already adopted by U.S. EPA. Therefore, no additional cost is anticipated from the adoption of the proposed Tier 3 standards in California.

The estimated cost of the federal requirements based on U.S. EPA's analysis is described below. To determine the costs for their Phase 2 handheld engine standards outlined in the Final Rulemaking, released in March 2000, the U.S. EPA used cost information obtained from a 1996 ICF Consulting Group and Engine, Fuel and Emissions Engineering, Inc., cost study, manufacturer submitted data, along with comments submitted regarding U.S. EPA's previous Notice of Proposed Rulemaking and Supplemental Notice of Proposed Rulemaking. Costs were based on the use of three technologies: 1) four-stroke engine, 2) compression wave technology, with and without a catalyst, and 3) stratified scavenging with lean combustion and a catalyst. The U.S. EPA estimated that, on average, the incremental cost of designing a California Tier 2 engine to meet the 50 g/kW-hr HC+NOx standard would be $11.55 (1998 dollars) for engines 20-50 cc (March 2000 Regulatory Impact Analysis, Appendix E). No engines below 20 cc are currently certified in California.

5.2.1.2 Engines above 80 cc

The staff projects that manufacturers will meet the proposed Tier 3 exhaust emission standards by using Tier 2 engines equipped with catalysts. Cost estimates for catalyst systems were supplied by MECA. According to MECA, the cost to manufacturers to incorporate a fully optimized catalyst system (50 percent HC+NOx conversion at the end of useful life) on a Tier 2 engine would be approximately $1.50 - $2.50 per horsepower for engines between 80 cc and 225 cc, and approximately $2.00 - $3.50 for engines 225 cc and above. Cost estimates are based on an engine family with annual sales of approximately 10,000 units for engines between 80 cc and 225 cc, and approximately 2,000 units for engines 225 cc and above. Additional costs could result from other engine integration modifications such as the addition of a passive air injection system, carburetor adjustments, and heat shielding. These additional technologies are also included in the cost analysis to provide a conservative estimate. In addition to the cost estimates supplied by MECA, staff also utilized cost estimates from ARB's 1998 small engine Staff Report and an Engine Fuels, and Emissions Engineering, Inc. report on handheld equipment costs (see References). From the handheld equipment report staff incorporated the manufacturer's markup estimates of 7.5%, equipment manufacturer's markup of 7.5%, and dealer's markup of 16% for engines >80 - <225 cc, and 30% for engines >225 cc.

It is possible that unique applications may result in the need for a custom converter. Without the advantage of high volume production cost reductions, this could result in higher catalyst costs for certain applications. Conversely, MECA commented that previous costs for compliance with other categories of engines and vehicles often proved to be less than the estimates made at the time of proposal.

Table 5.2 shows the estimated cost increase of equipping a Tier 2 engine with a catalyst. The cost analysis used a sales weighted average of 5 horsepower for engines >80 - <225 cc, and 12 horsepower for engines 225 cc and above.

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Table 5.2
Exhaust Emissions Reduction Technologies
(Retail Price Increase)

Engine Size	Exhaust Emissions Control Technology	Cost Estimate per Unit
>80 - <225 cc	Catalyst System	$7.50 - $12.50
	Air Induction System	$1.00
	Heat Shield	$2.33
	Total (with markup)	$14.52 - $21.22
	Engine Modification/System Integration*	$1.15
	Total Estimated Cost	$15.67 - $22.37
≥ 225 cc	Catalyst System	$24.00 - $42.00
	Air Induction System	$1.00
	Heat Shield	$5.51
	Total (with markup)	$45.83 - $72.88
	Engine Modification/System Integration*	$1.15
	Total Estimated Cost	$46.98 - $74.03

* Engine modification/system integration estimates were based on retail cost estimates, and therefore no markup was included in these estimates.

5.2.2 Cost Estimates to Reduce Evaporative Emissions

Staff presented a preliminary cost estimate of $15.00 per equipment unit for evaporative controls to meet the proposed diurnal standards to stakeholders for comment at a public workshop on April 25, 2002. Subsequent to the workshop, staff evaluated carbon canister systems and believes canisters are also an option for meeting the proposed diurnal standards. The current cost estimate for control technology now ranges from $2.16 to $105.32 per unit depending on the control technology selected. As with the estimates for exhaust control, Staff used a manufacturer's markup of 7.5%, an equipment manufacturer's markup of 7.5%, and a dealer's markup of 16% for engines <225 cc, and 30% for engines ≥225 cc. Table 5.3 is a breakdown of the cost estimate:

Table 5.3
Evaporative Emissions Reduction Technologies
(Retail Price Increase)

Engine Size	Evaporative Emissions Control Technology	Cost Estimate per Unit
≤ 80 cc	Tank Permeation	\$1.00 - \$3.00
	Testing	\$0.61
	Total Estimated Cost	\$2.16 - \$4.84
>80 cc – <225 cc	Tank Permeation	\$1.00 - \$6.00
	Fuel Cap	\$1.00
	Fuel Hose Permeation	\$1.00 - \$2.00
	Venting Control (Sealed Tank)	\$10.00
	Testing	\$3.21*
	Total Estimated Cost (Sealed Tank Option)	\$21.72 - \$29.76
≥ 225 cc	Tank Permeation	\$1.00 - \$27.00
	Fuel Cap	\$1.00
	Fuel Hose Permeation	\$1.00 - \$2.00
	Venting Control (Carbon Canister)	\$10.00 – \$37.00
	Testing	\$3.21*
	Total Estimated Cost (Carbon Canister Option)	\$24.32 - \$105.32

*Note: It is assumed that an engine manufacturer will build and operate a SHED to certify all engines > 80cc that they produce.

Manufacturing costs are based on preliminary estimates received from industry and do not include R&D costs.

5.2.2.1 Cost Estimates to Reduce Permeation Emissions

Testing Costs

In order to estimate permeation testing costs, staff assumed a manufacturer with annual sales of 197,012 units (20 percent market share) would have 10 evaporative families. Staff also assumed that product changes would require that a manufacturer recertify evaporative families every three years. Each evaporative family would need 30 (industry standard) permeation tests costing \$1200 per test. The total testing cost for 300 tests is \$360,000 or \$0.61 per unit.

Tank Permeation

The current cost to produce a monolayer HDPE mower tank ranges from \$0.59 to \$1.60 per tank. There are six potential options for producing a tank that will meet the proposed permeation standard. Options include co-extruded multilayer tanks, using barrier resin blends such as Selar®, using material substitutes for HDPE such as acetal copolymers (POM), barrier surface treatments such as fluorination and sulfonation, and metal tanks. For a typical mower tank, staff estimate manufacturers will incur added costs that range from \$1.00 to \$6.00 per tank depending on the option chosen and equipment application. For commercial turf equipment the highest estimate received by staff is \$27.00 for a five-gallon co-extruded multilayer tank. Staff has not received an estimate for a comparable metal tank, which could be higher.

Fuel Cap

The estimated cost to produce a compliant fuel cap is \$1.00.

Fuel Hose Permeation

The current cost for fuel line used on most lawn and garden equipment is less than \$0.46 per foot. Depending on the amount of fuel line purchased the added cost to switch to a flexible low permeation fuel line that would meet SAE J30R9, J30R11-A, J30R12-A, or J2260 Category 1 permeation specification ranges from \$1.00 to \$2.00.

5.2.2.2 Cost Estimates to Reduce Venting Emissions

Testing Costs

In order to estimate diurnal testing costs, staff assumed a manufacturer would need to build and operate a SHED. The annual SHED operating costs are estimated at \$497,153. The SHED would be used to certify all the engines the manufacturer produced. Staff assumed a manufacturer with annual sales of 154,694 units (20 percent market share). The total testing cost per unit produced is \$3.21 per unit.

Sealed Tanks

Valves that limit diurnal venting by sealing the fuel tank during storage exist on most current SORE equipment. However, mechanically controlled fuel shut-off valves found on a particular commercial mower cost approximately \$3.50 to produce. A passively controlled venting mechanism would need two such valves and a cable or similar control linkage. Staff estimates that the control linkage can be manufactured for no more than \$3.00 per unit. Therefore, staff estimates the total cost for a controlled venting mechanism to seal a fuel tank to be approximately \$10.00 per unit. Staff presented this estimate to stakeholders at an April 25, 2002 public workshop and requested comment. No comments were received from stakeholders.

Canister Systems

Based on comment received from various canister manufacturers, staff estimates that the cost to mass-produce a canister system for SORE equipment is between $10.00 and $17.00 per unit, depending on canister capacity and production volumes. However for ≥ 225 cc equipment, one engine manufacturer provided a cost estimate of $37.00 for an installed canister system.

5.2.2.3 Total Cost Estimates to Reduce Exhaust and Evaporative Emissions

Table 5.4 shows the total per unit retail cost increase for complying with the proposed exhaust and evaporative emission requirements.

Table 5.4
Total Per Unit Retail Cost Increase

Engine Size	Emissions Control	Cost Estimate per Unit
≤ 80 cc	Total Exhaust Cost*	$0
	Total Evaporative Cost*	$2.16 - $4.84
	Total Estimated Cost	$2.16 - $4.84
>80 cc – <225 cc	Total Exhaust Cost*	$15.67 - $22.37
	Total Evaporative Cost*	$21.72 - $29.76
	Total Estimated Cost	$37.39 - $52.13
≥ 225 cc	Total Exhaust Cost*	$46.98 - $74.03
	Total Evaporative Cost*	$24.32 - 105.32
	Total Estimated Cost	$71.30 - $179.35

One engine manufacturer provided a total cost per unit increase estimate of $78 (which included converting an engine from "L-head" to an overhead valve design) for engines >80 - <225 cc, and $127 for engines ≥ 225 cc[4]. Many of the calculations and assumptions the manufacturer used differed from the calculations and assumptions traditionally used by staff to determine costs. While the manufacturer acknowledges that the cost estimates provided to staff were preliminary and not complete, staff analyzed the costs of incorporating a catalyst and evaporative system utilizing the cost estimates supplied by the manufacturer. The per unit cost increase of the proposal, using the data supplied by this manufacturer, is in the ballpark of that calculated by staff.

4 The manufacturer provided incremental cost estimates reflecting the staff's current proposal. Details of these costs were submitted confidentially, and thus are not included in this report.

5.2.3 Cost-Effectiveness of Proposed Regulations

Staff used estimated cost information and lifetime unit exhaust and evaporative emissions to calculate the cost-effectiveness of the proposed standards. The cost of controls, both exhaust and evaporative, are based on estimates provided by emission control component manufacturers and trade associations. Tables 5.5, 5.6, and 5.7 list lifetime emission reductions based on the proposed standards for typical engines and equipment ≤ 80cc, > 80 cc - <225 cc, and ≥225 cc.

Table 5.5
Engines ≤ 80 cc Cost Effectiveness (HC)*

Equipment Type	Lower Cost per Unit	Upper Cost per Unit	Lifetime Emission Reductions Per Unit (lbs.)	Lower C/E Ratio ($/lb.)	Upper C/E Ratio ($/lb.)
Evap, Leaf Blower	$2.16	$4.84	1.26	**$1.71**	**$3.84**
Evap, String Trimmer	$2.16	$4.84	0.78	**$2.77**	**$6.21**

*The cost-effectiveness is based only on the cost and emissions benefits associated with the evaporative standard requirements. Although per unit lifetime emissions will also be reduced from these engines by the implementation of the new exhaust emission standards, the costs of meeting these standards were already included in U.S. EPA's cost analysis of the federal standards. Thus, the emissions reductions and associated costs were not included in staff's cost-effectiveness calculations.

Table 5.6
Engines > 80 cc - < 225 cc Cost Effectiveness (HC+NOx)

Equipment Type	Lower Cost per Unit	Upper Cost per Unit	Lifetime Emission Reductions Per Unit (lbs.)	Lower C/E Ratio ($/lb.)	Upper C/E Ratio ($/LB)
Evap, Mower (Incl. Testing)	$21.72	$29.76	11.41	$1.90	$2.61
Exhaust, Mower	$15.67	$22.37	3.14	$4.99	$7.12
Combined	$37.39	$52.13	14.55	**$2.57**	**$3.58**
Evap, Generator	$21.72	$29.76	133.60	$0.16	$0.22
Exhaust, Generator	$15.67	$22.37	54.89	$0.29	$0.41
Combined	$37.39	$52.13	188.49	**$0.20**	**$0.28**

Table 5.7
Engines ≥ 225 cc Cost Effectiveness (HC+NOx)

Equipment Type	Lower Cost per Unit	Upper Cost per Unit	Lifetime Emission Reductions Per Unit (lbs.)	Lower C/E Ratio ($/lb.)	Upper C/E Ratio ($/lb.)
Evap, Rear Engine Riding Mower	$24.32	$105.32	33.38	$0.73	$3.16
Exhaust Rear Engine Riding Mower	$46.98	$74.03	8.29	$5.67	$8.93
Combined	$71.30	$179.35	41.67	**$1.71**	**$4.30**
Evap, Commercial Turf	$24.32	$105.32	39.41	$0.62	$2.67
Exhaust, Commercial Turf	$46.98	$74.03	280.34	$0.17	$0.26
Combined	$71.30	$179.35	319.75	**$0.22**	**$0.56**

For equipment below 80 cc, the retail cost effectiveness ratio ranges from a high of \$6.21 per pound of HC reduced for a string trimmer, to a low of \$1.71 per pound of HC reduced for a leaf blower. For equipment greater than 80 cc, the retail cost effectiveness ratio ranges from a high of \$4.30 per pound of HC + NOx reduced for a rear engine riding mower, with an engine greater than 225 cc, to a low of \$0.20 per pound of HC + NOx reduced for generator with an engine greater than 80 cc and less than 225 cc. Staff's proposal is very cost effective when compared with recently adopted control measures.

5.3 Economic Impact on the Economy of the State

The proposed regulations are not expected to impose a significant cost burden to engine or equipment manufacturers. Staff anticipates manufacturers will pass on the added costs to consumers. Staff estimates that the added retail price of emission controls for equipment with displacements of less than 80 cc will range from \$2.16 to \$4.84 per unit. For equipment greater than 80 cc but less than 225 cc, staff estimates that the added retail price of emission controls will range from \$37.39 to \$52.13 per unit. Finally, staff estimates that the added retail price of emission controls for all equipment with displacements at or above 225 cc will range from \$71.30 to \$179.35 per unit.

As shown in Table 5.8, using the upper range of the price increases staff estimates a statewide dollar cost of control of approximately \$760 million. This analysis is based on Calendar Year (CY) 2020 population estimates since all equipment is assumed compliant by that year.

Table 5.8
Total Statewide Dollar Cost Increase

Engine Category	*Increase in Retail Price Per Unit*		*2020 Population*	*Statewide Dollar Cost for Fleet Turnover*	
	Lower	*Upper*		*Lower*	*Upper*
Equipment ≤ 80 cc	\$2.16	\$4.84	7119171	\$15,377,409	\$34,456,787
Equipment > 80 cc - < 225 cc	\$37.39	\$52.13	6572217	\$245,735,194	\$342,609,672
Equipment ≥225 cc	\$71.30	\$179.35	2134932	\$152,220,652	\$382,900,054
	Total Statewide Dollar Cost Estimate			**\$413,333,255**	**\$759,966,513**

To determine the annual cost to consumers, staff multiplied projected 2020 annual sales by the average price increase for all equipment. Again, based on the average retail price increase, staff estimates the annual cost increase to consumers to be approximately $85 million per year as shown in Table 5.9. In comparison, California consumers spent over $2.6 billion on lawn and garden equipment in 1997[5].

Table 5.9
Estimates of Annual Cost to Consumers

Engine Category	Average Price Increase	Annual Cost
Equipment ≤ 80 cc	$3.50	$4,811,166
Equipment > 80 cc - < 225 cc	$44.76	$44,198,038
Equipment ≥225 cc	$125.33	$36,448,721
	Total Annual Cost to Consumers	$85,457,925

In addition to the previous estimates, staff determined the approximate retail price increases for various types of equipment by engine category. As shown in Table 5.10, the estimated retail price increase for small displacement equipment with a unit price of $100.00 is approximately four percent. The estimated retail price increase for mowers with displacements of greater than 80 cc but less than 225 cc with a unit price of $250.00 is approximately 18 percent. Staff estimates that the retail price increase for commercial turf equipment with engine displacements of greater than 225 cc and a unit price of $4,000.00 is approximately three percent.

Table 5.10
Percent Retail Price Increases

Engine Category	Approximate Unit Cost	Percent Retail Price Increase
Handheld Equipment ≤ 80 cc	$100.00	4%
Walk-Behind Mowers > 80 cc - < 225 cc	$250.00	18%
Commercial Turf Equipment	$4000.00	3%

Although a $45 price increase for walk-behind mowers may persuade a consumer to delay the purchase of a new mower in the short term, it is not expected to significantly impact the long-term demand because mowers eventually wear out and are necessary for lawn care. Based on the above assumptions, staff expects the proposed regulations to impose no adverse impact on California competitiveness and employment. The following sections are intended to fulfill ARB's legal requirements related to economic analysis and economic impact for stakeholders affected by these proposed regulations.

5 United States Census Bureau's sales data for California lawn and garden equipment and supplies stores, which comprises establishments primarily engaged in retailing new lawn and garden equipment and supplies.

5.3.1 Legal Requirement

Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulations. The assessment shall include a consideration of the impact of the proposed regulations on California jobs, business expansion, elimination or creation, and the ability of California business to compete.

Also, section 11346.5 of the Government Code requires State agencies to estimate the cost or savings to any state, local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate shall include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

5.3.2 Businesses Affected

Any business involved in the manufacturing of small engines and equipment will potentially be affected by the proposed regulations. Also, potentially affected are businesses that supply engines and parts to these manufacturers, and those businesses that buy and sell equipment in California. The focus of this analysis, however, will be on the engine and equipment manufacturers because these businesses would be directly affected by the proposed regulations.

5.3.2.1 Engine Manufacturers

There are currently 30 small engine manufacturers that market certified engines in California, as shown in Table 5.11. Seventeen of these are involved in the manufacturing of small engines less than or equal to 80 cc for use in such applications as chainsaws, trimmers, brush cutters, hedge trimmers, and other handheld products. Eighteen manufacturers are involved in the manufacturing of small engines greater than 80 cc for use in such applications as walk-behind and riding mowers, mulching lawn mowers, tillers, portable generators, and other nonhandheld products. Some of these manufacturers produce engines for both handheld and nonhandheld applications. None of the manufacturers are located in California although some have small repair and distribution operations in California.

Table 5.11
Manufacturers with Small Engines Certified in California

Produce ≤ 80 cc	Produce > 80 cc	Produce Both
Andreas Stihl	Alto U.S.	Briggs & Stratton
Electrolux Home Products	Daihatsu Motor Company	Honda Motor Company
Fuji Robin	Eagle Solutions	Kawasaki Heavy Industries
Homelite Consumer Products	Fuji Heavy Industries	Mitsubishi Heavy Industries
Husqvarna	Generac Power Systems	Yamaha
Kioritz	Kohler	
Komatsu	Kohler Company Generator Division	
Maruyama	Kubota	
MTD Southwest	Lister-Petter	
Shindaiwa	Onan	
Solo Inc.	Pioneer Eclipse	
Tanaka	Tecumseh	
	Westerbeke	

5.3.2.2 Equipment Manufacturers

There are over one thousand manufacturers of small engine equipment nationwide. Many are small manufacturers that do not meet the definition of a "Small Business" as defined in Government Code Section 11342.610. The majority of equipment is manufactured outside California. These manufacturers produce a wide variety of products. Table 5.12 provides a partial list of large and small manufacturers.

Table 5.12
Small Engine Equipment Manufacturers

Large Equipment Manufacturers	Small Equipment Manufacturers
American Honda Motor Co.	Auburn Consolidated Industries.
Ariens Co.	Bush Hog L.L.C.
Dixon Industries	Hoffco, Inc.
Deere & Co.	Minuteman Parker
Echo, Inc.	Redmax
Electrolux Home Products	Scag Power Equipment, Inc.
Exmark Manf. Co.	Solo, Inc.
Husqvarna Forest & Garden	Simplicity Manufacturing Inc.
Homelite Consumer Products	Textron Golf, Turf & Specialty Products
Kawasaki Motors Corp., USA	Tennant Co.
Kubota Tractor Corp.	Wolf Garten of North America L.P.
Makita USA, Inc.	Woods Equipment Co.
MTD Southwest Inc.	
Murray, Inc.	
New Holland North America Inc.	
Robin America	
Shindaiwa, Inc.	
Snapper, Inc.	
Stihl, Inc.	
Tanaka Power Equipment	
The Toro Co.	
Yamaha Motor Corp.	

The affected engine and equipment manufacturers fall into different industry classifications. A list of the industries that staff has been able to identify is provided in Table 5.13.

Table 5.13
Industries with Potentially Affected Manufacturers

SIC Code	Industry
3053	Gaskets, Packing, and Sealing Devices
3087	Custom Compounding of Purchased Plastic Resins
3089	Plastic Products
3519	Internal Combustion Engines, NEC
3523	Farm Machinery and Equipment
3524	Lawn and Garden Equipment
3531	Construction Machinery
3561	Pumps and Pumping Equipment
3563	Air and Gas Compressors
5261	Lawn and Garden Supply Stores

5.3.3 Impact on Small Businesses

The proposed regulations will have some impact, although not significant, on small businesses that buy and sell lawn and garden equipment. For small retailers, during the initial years of implementation, the increased cost of equipment may lead to a slight drop in demand that could result in lower profits. For example, a small retailer that usually sells 65 lawn mowers a year might sell 10 percent or 7 fewer mowers during the first year of implementation. Assuming a 20 percent profit on a $250 mower, the regulation would cost the retailer $350 in profit the first year. The retailer would carry over unsold stock to the next year, possibly incurring less profit on the sale of these units.

Regarding impacts on small businesses that purchase equipment, a small two-person lawn care company that purchases six pieces of equipment per year for example, may experience $225 in added costs (as shown in Table 5.14 below).

Table 5.14
Example of Additional Costs Incurred by a Small Lawn Care Company

Equipment Type	Units Purchased	Increased Retail Cost Per Unit	Added Costs
String Trimmers	2	$3.50	$7.00
Leaf Blower	1	$3.50	$3.50
Walk-Behind	2	$44.76	$89.52
Commercial Turf	1	$125.33	$125.33
		Total	**$225.35**

5.3.4 Potential Impact on Distributors and Dealers

Most engine and equipment manufacturers sell their products through distributors and dealers, some of which are owned by manufacturers and some are independent. Most independently owned dealers are small businesses. Some low-volume manufacturers also deal directly with their customers. The distributors and dealers sell about 1,700,000 units of small engine equipment per year in California. Although they are not directly affected by the proposed amendments, the amendments may affect them indirectly if an increase in the price of small engines and equipment reduces sales volume. Dealers' revenue would be affected adversely by significant reduction in sales volume.

5.3.5 Potential Impact on Business Competitiveness

The proposed amendments would have no significant impact on the ability of California small engine and equipment manufacturers to compete with manufacturers of similar products in other states. This is because all manufacturers that produce small engines and equipment for sale in California are subject to the proposed amendments regardless of their location. Furthermore, all of the engine manufacturers, and most of the equipment manufacturers, are located outside of California.

5.3.6 Potential Impact on Employment

The proposed regulations are not expected to cause a noticeable reduction in California employment because California accounts only for a small share of manufacturing employment in small engine, equipment, and component production. However, some small businesses operating outside of California may leave the California market due to cost increases, which may result in a few jobs being eliminated.

6. ALTERNATIVES CONSIDERED

Staff evaluated four additional alternatives to the currently proposed regulations. These included:

- Take no action.
- Setting More Stringent Emission Standards Based on the Use of Zero-Emission Technology
- Setting More Stringent Evaporative Emission Standards That Would Require a Redesigned Carburetor or Fuel injection System.
- Setting More Stringent Evaporative Emission Standards That Would Require the use of Alternative Fuels.

6.1 No Action

The first alternative evaluated was to take no action. Under this alternative, it is likely that few, if any, engine and equipment manufacturers would voluntarily incorporate emission control technology into their designs. The few manufacturers that may adapt the control technology would be at a competitive disadvantage compared to manufacturers electing to not incorporate the emission control technology. Clearly, most of the exhaust and evaporative emission control technologies used in cars have not been adapted for use in small engines and equipment because manufacturers perceive the costs outweigh performance and fuel usage benefits. Therefore, this proposal would have no impact on manufacturers and is likely to result in no emission reductions, except the exhaust emissions benefits for handheld equipment associated with this proposal will still be achieved because the federal rule will apply. This alternative would not contribute to the State's control strategy to attain Federal and State ambient air quality standards for ozone. The cost to the state is the potential loss of Federal highway funding, should an adequate SIP not be implemented. In addition, the failure to propose further emission reductions from small engines defaults on ARB's SIP settlement commitment, and could provoke a court order.

6.2 Setting More Stringent Emission Standards Based on the Use of Zero-Emission Technology

Another alternative option to the proposed standards is a requirement that small engine equipment standards be set at zero, forcing the use of electric equipment. There are many advantages to using electric powered equipment over internal combustion engine equipment. Electric equipment does not require fuel and has no exhaust or evaporative emissions stemming from the unit. Engine tune-ups and oil changes are not required, thus maintenance costs are lower. The elimination of the pull-cord start makes "starting" the equipment unnecessary.

Staff inspection of retail stores and web sites showed that electric powered handheld equipment was readily available for the residential user's market. Most of the electric units currently available are the smaller, lower weight and cost units. For example, the cutting path designed for electric line trimmers are generally less than 15 inches, while gasoline powered trimmers have a wider cutting path, in the range of 15 to 24 inches. There was some larger electric equipment available, but these seem to be aimed at residential users, such as a riding mower powered by lead-acid batteries. Virtually no electric equipment is readily available for commercial users because of the demands for mobility and extended activity.

Currently, the electric mower is estimated to be about ten percent of the California market. The corded walk-behind lawn mowers draw power from a 110-volt AC electric outlet with a long extension cord. The power available typically provides only enough power for a cutting path up to 19 inches, thus its use is primarily limited to smaller-sized lots. Battery powered mowers tend to have added weight due to the battery, and battery size is limited. The weight of the battery can be between 20 and 50 pounds, which makes pushing the mower more difficult. Operation time is limited between recharges for battery powered units, which is problematic for commercial use.

It would be very difficult to switch over an equipment type to electric only. There are issues related to equipment performance, recharging/refueling time, size, and weight. The electric equipment available is designed for residential applications. Staff believes that electric equipment could not perform adequately in commercial uses, which typically require greater mobility than afforded by corded equipment and greater operating time than provided by current battery-powered units. However, corded or cordless electric units could replace certain handheld equipment designed for residential users. In addition, as mentioned above, electric nonhandheld equipment can be an ideal alternative to internal combustion powered equipment for residential applications with smaller sized lots, where large cutting paths are not essential. The demographic shift toward smaller residential lots could result in an increase in the purchase of electric equipment. Staff conducted surveys of lawn and garden retail stores in 2000, 2001 and 2002. Table 6.1 shows staff's findings regarding the specifications of available electric lawn and garden equipment. Table 6.2 lists various lawn and garden applications and staff's estimate of the potential for those applications to be converted to electric.

Table 6.1
Features and Specifications for Currently Available Electric Equipment

Equipment Type	Cordless (Running Time Per Charge)	Corded	Features	
			Electric Equipment	Gasoline Powered Equipment
Line trimmer	Y (45 min)	Y	Cutting path: 7"-17"	Cutting path: 15"-24"
Hedge trimmer	Y (35 min)	Y	Blade length: 6"-22"	Blade length: 17"-40"
Non-backpack blower	Y (10 min)	Y	Air volume: 78-405 cfm Air speed: 110-225 mph	Air volume: 300-400 cfm Air speed: 130-200 mph
Backpack blower	N	N	N/A	Air volume: 375-1,200 cfm Air speed: 155-205 mph
Chain saw	Y (93 pieces of 1-3/4" hard wood)	Y	Bar length: 7"-20"	Bar length: 10"-20"
Tiller	Y	N	Tilling depth: 10"	Tilling depth: 10"-20"
Walk-behind Mower	Y (2 hr / 1/2-acre)	Y	Cutting path: up to 19"	Cutting path: 21"-22" Self-propelled
Riding mower & Tractor	Y (5 hr)	N	Lead-acid battery: 6×6V Top speed: 4.75 mph	Top speed: 7.5 mph

Table 6.2
Electric Lawn and Garden Equipment Availability and Potential for Application Conversion to Use of Electric

Equipment Type	User	Electric Available Today	Widespread Electric Conversion		
			Likely	Maybe	Unlikely
Line Trimmers	Residential	Y	X		
	Commercial	N		X	
Hedge Trimmers	Residential	Y	X		
	Commercial	N		X	
Non-backpack Blowers	Residential	Y	X		
	Commercial	N		X	
Backpack Blowers	Residential	N			X
	Commercial	N			X
Chainsaws	Residential	Y	X		
	Commercial	N			X
Tillers	Residential	Y			X
	Commercial	N			X
Walk-Behind Mowers	Residential	Y		X	
	Commercial	N			X
Riding Mowers & Tractors	Residential	Y		X	
	Commercial	N			X
Other Lawn and Garden Equipment				X	

Environmental groups and the SCAQMD have suggested, as part of their 2003 SIP, that new residential lawn and garden equipment sold in California be required to be electric. Residential equipment comprises 88 percent of the lawn and garden equipment population, but only accounts for 32 percent of the usage time, and thus is a smaller portion of the lawn and garden emissions inventory. Staff considered a regulatory scheme of proposing a zero emission requirement for residential applications, and the currently proposed standard for commercial applications. However, the residential/commercial markets are not distinct, and it would be extremely difficult to enforce such a rule. For example, in practical terms, such a proposed rule would not prevent a homeowner from purchasing a "commercial" (non-electric) lawn mower. Also, many moderately priced lawn mowers, typically used in residential applications, are used by small, independent commercial gardening businesses. Replacing the moderately priced lawn mowers with more expensive, limited operation electric equipment could negatively affect the livelihood of these businesses.

Improved battery and fuel cell technologies provide reasonable promise for lawn and garden equipment in the future. The rechargeable batteries designed for electric golf carts may be used in some non-handheld equipment, such as garden tractors and riding mowers. However, the cordless electric equipment has, to date, had limited commercial market acceptance due to limited performance. With further improvements to the electric engine technology, it is likely that consumer acceptance of these products will increase.

The importance of electric equipment is primarily that it will remain available in some applications as a consumer choice when gasoline products experience modest price increases. Market shifts to electric would produce additional emissions benefits.

6.3 Setting More Stringent Emission Standards That Would Require a Redesigned Carburetor or Fuel Injection System

A third alternative evaluated would set more stringent evaporative emission standards that would also require a redesigned carburetor or fuel injection system. Virtually all nonhandheld small off-road engines use gravity fed carburetors that vent to the atmosphere. For a typical carburetor on a summer day these emissions are about 0.7 grams/day. Conceivably, carburetors could be redesigned to limit these evaporative emissions during equipment storage. Fuel injection systems are another type of technology that could be used to limit emissions because they do not vent to the atmosphere. Staff received industry cost estimates that ranged from $10.00 for a redesigned carburetor to $150.00 for a fuel injection system. These added costs would be in addition to costs to control permeation and vented evaporative emissions. Staff evaluated the cost effectiveness for the least cost-effective equipment type, a mower with an engine greater than 80 cc and less than 225 cc. Staff estimated the lifetime emissions by assuming the proposed diurnal emission standard would be lowered from 1.0 to 0.5 grams HC/day. Table 6.3 lists the upper and lower ranges of cost effectiveness for this alternative.

Table 6.3
Engines > 80 cc - < 225 cc Cost Effectiveness (HC+NOx)
Alternative Two

Equipment Type	Lower Cost per Unit	Upper Cost per Unit	Lifetime Emission Reductions Per Unit (lbs.)	Lower C/E Ratio ($/lb.)	Upper C/E Ratio ($/lb.)
Evap, Mower (Incl. Testing)	$35.12	$230.76	13.21	$2.66	$17.47
Exhaust, Mower	$15.67	$22.37	3.14	$4.99	$7.12
Combined	$50.79	$253.13	16.35	**$3.11**	**$15.48**

The cost to an equipment manufacturer would range from a low of $50.79 to possibly as high as $253.13 per unit. The upper estimate of cost effectiveness is $15.48 per pound of HC+NOx reduced. Staff rejected this alternative for the following reasons:

- It would have a significant impact on manufacturers by requiring a redesign of all fuel systems.
- It would provide less than one ton per day of additional HC reductions in 2010.
- It may not be technically feasible for all engine applications.
- Cost-effectiveness is poorer than other alternatives.

6.4 Setting More Stringent Emission Standards That Would Require the Use of an Alternative Fuel

The fourth alternative evaluated would set more stringent evaporative emission standards that would require the use of an alternative fuel such as propane. Ideally, equipment that operated on compressed gas would have virtually no evaporative emissions. Staff evaluated a mower retrofitted to operate on propane. Its diurnal emissions were measured at 0.2 grams/day. Conceivably, most nonhandheld equipment could be manufactured to operate on propane. In evaluating this alternative, staff received industry cost estimates that ranged from $50.00 to $100.00 per unit. Again staff evaluated the cost effectiveness for the least cost-effective equipment type, a mower with an engine greater than 80 cc and less than 225 cc. Staff estimated the lifetime emissions by assuming the proposed diurnal emission standard would be lowered from 1.0 to 0.3 grams HC/day. Table 6.4 lists the upper and lower ranges of cost effectiveness for this alternative.

Table 6.4
Engines > 80 cc - < 225 cc Cost Effectiveness (HC+NOx)
Alternative Three

Equipment Type	Lower Cost per Unit	Upper Cost per Unit	Lifetime Emission Reductions Per Unit (lbs.)	Lower C/E Ratio ($/lb.)	Upper C/E Ratio ($/lb.)
Evap, Mower (Incl. Testing)	$71.30	$154.82	13.79	$5.17	$10.03
Exhaust, Mower	$15.67	$22.37	3.14	$4.99	$7.12
Combined	$86.97	$160.67	16.93	**$5.14**	**$9.49**

Staff estimates that the cost to an equipment manufacturer would range from a low of $86.97 to a high as $160.67. The upper estimate of cost effectiveness is $9.49 per pound of HC+NOx reduced, which is two times higher than the cost effectiveness of staff's proposal. Staff rejected this alternative for the following reasons:

- It would have a significant impact on manufacturers by requiring a redesign of fuel just for California.
- It would provide two tons per day of additional HC reductions in 2010 at significantly greater costs.
- There are issues concerning propane distribution and availability.
- It may not be technically feasible for all engine applications.
- It is not the most cost-effective alternative.

6.5 Summary of Alternatives Evaluated

Table 6.5 summarizes the staff's evaluation of four alternatives to the proposal during the regulatory development process. Statewide 2010 and 2020 HC emissions are shown for comparison based on a phased-in implementation schedule beginning on January 1, 2007. It should be noted that the emissions presented in this comparison are in annual average tons per day and do not include preempt equipment.

Table 6.5
Emission Inventory Associated with the Alternative Strategies

Alternatives Evaluated	SCAB 2010 HC Emissions (TPD)	Statewide 2010 HC Emissions (TPD)	Statewide 2020 HC Emissions (TPD)	Comment
No Action	40.9	98.9	107.3	Violates Legal Settlement
Zero-Emission Residential Equipment	27.9	68.5	41.7	Implementation and Enforcement Problematic
Require Fuel Injection	33.0	79.5	61.1	Less Cost-Effective
Require LPG	32.8	78.9	59.5	Significant Impact on Manufacturers
Current Proposal	33.2	80.4	65.2	Most Cost-Effective Approach

7. ISSUES

In the development of this control measure, ARB staff has met with industry on numerous occasions to come up with standards and procedures that would ensure emission reductions and still meet the needs of industry. Throughout this process, industry has raised several points, many of which were integrated into this control measure. However, staff and industry remain divided on the best approach. Staff is continuing to meet with industry representatives to further discuss other items of concern. This section provides a summary of the items raised by industry and staff's proposed changes to this control measure.

7.1 Design-Based versus Performance-Based Standards

Staff's proposal requires testing to a performance-based standard to verify emission reductions are achieved. Industry believes a design-based standard is sufficient to ensure emission reductions and also reduce testing costs. Initially, as requested by industry, staff considered a design-based certification option for evaporative emissions. Conceptually, design-based certification would allow engine and equipment manufacturers to avoid the cost of performance-based certification testing for evaporative emissions by using approved components and technology. Manufacturers certifying by design would need to reference an ARB approved control technology in a certification application to gain approval to sell their equipment in California.

Staff's initial design-based proposal was presented to industry at a SORE workshop on November 13, 2002. The concept was based on suppliers of evaporative control equipment, such as tanks, lines, and pressure control systems, certifying the emission rates of new equipment with ARB. A manufacturer that selected equipment from the certified lists would not have to perform emission tests to gain certification of the assembled system. To assure emission reductions, staff proposed that ARB post production testing for compliance be based on performance, i.e. compliance with a specified emission limit. Industry did not embrace the approach, indicating any potential in-use liability measured against an emission limit would force them to perform pre-production certification emission testing, negating the benefits of the design-based approach.

Staff and industry continued to seek a design-based approach, which met both sides' needs. However, a consensus was not reached. Staff's proposal would require that the manufacturers be responsible for emission performance of the engine and emission control systems they produce. Also, the compliance procedures aimed at reducing compliance cost must incorporate liability based on emission performance. Furthermore, design-based certification requires significant resources to evaluate and approve components and technology. Certification of hundreds of components by ARB would require significant new resources. As a result, staff has proposed a performance (emission testing) based certification and compliance program. However, per industry's suggestion, staff has incorporated several provisions to reduce testing cost, including a small volume exemption and a provision for equipment manufacturers to use custom fuel tanks and lines that do not incur a new testing burden.

At the time this staff report was finalized, industry indicated it was making one more attempt to develop a design-based compliance program. Staff will evaluate any proposal made and share its evaluation with the Board during the September hearing on this proposed regulation.

7.2 Testing For Diurnal Performance Standards

Industry' is opposed to regulations that require engine or equipment manufacturers to conduct significant testing. Their concern has merit because there are considerable costs involved in building and operating SHEDs that might otherwise be spent on emission controls. The current proposal requires manufacturers of engines or equipment > 80 cc to conduct a durability demonstration and a SHED test to certify to diurnal performance standards. These requirements ensure that small off-road engines or equipment that use such engines meet applicable diurnal evaporative emission performance requirements prior to being offered for sale in California and throughout their useful life.

Industry's position is that SHED testing to determine evaporative emissions would be too onerous for equipment and engine manufacturers. The cost for an individual manufacturer to build and operate a SHED for seven years is estimated at 3.5 million dollars. Staff has also solicited work task pricing from contractors who conduct such testing. The absolute costs and resulting cost-effectiveness are deemed reasonable by staff as presented in this report.

Staff's proposal will require that engines or equipment undergo SHED emission tests in order to be certified. Industry has interpreted this requirement as forcing each engine manufacturer and each equipment manufacturer to build and maintain expensive SHED testing facilities. Although engine manufacturers will incur that expense, this is not likely for equipment manufacturers for three reasons:

1. Staff expects engine manufacturers will likely supply engines with complete fuel systems to equipment manufacturers for most equipment, thereby saving them testing costs.

2. In those cases where complete fuel systems are not provided, staff's proposal allows manufacturers to use "equivalent" fuel tanks and lines of their own design and exempts small volume manufacturers.

3. Equipment manufacturers can contract out for SHED testing on the few models of equipment they produce using their own evaporative emission control systems. Staff estimated reasonable costs for such situations at $2,500 per diurnal test.

7.3 Stringency of Diurnal Standards

Industry has three central concerns regarding the proposed diurnal standards. They are:

- Carburetor Emissions – Industry has asserted that staff has not accounted for the variability in carburetor emissions in the proposed diurnal standards.

- Unique Equipment Types - Industry has asserted that the proposed standards are too stringent for some current equipment configurations, especially those with large fuel tanks and long fuel lines.

- Rotationally Molded Tanks - Industry has also asserted that there are no technological options for controlling permeation from rotationally molded fuel tanks.

Regarding carburetor emissions, staff did not perform a specific study on carburetor variability. However, testing was conducted on mower engines whose evaporative emissions where controlled from all sources except the carburetor. The data indicates that typical Class I engines have carburetor emissions in the 0.5 to 0.7 gram/day range. Staff acknowledges that there are some carburetors that have higher emissions due to their design characteristics. Staff believes some carburetors may have to be vented to carbon canisters or air filters or redesigned to allow for sufficient compliance margin. Staff has amended the proposal presented at the July 2, 2003 workshop to allow manufacturers more time to make the necessary design changes.

With respect to unique equipment types, staff has amended the proposal to include a diurnal standard based on tank volume for Class I engines and equipment (excluding walk-behind mowers). The new Class I diurnal standard allows manufacturers additional compliance margin for unique equipment types.

Finally, regarding rotationally molded fuel tanks; staff believes that these tanks can be replaced with metal or coextruded multilayer tanks to meet the proposed diurnal standards at a reasonable cost-effectiveness level. Staff performed an emissions test on a large lawn tractor originally equipped with a rotationally molded fuel tank. When retrofitted with a metal tank and carbon canister system, the tractor met the proposed diurnal standard. The results of the study are included in this report.

To further address the stringency of the evaporative standard, and in particular the variability in emissions and uncertainty of designing a new emission control system, staff is proposing a compliance cushion for newly certified engine families. The cushion applies to testing of production engines, and thus addresses the anticipated production variability or higher emissions than projected. Enforcement action would not be taken unless the production testing exceeds 1.5 times the standard in the first year an engine family is certified, 1.3 times the standard in the second year, and finally 1.1 times the standard the third and subsequent years.

Additionally, staff is proposing sufficient lead times to allow manufacturers time to redesign fuel system components and minimize production variability to meet the stringent diurnal standards.

7.4 Enforcement and Liability

Industry wants clear lines of responsibilities for enforcement and liability between the engine and equipment manufacturers. The current proposal provides such clarity and contains two options for certifying evaporative emission control systems on engines or equipment.

- Option one allows an engine manufacturer to certify a complete evaporative emission control system installed on a small off-road engine.

- Option two allows the equipment manufacturer to certify a complete evaporative emission control system installed on equipment that uses a small off-road engine.

The first certification option is intended for engine manufacturers that provide an engine with complete evaporative emission control system to an equipment manufacturer.

Engine manufacturers are liable for the performance of the evaporative emission control system.

The second certification option is intended for equipment manufacturers providing their own complete evaporative emission control systems. Equipment manufacturers are liable for the performance of the evaporative emission control system.

Staff's proposal also allows an equipment manufacturer to modify a certified evaporative emission control system by using equivalent fuel tanks and/or fuel lines without affecting the system's certification. Equivalent fuel tanks and lines are defined in the proposed regulations and have similar permeation characteristics and are functionally equivalent to certified fuel tanks and lines.

Staff believes that the current proposal assigns liability to the responsible party and is enforceable.

7.5 Allowing a Small Volume Exemption

Industry has requested an exemption from the proposed evaporative regulations for small volume equipment manufacturers. Staff has included a small volume exemption in the proposal because it allows equipment manufacturers to produce specialty equipment without incurring significant fuel tank retooling costs. The selection of the small volume limit of 400 units per year was based on California sales data supplied by industry. The data indicated that most models of specialty equipment with common evaporative features have annual California sales of less than 400 units. Staff estimated the 2010 uncontrolled evaporative emissions from specialty equipment that will qualify for the exemption at 49 lbs./day. The proposal does not address industry cost concerns for manufacturers selling more than 400 units per year. However, setting a higher small volume limit would greatly reduce the emission reduction benefits of staff's proposal.

7.6 Implementation Date of Diurnal Standards for >80 cc Equipment

Industry is concerned that staff's current proposal does not allow sufficient time for implementation. Industry desires additional time to procure, test, and certify engines/equipment.

At the April 2002 public workshop, staff proposed an implementation schedule and requested comment on an appropriate phase-in. Industry responded that they need at least 18 months to develop and validate new designs in addition to the minimum six months necessary to test and certify control systems. At the July 2003 public workshop, some industry representatives stated that they wanted much longer lead times for meeting the standard on the order of eight years. After careful consideration, staff changed its proposal to include additional lead-time. The proposal now provides for a staged implementation over two years beginning in 2007. This change will allow industry 33 months to design, test, and certify Class I engines and an additional year for larger Class II engines. Since the technology to control evaporative emissions is readily available, staff believes the current proposed implementation dates are reasonable and still ensures the majority of 2010 emissions benefits in the original proposal are achieved.

7.7 Equipment with Large Fuel Tanks

Industry has expressed concern that they may not be able to meet the proposed 1.0 gram/day diurnal evaporative emission performance standard for engines >80 cc to <225 cc that use large fuel tanks, due to permeation emissions. Based on specific requests from industry, staff's current proposal now includes a sliding scale standard for Class I engines (excluding walk-behind mowers) based on tank volume. The change in staff's proposal provides an acceptable compliance margin for Class I engines with larger fuel tanks without requiring fuel tanks with near-zero permeation emissions. A sliding scale is not proposed for walk-behind mowers because they use small fuel tanks.

Industry has also indicated that they would prefer a sliding scale standard for Class II equipment with fuel tanks larger than 5 gallons. Staff believe the proposed 2 gram standard for all Class II equipment is technically feasible, and that a sliding scale standard for this Class is not needed.

7.8 Pressurized Fuel Tanks

Industry has expressed concern that the proposal's current fuel cap requirement for evaporative systems with sealed tanks will result in issues with pressurized tanks such as tank deformation and reduced impact resistance. Staff acknowledges that existing thin walled tanks, predominately found on Class I and Class II engines, are not designed to withstand pressure and would be permanently deformed if pressurized. However, handheld tanks and personal watercraft are designed to withstand pressure. Underwriter's Laboratories (UL) has published standards (UL 558) that require large industrial truck fuel tanks be vented at not more than 5.0 PSIG. Given adequate time, manufacturers could redesign their fuel tanks to withstand pressure. Another option would be for manufacturers to incorporate carbon canister technology into their systems that does not involve pressurizing the fuel tanks. In any event, the current proposal allows manufacturers sufficient time to redesign their fuel systems to withstand pressure if they choose to incorporate sealed tank technology.

To reduce safety concerns, staff's current proposal allows tanks to vent as long as they can pass the diurnal performance standard. Manufacturers maintain that allowing pressure relief may require them to design valves that open at 5 or 6 PSIG because most inexpensive valves begin to leak at pressures below their set cracking pressure. It is questionable whether manufacturers actually need a pressure relief valve because ARB tank testing under extreme (65 - 122°F) temperature profiles showed a maximum pressure increase of only 3.7 PSIG. The evaporative emission cost effectiveness estimates contained in this proposal assume either sealed systems with no relief for the lower limit or canister technology for the upper limit. If manufacturers feel they need a relief valve for safety reasons, the current proposal allows venting but there is no specific requirement that relief valves be incorporated into sealed tank systems.

7.9 Emissions Inventory

Under a grant from the U.S. EPA, staff conducted a survey of California households to determine the population and usage of lawn and garden equipment. Over 15,000 surveys were sent to randomly selected households. In addition, a subset of survey respondents also agreed to install instrumentation capable of electronically recording the date, time and duration of usage on their lawn and garden equipment.

As a result of this survey, the OFFROAD emissions inventory model has recently been updated with better estimates of lawn and garden equipment activity and population. The improved inventory increases the 2010 emissions from small engines by about 38 TPD for exhaust HC+NOx and 21 TPD for evaporative HC. The updated inventory has been incorporated into the baseline and emissions benefit estimates in this report.

Industry has raised concerns regarding staff's interpretation of the survey results in determining the small engine populations. In addition, industry has raised concerns with the current OFFROAD model emission factors for lawn and garden equipment and whether the emission factors incorporated in the model accurately represent the emissions of engines currently produced. Industry has promised to provide additional data. As a part of ongoing negotiations between industry and staff, staff has agreed to review it.

7.10 Addition of a Catalyst System to Engines > 80 cc

Although there are many types of small engine equipment with catalytic converters offered today (primarily on lawn mowers in Europe, and on handheld equipment in California), some manufacturers have expressed concerns regarding the use of catalytic converters on nonhandheld equipment. The concerns include increased heat management, packaging, and catalyst deactivation by poisoning.

7.10.1 External Heat Management

The main concern raised by manufacturers has been safety and increased temperatures resulting from incorporation of a catalyst. Oxidation of HC and CO is an exothermic reaction, and the heat it generates, along with possible enleanment of the air-fuel ratio to meet the proposed standards could lead to increased exhaust gas temperatures and catalyst/muffler skin temperatures. Manufacturers have raised the issue that some equipment requires locating the engine in a very small engine compartment, often subjected to high temperatures and flammable materials. For example, many current turf care equipment designs, such as those used in commercial turf mowers, do not have a lot of engine compartment room available for additional components. They are also subjected to grass clippings that can become packed around engine components. In such cases there is the potential danger of these materials igniting upon exposure to potentially high temperature exhaust components like manifolds and catalytic converters.

Manufacturers have noted potential for operator injury from burning, turf browning after engine shutoff in lawn care applications, fire during refueling, and melting of fuel tanks and other plastics incorporated in the equipment. While the American National Standards Institute (ANSI) temperature guidelines vary, the Outdoor Power Equipment Institute (OPEI) has specifically indicated that individual equipment manufacturers frequently prefer to adhere to heat exposure temperature limits in the range of 150°F. However, ARB in-house testing on two engines and SwRI testing on one Honda 161 cc engine showed existing muffler skin temperatures (i.e., without enleanment or catalysts) between 500 and 570 °F[6], far exceeding the OPEI preferred limits.

Regardless of whether OPEI's upper temperature range is a valid standard, staff acknowledges that these temperature issues are real and that manufacturers need to address these potential issues when developing a catalyst system to meet the proposed standards. But, as indicated by MECA and individual catalytic converter/muffler manufacturers, these issues are not insurmountable, and, as has been done with many handheld two-stroke engines with which many of these same issues existed, they can be adequately addressed in the design of the system. For instance, many of the temperature issues can be addressed by incorporating heat shields and/or catalyst insulation. Many manufacturers already currently protect engines with shields and other insulating material. One set of tests performed at SwRI with a catalyst equipped engine showed that the skin temperature of the catalyst shield was significantly lower than the surface of the catalyst/muffler, with an average reduction of 490 degrees Fahrenheit at 100 percent load. The temperatures observed on the catalyst shield were in the range of the temperatures observed during the ARB and SwRI testing on the stock mufflers (i.e., without a catalyst) noted above. Some manufacturers may choose to use a systems approach to designing an engine, first reducing the engine out emissions by such methods as optimizing the fuel system, or redesigning the cylinder and/or piston, before incorporating a catalytic converter. Any engine modifications made that result in reduced engine out emissions will reduce the burden on the catalyst, thereby allowing the manufacturer to use a less efficient catalyst to meet the proposed standards. The catalyst will then generate less heat since less pollutants will oxidized.

In summary, external heat management issues are not new. Every single engine that has been equipped with a catalytic converter, starting in 1975 when the device was first applied to passenger cars, has had to address the issue of increased exhaust system temperatures, and concerns with potential burns and fires. For instance, motorcycles and mopeds, which were claimed to be infeasible for catalytic devices because of the threat of operator burns, are now equipped with catalysts. Catalysts are also now appearing on some lawn and garden handheld equipment, despite the concerns raised by industry about fires and operator safety. The engineering techniques to deal with these hot surfaces also continue to progress, but they are straightforward - reduce the

6 The addition of a catalyst with passive air injection raised the muffler skin temperature on the Honda engine from an average of 570°F, to an average of 685°F (at 100 percent load).

heat load, insolate the heat source, isolate the heat source, and actively cool. Staff is certain that the engine/equipment manufacturers will be able to address the problem of hot surfaces using similar approaches to others who have faced the same problems over the last 28 years.

7.10.2 Internal Engine Heat Management

Enleanment of the air-fuel ratio could result in additional heat stress to an engine. Enleanment can increase engine temperatures, which could cause warping or distortion in the cylinder, resulting in valve or cylinder leakage and incomplete combustion or engine deterioration. Heat radiating from a catalytic muffler could also affect an engine. *To offset additional engine temperatures, manufacturers may choose to derate the* engine. Other methods to decrease the engine temperatures would be to increase the number or size of cooling fins, or increase the cooling airflow. The SwRI testing shows that not all engines will need to be enleaned to meet the proposed exhaust emission standards, so there are cases where no additional engine cooling will be needed. Conversely, if an engine requires enleanment and also already has marginal cooling, some engine redesign may be necessary.

7.10.3 Packaging

Industry is concerned that changes to equipment designs may be required to accommodate engines with catalysts. While staff believes that many current engine designs are amenable to the incorporation of a catalyst into existing engine/muffler designs with minimal changes, staff acknowledges that some engines and equipment may require some redesign to meet the proposed emission standards. Staff modified its original proposed implementation schedule to include additional lead-time for manufacturers. The proposal now provides for a staged implementation over two years beginning in 2007. The proposed implementation schedule was designed to allow additional time for manufacturers to address any necessary changes to engines and equipment.

7.10.4 Poisoning

Catalyst poisoning is primarily related to engine oil passing the engine's piston rings and valve guide seals and entering the exhaust stream, resulting in catalyst site deactivation. Additives in the oil, such as phosphorus and zinc, coat the catalyst, reducing its activity. The extent of the problem depends upon overall oil consumption. One of the major contributors to oil consumption is cylinder bore distortion when the engine is hot. This problem is more severe with side-valve engines than with overhead-valve engines because a side-valve engine's exhaust port is adjacent to the cylinder and more difficult to cool. The industry trend toward overhead-valve engines has helped alleviate problems associated with oil consumption. Other approaches include tighter manufacturing tolerances and the use of improved seals, which limit the oil available to the valve guides. Briggs & Stratton stated that some of their newer engines have reduced oil consumption upwards of 80% compared to previous models.

Catalyst manufacturers are aware of the effects of lubrication oil contamination and have designed catalysts that resist it for other applications. MECA estimates that more than 15 million motorcycles and mopeds worldwide have been equipped with catalysts, with a majority of these units being powered by two-stroke engines. In addition, many two-stroke engines equipped with catalysts have been certified to California's current exhaust emission standards. These two-stroke engines burn lubricating oil that has been mixed with the fuel; hence, the concentrations of oil contaminants in the exhaust are significantly higher than typical automotive (or lawnmower) exhaust. In addition, MECA has stated that catalyst manufacturers continue to research methods to reduce lube oil poisoning in four-stroke automobile applications as automobile standards begin to reach very low levels.

7.11 Catalyst Disposal

Because the proposed Tier 3 emissions standards for nonhandheld equipment are catalyst-based standards, the rate of spent catalyst disposal is expected to increase in California. This means increased impacts on solid waste disposal facilities. According to the highest sales record from the past five years, approximately one million units of nonhandheld equipment were sold in California each year. If that sales number remains unchanged, there would be one million used catalytic converters disposed of annually by the year 2015 based on an assumption of six to nine years average useful life of nonhandheld equipment.

Ideally, used catalysts will be diverted from solid waste facilities and recycled. If not recycled, spent catalysts may simply be sent to solid waste disposal facilities where heavy metals from the catalysts have the potential to add to soil contamination, and localized groundwater contamination. Although recycling of spent catalysts will produce air emissions, wastewater and solid waste; these tightly-regulated impacts are preferable to the uncontrolled disposal of spent catalysts. At this time, there are many facilities in the United States capable of recycling automotive catalytic converters and the average market price is around five dollars for each converter. With recycling facilities and technologies already in place, it should be relatively easy to encourage expanding recycling programs to include small engines.

Currently, most catalyst vendors have their own precious platinum group metals (PGM) recovery program. Global growth in PGM recovery is a future trend because of the increased use of catalysts in cars, heavy-duty vehicles, motorcycles and off-road equipment, and also the increasing cost of PGM. To ensure a minimal impact of catalysts, the staff will work with the Department of Toxic Substances Control, the Integrated Waste Management Board, and the Office of Environmental Health Hazard Assessment to assure that the maximum feasible degree of recycling occurs.

7.12 Potential Changes to the Federal Handheld Small Engine Rule

To ease the burden of certifying engine families with multiple units to both the federal and California emission standards staff has made every effort to harmonize State and federal exhaust emissions requirements. The U.S. EPA's Final Rulemaking for handheld engines was published on April 25 2002. Staff's proposal attempts to align with the federal handheld standards and test procedures adopted where feasible and justifiable.

On February 20, 2003 OPEI formally petitioned the U.S. EPA requesting changes to the federal handheld regulations. OPEI requested three specific changes, discussed below.

The current federal regulations include a phase-in of the Phase 2 emissions standards for handheld engines over 50 cc over the 2004 - 2007 model year. OPEI has requested a one year delay of the phase-in, to 2005 - 2008.

The current federal regulations include two programs for the averaging, banking and trading of certification credits. Prior to 2005, California's standards are more stringent than U.S. EPA's, and manufacturers are allowed to generate credits at full value if an engine family is certified to below California's emission standard, or, if not below California's emission standard, at a discounted rate. OPEI has requested that U.S. EPA adjust the banking program to allow for credits to be banked, without discounting, for engines certifying to below the federal standard.

In addition, OPEI has requested that the federal regulations include a production line testing credit program similar to California's program.

The U.S. EPA is currently reviewing the OPEI petition. OPEI's requested changes to the federal handheld regulations should not impact California's harmonization with the federal handheld regulations as outlined in this proposal. California's current emission standards for engines above 50 cc are already equal to the most stringent federal Phase 2 emission standards for these same engines. Credits generated and banked federally are not available for use in California's certification program. The production line testing credit program OPEI has requested is already established in California's regulations.

8. CONCLUSIONS AND RECOMMENDATIONS

In developing the proposed regulations for small engines, staff's goal has been to achieve the greatest possible emissions reductions in a technologically feasible and cost effective manner. The proposed performance standards for small off-road engines are achievable using existing technologies and manufacturing processes. The emissions reductions are cost effective when compared to recent control measures adopted by the Board. The proposed regulations are necessary to meet air quality emissions reduction goals and to achieve health based ambient air quality standards.

No alternatives considered by the Board would be more effective in achieving the purpose for which the regulations are proposed or would be as effective or less burdensome to affected private persons than the proposed regulations.

The staff recommends that the Board approve its proposal to amend sections 2400 to 2409, Title 13, California Code of Regulations, and the incorporated "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," and adopt "California Exhaust Emission Standards and Test Procedures for 2005 and Later Small Off-Road Engines," and adopt sections 2750 to 2773, Title 13, California Code of Regulations, and Test Methods 901 and 902 and Certification Procedures CP-901 and CP-902 incorporated by reference therein, as provided in appendices A - E of this Staff Report.

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APPENDIX A: PROPOSED AMENDMENTS TO THE EXHAUST EMISSION REGULATIONS

Proposed Regulation Order

Note: This document is printed in a style to indicate changes from the existing provisions. All existing language is indicated by plain type. All additions to language are indicated by underlined text. All deletions to language are indicated by ~~strikeout~~. Only those sections with proposed changes are included. Sections 2402 and 2406 remain unchanged.

Amend Article 1, Chapter 9, Division 3, Title 13, California Code of Regulations, to read as follows:

Chapter 9. Off-Road Vehicles and Engines Pollution Control Devices

Article 1. Small Off-Road Engines

§ 2400. Applicability.

(a) (1) This article applies to small off-road engines ~~(below 25 horsepower)~~ produced on or after January 1, 1995 and any equipment produced on or after January 1, 1995 that uses such engines.

(2) Every new small off-road engine that is manufactured for sale, sold, or offered for sale in California, or that is introduced, delivered or imported into California for introduction into commerce, and that is subject to any of the standards prescribed in this article must be covered by an Executive Order, issued pursuant to this article.

(3) This article does not apply to compression-ignition engines, as defined in Section 2421, below 25 horsepower, produced during the 2000 and later model years or any equipment that uses such engines produced during the 2000 and later model years.

(b) Each part of this article is severable, and in the event that any part of this article is held to be invalid, the remainder of this article remains in full force and effect.

(c) (1) For purposes of this article, military tactical vehicles or equipment means vehicles or equipment owned by the U.S. Department of Defense and/or the U.S. military services and used in combat, combat support, combat service support, tactical or relief operations, or training for such operations.

(2) This article shall not apply to engines used in off-road military tactical vehicles or equipment which have been exempted from regulations under the federal national security exemption, 40 CFR, subpart J, section 90.908. It shall also not apply to those vehicles and equipment covered by the definition of

military tactical vehicle that are commercially available and for which a federal certificate of conformity has been issued under 40 CFR Part 90, subpart B.

(3) On January 1, 1997, the U.S. Department of Defense shall submit to the ARB a list of all vehicle and equipment types that are exempted under the above provisions and which are located in the State of California. If any additional vehicle and equipment types are added to the list during the previous 12 months, the U.S. Department of Defense shall update the list and submit it to the ARB by January 1 of the following year.

NOTE: Information regarding authorization to adopt regulations that are included in this chapter for nonpreempted nonroad vehicles or engines pursuant to section 209(e) of the federal Clean Air Act (42 U.S.C. 7543(e)) may be obtained from the Air Resources Board at 9528 Telstar Avenue, El Monte, California 91731.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2401. Definitions.

(a) The definitions in Section 1900 (b), Chapter 1, Title 13 of the California Code of Regulations, apply with the following additions:

(1) "ARB Enforcement Officer" means any officer or employee of the Air Resources Board so designated in writing by the Executive Officer or by the Executive Officer's designee.

(2) "Assembly-~~L~~line ~~T~~tests" are those tests or inspections that are performed on or at the end of the assembly-line.

(3) "Averaging" means the exchange of emission credits among engine families within a given manufacturer's product line.

(4) "Banking" means the retention of small off-road engine emission credits by the manufacturer generating the emission credits for use in future model year averaging or trading as permitted by these regulations.

(5) "Basic ~~E~~engine" means an engine manufacturer's unique combination of engine displacement, number of cylinders, fuel system, emission control system and other engine and emission control system characteristics specified by the Executive Officer.

(6) "Calendar ~~Y~~year" is the twelve month period commencing on January 1 through December 31.

(7) "Certification ~~E~~emission ~~R~~reduction ~~C~~credits" means the amount of emission reduction or exceedance, by an engine family, below or above the applicable $HC+NO_x$ (or $NMHC+NO_x$, as applicable) or Particulate Matter emission standard, respectively. Family emission levels (FEL) below the standard create "positive credits," while FELs above the standard create "negative credits." Some or all of these credits may be revoked if the Executive Officer's review of the end-of-year reports or any subsequent audit action(s) reveals problems or errors of any nature with credit computations.

(A) "Projected credits" refer to emission credits based on the projected applicable production/sales volume of the engine family.

(B) "Reserved credits" are emission credits generated within a model year available for reporting to the Executive Officer at the end of the model year.

(C) "Actual credits" refer to emission credits based on California's share, determined by market analysis, of actual federal production/sales volume as contained in the end-of-year reports submitted to the Executive Officer.

(8) "Certification value" means the product of the measured emissions of the prototype engine at zero hours and the (calculated or assigned) deterioration factor.

(9) "Blue Sky Series engine" means a small off-road engine meeting the requirements of Section 2403(b)(2)(A).

~~(9)~~(10) "Complete ~~E~~engine ~~A~~assembly" or "Engine ~~C~~configuration" means an assembly of a basic engine and all of the specific applicable components (e.g., air inlet, fuel and exhaust systems, etc.) and calibrations (e.g., carburetor jet size, valve timing, etc.) required for the assembly to be installed into a new unit of equipment.

~~(10)~~(11) "Crankcase ~~E~~emissions" means airborne substances emitted into the atmosphere from any portion of the engine crankcase ventilation or lubrication system.

~~(11)~~(12) "Deterioration factor" means the calculated or assigned number that represents the certification engine's emissions change over the durability period. It is multiplied by zero hour (new) engine test results to determine the engine family compliance level. The deterioration factor is determined as per Part II, Section 3 of the 1995-2004 Test Procedures and Subpart B, Section 90.104 of the 2005 and Later Test Procedures. See "Emissions ~~D~~durability ~~P~~period," below.

~~(12)~~(13) "Emission ~~C~~control ~~S~~system" includes any component, group of components, or engine modification that controls or causes the reduction of substances emitted from an engine.

~~(13)~~(14) "Emissions ~~D~~durability ~~P~~period" is the period that represents an engine's useful life. The emissions durability period is selected from the choices listed in Part II, Section 1 of the 1995-2004 Test Procedures and Subpart B, Section 90.104 of the 2005 and Later Test Procedures. The durability periods are also noted in the table in section 2403 (b). The emissions durability period is used to determine an engine family's deterioration factors and in the calculation of certification and production emission reduction credits.

~~(14)~~(15) "Emissions durability values" means emissions from an engine that has accumulated service equivalent to that engine's emissions durability period, or the result of the product of the zero hour (new) engine test results and the appropriate deterioration factor (e.g., the certification values). The Executive Officer must approve the methods of service accumulation before the manufacturer begins service accumulation.

(16) "Emission-related defect" means a defect in design, materials, or workmanship in a device, system, or assembly described in the approved

application for certification which affects any applicable parameter, specification, or component enumerated in Appendix A to Article 2.1, Chapter 2, Division 3, Title 13, California Code of Regulations or listed in the Emission Warranty Parts List pursuant to section 2405(d).

~~(15)~~(17) "End of ~~A~~assembly~~-L~~line" is defined as that place where the final inspection test or production line test is performed.

~~(16)~~(18) "Engine ~~F~~family" is a subclass of a basic engine based on similar emission characteristics. The engine family is the grouping of engines that is used for the purposes of certification.

~~(17)~~(19) "Engine ~~F~~family ~~N~~name" means a multi-character alphanumeric sequence that represents certain specific and general information about an engine family.

~~(18)~~(20) "Engine ~~M~~manufacturer" means the manufacturer granted certification.

~~(19)~~(21) "Exhaust ~~E~~emissions" means substances emitted into the atmosphere from any opening downstream from the exhaust port of an engine.

~~(20)~~(22) "Extreme nonattainment area" means any area classified as an extreme ozone nonattainment area by the U.S. Environmental Protection Agency pursuant to Section 181(a) of the Clean Air Act, as amended, including Orange County and the portions of Los Angeles, San Bernardino and Riverside Counties described as extreme ozone nonattainment areas in Title 40, section 81.305 of the Code of Federal Regulations.

~~(21)~~(23) "Family emission level" or "FEL" means an emission level that is declared by the manufacturer to serve for the averaging, banking, and trading program and in lieu of an emission standard for certification. The FEL serves as the engine family's emission standard for emissions compliance efforts. If the manufacturer does not declare an FEL for an engine family, the applicable emissions standard must be treated as that engine family's FEL for the purposes of any provision of this Article.

~~(22)~~(24) "Final ~~C~~calendar ~~Q~~quarter ~~P~~production" is defined as the calendar quarter in which the production of an engine family ends.

~~(23)~~(25) "First ~~C~~calendar ~~Q~~quarter ~~P~~production" is defined as the calendar quarter in which the production of an engine family begins.

~~(24)~~(26) "Fuel ~~S~~system" means the combination of any of the following components: fuel tank, fuel pump, fuel lines, oil injection metering system, carburetor or fuel injection components, or all fuel system vents

~~(25)~~(27) "Gross ~~E~~engine ~~M~~malfunction" is defined as one yielding an emission value greater than the sum of the mean plus three (3) times the standard deviation. This definition shall apply only for determination of control limits.

~~(26)~~(28) "Horizontal-shaft engine" means any engine that is designed to operate with the axis of the crankshaft in a horizontal position.

~~(27)~~(29) "Incomplete ~~E~~engine ~~A~~assembly" means a basic engine assembly that does not include all of the components necessary for designation as a complete engine assembly, and is marketed in order to be a part of, and assembled into, a new unit of equipment that is marketed to ultimate purchasers.

~~(28)~~(30) "Model year" means the manufacturer's annual production period that includes January 1 of a calendar year or, if the manufacturer has no annual production period, the calendar year.

~~(29)~~(31) "Off-~~R~~road ~~V~~vehicle" or "Off-road equipment" means any non-stationary device, powered by an internal combustion engine or motor, used primarily off the highways to propel, move, or draw persons or property including any device propelled, moved, or drawn exclusively by human power, and used in, but not limited to, any of the following applications: Marine Vessels, Construction/Farm Equipment, Locomotives, Small Off-Road Engines, Off-Road Motorcycles, and Off-Highway Recreational Vehicles.

~~(30)~~(32) "Point of first retail sale" means the point that the engine is first sold directly to the ultimate purchaser. Generally, this point is the retail engine or equipment dealer. If the engine is sold first to an equipment manufacturer for installation in a piece of equipment, the equipment manufacturer is the point of first retail sale if the equipment manufacturer cannot demonstrate to a reasonable certainty that the engine will be exported or destined for retail sale outside California.

~~(31)~~(33) "Production ~~E~~emission ~~R~~reduction ~~C~~credits" means the amount of emission reduction or exceedance by an engine family below or above, respectively, the applicable FEL to which the engine family is certified. Emission reductions below the standard are considered "positive credits," while emission exceedances above the standard are considered "negative or required credits." (See Section 2409.)

~~(32)~~(34) "Production ~~L~~line ~~T~~test" is defined as the emissions test performed on a sample of production engines produced for sale in California and conducted according to the Emissions Standards and Test Procedures specified in Section 2403(b) and (~~c~~d).

~~(33)~~(35) "Sales" or "Eligible sales" means the actual or calculated sales of an engine family in California for the purposes of averaging, banking or trading. Upon Executive Officer approval, an engine manufacturer may calculate its eligible sales through market analysis of actual federal production or sales volume. Actual sales are sales calculated at the end of a model year based on that model year's production, rather than on estimates of production.

~~(34)~~(36) "Scheduled ~~M~~maintenance" means any adjustment, repair, removal, disassembly, cleaning, or replacement of components or systems required by the engine manufacturer that is performed on a periodic basis to prevent part failure or equipment or engine malfunction, or anticipated as necessary to correct an overt indication of malfunction or failure for which periodic maintenance is not appropriate.

~~(35)~~(37) "Small off-road engine" means any engine that produces a gross horsepower less than 25 horsepower (at or below19 kilowatts for 2005 and later model year), or is designed (e.g., through fuel feed, valve timing, etc.) to produce less than 25 horsepower (at or below19 kilowatts for 2005 and later model year), that is not used to propel a licensed on-road motor vehicle, an off-road motorcycle, an all-terrain vehicle, a marine vessel, a snowmobile, a model airplane, a model car, or a model boat. If an engine family has models below 25 horsepower (at or below 19 kilowatts) and models at or above 25 horsepower (above 19 kilowatts), only the models under 25 horsepower (at or below 19 kilowatts) would be considered small off-road engines. Uses for small off-road engines include, but are not limited to, applications such as lawn mowers, weed trimmers, chain saws, golf carts, specialty vehicles, generators and pumps. All engines and equipment that fall within the scope of the preemption of Section 209(e)(1)(A) of the Federal Clean Air Act, as amended, and as defined by regulation of the Environmental Protection Agency, are specifically not included within this category. Any compression-ignition engine, as defined in Section 2421, produced during the 2000 and later model years shall not be defined as a small off-road engine.

~~(36)~~(38) "Third-~~P~~party ~~D~~distributor" is a party that is not an engine or equipment manufacturer, and that engages in wholesale or retail sales of complete or incomplete small off-road engine assemblies.

~~(37)~~(39) "Trading" means the exchange of small off-road engine emission credits between manufacturers.

~~(38)~~(40) "Ultimate ~~P~~purchaser" means the first person who in good faith purchases a new small off-road engine or equipment using such an engine for purposes other than resale.

~~(39)~~(41) "Unscheduled ~~M~~maintenance" means any inspection, adjustment, repair, removal, disassembly, cleaning, or replacement of components or systems that is performed to correct or diagnose a part failure that was not anticipated.

~~(40)~~(42) "Vertical-shaft engine" means any engine that is designed to operate with the axis of the crankshaft in a vertical position.

~~(41)~~(43) "Warrantable ~~C~~condition" means any condition of an engine that requires the manufacturer to take corrective action pursuant to Section 2405.

~~(42)~~(44) "Warranted ~~P~~part" any emissions-related part installed on an engine by the equipment or engine manufacturer, or installed in a warranty repair, that is listed on the warranty parts list.

~~(43)~~(45) "Warranty period" means the period of time that the engine or part is covered by the warranty provisions.

~~(44)~~(46) "Warranty station" means a service facility authorized by the equipment or engine manufacturer to perform warranty repairs. This includes all manufacturer distribution centers that are franchised to service the subject equipment or engines.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 45205.5 and 43210-43212, Health and Safety Code.

§ 2403. Exhaust Emission Standards and Test Procedures – Small Off-Road Engines.

(a) This section applies to small off-road engines produced on or after January 1, 1995.

(b) (1) Exhaust emissions from small off-road engines manufactured for sale, sold, or offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce, must not exceed:

Exhaust Emission Standards
grams per brake horsepower-hour
[grams per kilowatt-hour]

Calendar Year	Engine Class[1]	Hydrocarbon plus Oxides of Nitrogen[2]	Hydrocarbon[2]	Carbon Monoxide	Oxides of Nitrogen	Particulate
1995	I	12.0	—	300	—	0.9[3]
	II	10.0	—	300	—	0.9[3]
	III[4]	—	220	600	4.0	—
	IV[4]	—	180	600	4.0	—
	V[4]	—	120	300	4.0	—
1996 to1999	I	12.0[5]	—	350	—	0.9[3]
	II	10.0[5]	—	350	—	0.9[3]
	III[4]	—	220[5]	600	4.0[5]	—
	IV[4]	—	180[5]	600	4.0[5]	—
	V[4]	—	120[5]	300	4.0[5]	—

Exhaust Emission Standards for Spark-Ignition Engines
grams per brake horsepower-hour
[grams per kilowatt-hour]

Model Year	Engine Class~~[4]~~	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen[2]	Carbon Monoxide	Particulate
2000-2001[5]	~~SI~~	50/125/300	54	400	1.5[4]
	0-65 cc, inclusive		[72]	[536]	[2.0]
	~~SI~~	NA	12.0	350	
	>65 cc - <225 cc		[16.1]	[467]	
	~~SI~~	NA	10.0	350	
	≥225 cc		[13.4]	[467]	
2002-200~~5~~4[5]	~~SI~~	50/125/300	54	400	1.5[4]
	0-65 cc, inclusive		[72]	[536]	[2.0]
	~~SI~~ >65 cc - <225 cc	125/250/500	12.0	410	
	Horizontal-Shaft Engine		[16.1]	[549]	
	~~SI~~ >65 cc - <225 cc	NA	12.0	350	
	Vertical-Shaft Engine		[16.1]	[467]	
	~~SI~~	125/250/500	9.0	410	
	≥225 cc		[12.0]	[549]	
~~2006 and~~	~~SI~~	~~50/125/300~~	~~54~~	~~400~~	~~1.5[4]~~
	~~0-65 cc, inclusive~~		~~[72]~~	~~[536]~~	~~[2.0]~~
~~subsequent[5]~~	~~SI~~	~~125/250/500~~	~~12.0~~	~~410~~	
	~~>65 cc - <225 cc~~		~~[16.1]~~	~~[549]~~	
	~~SI~~	~~125/250/500~~	~~9.0~~	~~410~~	
	~~≥ 225 cc~~		~~[12]~~	~~[549]~~	

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Exhaust Emission Standards for Spark-Ignition Engines
grams per kilowatt-hour

Model Year	Displacement Category	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen[2][6]	Carbon Monoxide	Particulate
2005 and subsequent	<50 cc	50/125/300	50	536	2.0[4]
	50-80 cc, inclusive	50/125/300	72	536	2.0[4]
2005	>80 cc - <225 cc Horizontal-shaft Engine	125/250/500	16.1	549	
	>80 cc - <225 cc Vertical-shaft Engine	NA	16.1	467	
	≥225 cc	125/250/500	12.1	549	
2006	80 cc - <225 cc	125/250/500	16.1	549	
	≥ 225 cc	125/250/500	12.1	549	
2007	>80 cc - <225 cc	125/250/500	8.0	549	
	≥ 225 cc	125/250/500	12.1	549	
2008 and subsequent	>80 cc - <225 cc	125/250/500	8.0	549	
	≥ 225 cc	125/250/500/1000	6.0	549	

(1) "Class I" means small off-road engines greater than 65 cc to less than 225 cc in displacement.

"Class II" means small off-road engines greater than or equal to 225 cc in displacement.

"Class III" means small off-road engines less than 20 cc in displacement.

"Class IV" means small off-road engines 20 cc to less than 50 cc in displacement.

"Class V" means small off-road engines greater than or equal to 50 cc to 65 cc in displacement.

(2) The Executive Officer may allow gaseous-fueled (i.e., propane, natural gas) engine families, that satisfy the requirements of the regulations, to certify to either the hydrocarbon plus oxides of nitrogen or hydrocarbon emission standard, as applicable, on the basis of the non-methane hydrocarbon (NMHC) portion of the total hydrocarbon emissions.

(3) Applicable to all diesel-cycle engines.

(4) Applicable to all two-stroke engines.

(5) Engines used exclusively in snowthrowers and ice augers need not certify to or comply with the HC and NO_x standards or the crankcase requirements at the option of the manufacturer.

(6) Engines used exclusively to power products which are used exclusively in wintertime, such as snowthrowers and ice augers, at the option of the engine manufacturer, need not certify to or comply with standards regulating emissions of HC+NO_x or NMHC+NO_x, as applicable. If the manufacturer exercises the option to certify to standards regulating such emissions, such engines must meet such standards. If the engine is to be used in any equipment or vehicle other than an exclusively wintertime product such as a snowthrower or ice auger, it must be certified to the applicable standard regulating emissions of HC+NO_x or NMHC+NO_x as applicable.

(2) Low-emitting Blue Sky Series engine requirements.

(A) *Voluntary standards.* Engines may be designated "Blue Sky Series" engines by meeting the following voluntary exhaust emission standards, which apply to all certification and compliance testing. Blue Sky Series engines shall not be included in the averaging, banking, and trading program.

Voluntary Emission Standards
(grams per kilowatt-hour)

Model Year	Displacement Category	Hydrocarbon plus Oxides of Nitrogen	Carbon Monoxide	Particulate*
2005 and subsequent	≤50 cc	25	536	2.0
	50 - 80 cc, inclusive	36	536	2.0
2007 and subsequent	>80 cc - <225 cc	4.0	549	
2008 and subsequent	≥225 cc	3.0	549	

* Applicable to all two-stroke engines

(B) *Additional standards.* Blue Sky Series engines are subject to all provisions that would otherwise apply under this part.

(3) Evaporative emission requirements for small off-road engines are specified in Title 13, Chapter 9, Article 8.

(c) (1) For the 2000 through 2006 model years, ~~M~~manufacturers of small spark-ignited off-road engines between 65 and 225 cc displacement that are manufactured for sale, offered for sale, or sold in any extreme non-attainment area, or introduced, delivered or imported into any such extreme non-attainment area for sale to an ultimate purchaser in an extreme non-attainment area, and that are produced by manufacturers who produce more than 40,000 engines per year between 65 and 225 cc for sale in such areas (based on data for engines produced for sale in such areas in model year 1998), must meet the additional requirements of this subsection and achieve the additional emission reductions in subparagraph (3).

(2) No later than May 1, 1999, each manufacturer subject to this subsection shall submit a plan to achieve additional emission reductions. The plan shall include the following:

(A) An identification of the specific measures from subparagraph (4) that the manufacturer intends to implement in the extreme nonattainment areas, including but not limited to identification of engine families that in model years 2000 and 2001 will meet the exhaust emissions reduction requirements of subsection (b) for 2002 and subsequent model years prior to required implementation, and the projected sales volumes of such engine families in the extreme nonattainment areas;

(B) Data documenting the emissions performance of engines included in the plan when operated on fuels meeting the requirements of Chapter 5, Article 1, subarticle 2 of this Title applicable in the extreme nonattainment areas; and

(C) A description of the provisions made by the manufacturer to assure that all engines offered for sale or sold in the extreme nonattainment areas (or introduced, delivered or imported into the extreme nonattainment areas for sale to an ultimate purchaser in that area) will meet the requirements of the plan, including but not limited to a description of the methods to be used to determine actual sales of engines in the extreme nonattainment areas; provided, that in the case of manufacturers that maintain data on actual or projected Statewide engine sales, the Executive Officer may approve provisions that demonstrate compliance with the plan on a Statewide basis.

(3) The plans submitted under this subsection shall in the aggregate provide for emissions reductions and controls by or from the group of engines produced by the submitting manufacturers that are equal to or greater than the difference between: 1) reductions that would have been achieved in the extreme nonattainment areas in calendar years 2000, 2001, 2005 and 2010 by all manufacturers of engines greater than 65 cc displacement that would have met the emissions reduction requirements proposed in the staff report contained in Mail-Out MSC-98-02 released February 6, 1998; and 2) those same engines meeting the requirements of subsection (b). The Executive Officer shall determine whether a plan meets this requirement based on the estimated model year 1998 sales in the extreme nonattainment areas available at time of plan submission by manufacturers covered by this subsection, and using a proportional allocation between such manufacturers based upon such estimated sales.

(4) The manufacturer's plan shall achieve additional emission reductions or controls through one or more of the following measures:

(A) The certification and introduction of engines greater than 65 cc meeting the standards in subsection (b) before the applicable model year;

(B) The voluntary certification of engines not subject to emission reductions requirements of the ARB due to preemption under section 222 of U.S. Public Law No. 101-549. A manufacturer choosing voluntarily to certify an engine shall also certify that it will honor all compliance and warranty requirements set forth in the provisions of this Title for that engine;

(C) The certification of engines to Family Emission Levels below the standards in subsection (b), or of engines that otherwise generate emissions credits under section 2408 of this Article and that are not used for any other purpose;

(D) The certification of engines to useful life periods longer than the maximum requirements set forth in subsection (b);

(E) The introduction of engines that achieve in-use reductions in engine evaporative emissions demonstrated by procedures acceptable to the Executive Officer;

(F) The use of emission credits generated by the manufacturer pursuant to section 2409 of this Article and that are not used for any other purpose; and

(G) Other measures approved in advance by the Executive Officer.

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(5) The plan shall also demonstrate that at least 60 percent of engines greater than 65 cc sold in extreme nonattainment areas comply in model years 2000 and 2001 with the standards in subsection (b) applicable to the 2006 model year. The percentage shall be calculated based on the total projected sales by all manufacturers of engines greater than 65 cc in the extreme nonattainment areas in those model years, and shall be proportionally allocated between the manufacturers subject to this subsection.

(6) The provisions of this subsection are not applicable to engines offered for sale or sold outside an extreme nonattainment area, or introduced, delivered or imported into an extreme nonattainment area for sale to an ultimate purchaser outside an extreme nonattainment area.

(7) The Executive Officer shall determine if a plan timely submitted under this subsection meets the requirements of this subsection no later than June 1, 1999. The Executive Officer shall not issue any executive orders for individual engine families subject to the plan until the plan is approved. The manufacturer shall submit annual reports to the Executive Officer demonstrating compliance with the plan approved by the Executive Office and may, at its discretion, propose revisions to its plan on an annual basis. If, on the basis of information contained in a manufacturer's annual report or any other information, the Executive Officer finds that the manufacturer is not in compliance with an approved plan, the Executive Officer may direct the manufacturer to submit a revised plan; provided, that no such revision shall be required solely as a result of gain or loss in market share in the extreme nonattainment areas during the period while this subsection remains in effect. The Executive Officer shall act upon any proposed revision of a plan within 30 days of receipt. Pending approval of a revised plan, the Executive Officer shall not issue any Executive Orders for individual engine families subject to the revised plan. These actions of the Executive Officer are in addition to any remedies available under this Article or Part 5 of Division 26 of the Health & Safety Code.

(d) The test procedures for determining compliance with the standards for exhaust emissions from new small off-road engines are set forth in "California Exhaust Emission Standards and Test Procedures for 1995-2004 ~~and Later~~ Small Off-Road Engines", adopted March 20, 1992, and last amended ~~January 28, 2000,~~ __________ or "California Exhaust Emission Standards and Test Procedures for 2005 and Later Small Off-Road Engines," adopted __________, as applicable, which is incorporated herein by reference.

(e) Averaging. For new 2000 and subsequent model year small off-road engines, a manufacturer may comply with the standards established in paragraph (b), above, by choosing either to certify an engine family to the standards or to use the corporate average described below.

(1) For each model year, the corporate average value for a pollutant is defined by the following equation:

$$\frac{\sum_{j=1}^{n}(\mathrm{FEL}_j)(\mathrm{Sales}_j)(\cancel{\mathrm{HP}_j}\,\underline{\mathrm{Power}_j})(\mathrm{Load\ Factor})(\mathrm{EDP}_j)-\text{credits expended}}{\sum_{j=1}^{n}(\mathrm{Sales}_j)(\cancel{\mathrm{HP}_j}\,\underline{\mathrm{Power}_j})(\mathrm{Load\ Factor})(\mathrm{EDP}_j)}=\mathrm{AVG}$$

where

n = the number of small off-road engine families.

FEL = the Family emission level for an engine family.

$Sales_j$ = eligible sales of engine family j.

~~HP_j~~ $Power_j$ = sales-weighted maximum modal power, in horsepower or kilowatt as applicable, of engine family j, or an alternative approved by the Executive Officer.

EDP_j = Emissions durability period of engine family j.

AVG = For a given pollutant ($HC+NO_x$, CO, or Particulate Matter), a manufacturer's corporate average of the exhaust emissions from those California small off-road engines subject to the California corporate average pollutant exhaust emission standard, as established by an Executive Order certifying the California production for the model year. Engines certified to voluntary standards of 2403 (b)(2) are not eligible for corporate averaging.

Credits expended = $HC+NO_x$ or Particulate Matter credits, as defined in sections 2408 and 2409, that are expended by the manufacturer to adjust the corporate average. This term has no meaning for any pollutants other than $HC+NO_x$ and Particulate Matter.

Load Factor = For Test Cycle A and Test Cycle B, the Load Factor = 47% (i.e., 0.47). For Test Cycle C, the Load Factor = 85% (i.e., 0.85). For approved alternate test procedures, the load factor must be calculated according to the Load Factor formula found in paragraph (f)(1) of section 2408.

(2) The manufacturer's average pollutant exhaust emissions must meet the corporate average standard at the end of the manufacturer's production for the model year. At the end of the model year, the manufacturer must calculate a corrected corporate average using actual rather than projected sales. Any discrepancy must be made up with emission reduction credits as explained in paragraph (3).

(3) All excess $HC+NO_x$ or Particulate Matter emissions resulting from final non-compliance with the California standard must be made up with emission reduction credits or through incorporation in the following model year's corporate average.

(A) Emission reduction credits expended within the next model year to remedy final non-compliance will be used at a rate of 1 gram to 1 gram.

(B) Emission reduction credits expended after the end of the next model year to remedy final non-compliance must be used at a rate of 1.5 grams to 1 gram.

(f) In 1995 and subsequent years, fire and police departments, and other entities that specialize in emergency response may purchase emergency equipment powered by a non-California certified engine only when such equipment with a California-certified engine is not available. For purposes of this section, a request to purchase emergency equipment powered by a non-California certified engine must be submitted for approval to the Executive Officer.

(g) (1) No new engines below 225 cc may be produced for sale to replace pre-1995 model equipment after January 1, 1999, unless such new engines comply with the 1995 model emission standards.

(2) (A) A new small off-road engine equal to or greater than 225 cc, intended solely to replace an engine in a piece of off-road equipment that was originally produced with an engine manufactured prior to the applicable implementation date as described in paragraph (b), shall not be subject to the emissions requirements of paragraph (b) provided that:

~~(i)~~1. The engine manufacturer has ascertained that no engine produced by itself or the manufacturer of the engine that is being replaced, if different, and certified to the requirements of this article, is available with the appropriate physical or performance characteristics to repower the equipment; and

~~(ii)~~2. Unless an alternative control mechanism is approved in advance by the Executive Officer, the engine manufacturer or its agent takes ownership and possession of the engine being replaced; and

~~(iii)~~3. The replacement engine is clearly labeled with the following language, or similar alternate language approved in advance by the Executive Officer:

THIS ENGINE DOES NOT COMPLY WITH CALIFORNIA OFF-ROAD OR ON-HIGHWAY EMISSION REQUIREMENTS. SALE OR INSTALLATION OF THIS ENGINE FOR ANY PURPOSE OTHER THAN AS A REPLACEMENT ENGINE IN AN OFF-ROAD VEHICLE OR PIECE OF OFF-ROAD EQUIPMENT WHOSE ORIGINAL ENGINE WAS NOT CERTIFIED IS A VIOLATION OF CALIFORNIA LAW SUBJECT TO CIVIL PENALTY.

(B) At the beginning of each model year, the manufacturer of replacement engines must provide, by engine model, an estimate of the number of replacement engines it expects to produce for California for that model year.

(C) At the conclusion of the model year, the manufacturer must provide, by engine model, the actual number of replacement engines produced for California during the model year, and a description of the physical or performance characteristics of those models that indicate that certified replacement engine(s) were not available as per paragraph (A).

(h) Any new equipment engine certified to comply with California emission standards and test procedures for on-road or other off-road applications may, upon approval by the Executive Officer, be in compliance with these regulations.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2404. Emission Control Labels and Consumer Information – 1995 and Later Small Off-Road Engines.

(a) Purpose. The Air Resources Board recognizes that certain emissions-critical or emissions-related parts must be properly identified and maintained in order for engines to meet the applicable emission standards. In addition, the Board recognizes that information regarding engines' emissions levels may influence consumer choice. These specifications require engine or equipment manufacturers to affix a label (or labels) on each production engine (or equipment, as applicable) to provide the engine or equipment owner and service mechanic with information necessary for the proper maintenance of these parts in customer use. These specifications further require engine or equipment manufacturers to make information regarding relative emissions levels available to potential ultimate purchasers.

(b) Applicability. These specifications apply to

(1) 1995 and later small off-road engines, that have been certified to the applicable emission standards pursuant to Health and Safety Code Section 43013.

(2) Engine manufacturers and original equipment manufacturers, as applicable, that have certified such engines; and

(3) Original equipment manufacturers, regardless of whether they have certified the engine, if their equipment obscures the emissions control label of such certified engines.

(c) Engine Label Content and Location.

(1) A plastic or metal tune-up label must be welded, riveted or otherwise permanently attached by the engine manufacturer to an area on the engine (i.e., block or crankcase) in such a way that it will be readily visible to the average person after installation of the engine in the equipment. If such an attachment is not feasible, the Executive Officer may allow the label to be attached on components of the engine or equipment assembly (as applicable) that satisfy the requirements of Subsection (c)(2). Such labels must be attached on all engine assemblies (incomplete and complete) that are produced by an engine manufacturer.

(2) In selecting an acceptable location, the engine manufacturer must consider the possibility of accidental damage (e.g., possibility of tools or sharp instruments coming in contact with the label). Each engine label(s) must be affixed in such a manner that it cannot be removed without destroying or defacing the label, and must not be affixed to any engine (or equipment, as applicable) part that is likely to be replaced during the engine's (or equipment's,

as applicable) useful life. The engine label must not be affixed to any engine (or equipment, as applicable) component that is easily detached from the engine. If the manufacturer claims there is inadequate space to affix the label, the Executive Officer will determine a suitable location.

(3) The engine label information must be written in the English language and use block letters and numerals (i.e., sans serif, upper-case characters) that must be of a color that contrasts with the background of the label.

(4) The engine label must contain the following information:

(A) The label heading must read: "IMPORTANT ENGINE INFORMATION."

(B) The full corporate name or trademark of the engine manufacturer.

~~(i)~~1. An engine manufacturer may request the Executive Officer's approval to delete its name and trademark, and substitute the name and trademark of another engine manufacturer, original equipment manufacturer, or third-party distributor.

~~(ii)~~2. *Such an approval does not relieve the engine* manufacturer granted an engine family Executive Order of any requirements imposed on the applicable engines by this Article.

(C) For alternate-fuel or dual-fuel engines, "THIS ENGINE IS CERTIFIED TO OPERATE ON (specify operating fuel(s))."

(D) Identification of the Exhaust Emission Control System. The method utilized to identify the exhaust emission control systems must conform to the emission-related nomenclature and abbreviations method provided in the Society of Automotive Engineers' procedure J1930, "Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms", September 1991; and as specified in Section 1977, Title 13, California Code of Regulations.

(E) For otto-cycle engines, the maintenance specifications and adjustments recommended by the engine manufacturer, including, as applicable: valve lash, ignition timing, idle air/fuel mixture setting procedure and value (e.g., idle CO, idle speed drop), and high idle speed. For diesel-cycle engines, the specifications and adjustments recommended by the engine manufacturer, including, as applicable: initial injection timing, and fuel rate (in mm^3/stroke) at rated power. These specifications must indicate the proper transmission position, (if applicable), during tune-up and what accessories, if any, should be in operation, and what systems, if any (e.g., vacuum advance, air pump), should be disconnected during the tune-up. If the engine manufacturer does not *recommend adjustment of the foregoing specifications, the engine manufacturer* may include in lieu of the "specifications" the single statement "NO OTHER ADJUSTMENTS NEEDED." For all engines, the instructions for tune-up adjustments must be sufficiently clear on the engine label to preclude the need for a mechanic or equipment owner to refer to another document in order to correctly perform the adjustments.

(F) Any specific fuel or engine lubricant requirements (e.g., lead content, research octane number, engine lubricant type).

(G) The date of engine manufacture (month and year).

(H) An unconditional statement of compliance with the appropriate calendar year (for 1995-1999) or model year (for 2000 and later) California regulations; for example, "THIS ENGINE MEETS 2005 CALIFORNIA EMISSION REGULATIONS FOR SMALL OFF-ROAD ENGINES." For engines certified to emission standards subject to a durability period as set forth in §2403(b), the durability period must be stated in the owner's manual.

(I) Engine displacement (in cubic centimeters) of the engine upon which the engine label is attached.

(J) The engine family identification (i.e., engine family name).

(5) If there is insufficient space on the engine to accommodate an engine label that contains all of the information required in Subsection (4) above, the Executive Officer may allow the engine manufacturer to modify the engine label as follows:

(A) Exclude the information required in Subsections (4)(C), (D), (E), (F), and (I) from the engine label. The fuel or lubricant information must be specified elsewhere on the engine, or in the owner's manual.

(B) Substitute the information required in Subsection (4)(E) with the statement: "REFER TO OWNER'S MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSTMENTS." When such a statement is used, the information required by Subsection (4)(E) must appear in the owner's manual.

(C) Exclude the information required by Subsection (4)(G) on the engine label if the date the engine was manufactured is stamped permanently on the engine, and this stamped date is readily visible.

(D) Make such other reasonable modifications or abbreviations as may be approved by the Executive Officer.

(d) An engine label may state that the engine conforms to any applicable federal emission standards for new equipment engines; or any other information that the engine manufacturer deems necessary for, or useful to, the proper operation and satisfactory maintenance of the engine.

(e) Supplemental Engine Label Content and Location.

(1) When a final equipment assembly that is marketed to any ultimate purchaser is manufactured and the engine label attached by the engine manufacturer is obscured (i.e., not readily visible), the manufacturer of the final equipment assembly (i.e., original equipment manufacturer) must attach a supplemental engine label upon the engine or equipment. The supplemental engine label must be plastic or metal, must meet the visibility, durability and formatting requirements of paragraphs (f), (g) and (h), and must be welded,

riveted or otherwise attached permanently to an area of the engine or equipment assembly so as to be readily visible to the average person.

(2) The original equipment manufacturer required to attach a supplemental engine label must consider the possibility of accidental damage to the supplemental engine label in the determination of the label location. Such a label must not be attached to any engine or equipment component that is likely to be replaced during the useful life of the engine or equipment (as applicable). Such a label must not be attached to any engine or equipment component that is detached easily from the engine or equipment (as applicable).

(3) The supplemental engine label information must be written in the English language and use block letters and numerals (i.e., sans serif, upper-case characters) that must be of a color that contrasts with the background of the label.

(4) A supplemental engine label must contain the information as specified in Subsection (c)(4) (and (l), as applicable), except that the date of engine manufacture specified in (c)(4)(G) may be deleted from the supplemental engine label. When the date of engine manufacture does not appear on the supplemental engine label, the responsible original equipment manufacturer must display (e.g., label, stamp, etc.) the date elsewhere on the engine or equipment so as to be readily visible.

(f) As used in these specifications, readily visible to the average person means that a label is readable from a distance of 46 centimeters (18 inches) without any obstructions from equipment or engine parts (including all engine manufacturer or original equipment manufacturer (as applicable) available optional equipment) except for flexible parts (e.g., vacuum hoses, ignition wires) that can be moved out of the way without disconnection. Alternatively, information required by these specifications to be printed on the engine and supplemental engine (as applicable) must be no smaller than 2 millimeters in height provided that no equipment or engine parts (including all manufacturer available optional equipment), except for flexible parts, obstruct the label(s).

(g) The labels and any adhesives used must be designed to withstand, for the engine's or equipment's useful life, typical equipment environmental conditions in the area where the labels required by this section are attached. Typical equipment environmental conditions include, but are not limited to, exposure to engine fuels, lubricants and coolants (e.g., gasoline, motor oil, water, ethylene glycol). The engine manufacturer must submit, with its certification application, a statement attesting that its labels comply with these requirements.

(h) The engine manufacturer must obtain approval from the Executive Officer for all label formats and locations in conjunction with the engine family certification. Approval of the specific maintenance settings is not required;

however, the format for all such settings and tolerances, if any, is subject to review. If the Executive Officer finds that the information on the label is vague or subject to misinterpretation, or that the location does not comply with these specifications, the Executive Officer may require that the label or its location be modified accordingly.

(i) Samples of all actual production labels used within an engine family must be submitted to the Executive Officer within thirty days after the start of production. Engine manufacturers must provide samples of their own applicable production labels, and samples of applicable production original equipment manufacturer labels that are accessible to the engine manufacturers due to the direct market arrangement between such manufacturers.

(j) The Executive Officer may approve alternate label locations or may, upon request, waive or modify the label content requirements provided that the intent of these specifications is met.

(k) (1) If the Executive Officer finds any engine manufacturer using labels that are different from those approved or that do not substantially comply with the readability or durability requirements set forth in these specifications, the engine manufacturer will be subject to revocation or suspension of Executive Orders for the applicable engine families, or enjoined from any further sales or distribution, of such noncompliant engine families, or subgroups within the engine families, in the State of California pursuant to Section 43017 of the Health and Safety Code. Before seeking to enjoin an engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

(2) If the Executive Officer finds any original equipment manufacturer using labels for which it has responsibility for attaching that are different from those approved or that do not substantially comply with the readability or durability requirements set forth in these specifications, the equipment manufacturer will be subject to being enjoined from any further sales, or distribution, of the applicable equipment product line that uses such noncompliant labels in the State of California pursuant to Section 43017 of the Health and Safety Code. Before seeking to enjoin an equipment manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

(l) Air Index Label Content and Location. For engines certified to emission standards subject to a durability period as set forth in §2403(b) and for engines used to meet the requirements of §2403(c), each engine manufacturer must make Air Index and durability period information available to potential ultimate purchasers.

(1) The Air Index for each engine family is determined by the following formula:

~~Air Index = FEL * 3, Standard~~

$$\text{Air Index} = \frac{\text{FEL} \times 3}{\text{Standard}},$$

rounded to the nearest whole number in accordance with ASTM E 29-93a (May 1993),

where
FEL= the Family Emission Limit (or standard, if averaging is not being used) for the engine; and
Standard = The HC+NO_x emissions standard, as applicable in § 2403 (b).

(2) The emissions durability period must be indicated by the actual hours, by the descriptive terms shown in the table below, or by both.

For 2000 through 2004 model year small off-road engines:

Descriptive term	Applicable to Emissions Durability Period
Moderate	50 hours (0-65 cc, inclusive) 125 hours (~~65 cc and~~ greater than 65 cc)
Intermediate	125 hours (0-65 cc, inclusive) 250 hours (~~65 cc and~~ greater than 65 cc)
Extended	300 hours (0-65 cc, inclusive) 500 hours (~~65 cc and~~ greater than 65 cc)

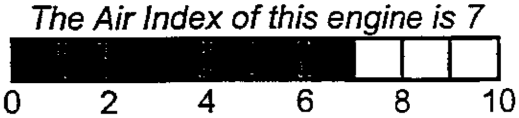
For 2005 and subsequent model year small off-road engines:

Descriptive term	Applicable to Emissions Durability Period
Moderate	50 hours (0-80 cc, inclusive) 125 hours (greater than 80 cc)
Intermediate	125 hours (0-80 cc, inclusive) 250 hours (greater than 80 cc)
Extended	300 hours (0-80 cc, inclusive) 500 hours (greater than 80 cc) 1000 hours (225 cc and greater)

(3) The Air Index information must include a graphical representation of the Air Index, information regarding the significance of the Air Index, and an indication of the emissions durability period of the engine.

(A) The Air Index information should be conveyed in the general the form of the following example.

The Air Index of this engine is 7



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Most Clean *Least Clean*
Note: The lower the Air Index, the less pollution.

This engine is certified to be emissions compliant for the following use:
☐*Moderate* [or appropriate hours, or both]
X *Intermediate* [or appropriate hours, or both]
☐*Extended* [or appropriate hours, or both]
Check the owner's manual for further details.

(B) The Executive Officer, upon request, may waive or modify the form of the Air Index information or may approve alternative forms, provided that the intent of providing Air Index information is met.

(4) No earlier than January 1, 2003, the Executive Officer will conduct a hearing to assess consumer awareness of Air Index information in purchasing decisions.

(A) At such hearing the Executive Officer will compare the degree of consumer awareness of Air Index information by purchasers of engines not meeting specifications (A)-(C) in subsection (l)(5) to the degree of consumer awareness of Air Index information by purchasers of engines substantially meeting specifications (A)-(C) of subsection (l)(5). If the Executive Officer determines that the degree of consumer awareness is statistically equivalent, the provisions of subsections (l)(1-3) shall remain in effect and the Executive Officer will not require engine manufacturers to meet the requirements of subsection (l)(5).

(B) If the Executive Officer determines that there are insufficient engines meeting specifications (A)-(C) in subsection (l)(5) to make the above comparison, the Executive Officer will compare the degree of consumer awareness of Air Index information by purchasers of engines not meeting specifications (A)-(C) in subsection (l)(5) to other similar consumer information programs including, but not limited to, the passenger car Smog Index labeling program. If the Executive Officer determines that the degree of consumer awareness is statistically equivalent to other similar consumer information programs, the provisions of subsections (l) (1-3) shall remain in effect and the Executive Officer will not require engine manufacturers to meet the requirements of subsection (l)(5).

(C) If the Executive Officer determines that the degree of consumer awareness is not statistically equivalent under (A) and (B), then no earlier than at the beginning of the first full model year following the Executive Officer's final determination, provided that manufacturers have no less than 9 months of lead time, the Executive Officer will require engine manufacturers to meet the requirements of subsection (l)(5).

(5) If the Executive Officer has made the determination in subsection (l)(4)(C), then the following requirements apply:

(A) All information required on the Air Index Label must be no smaller than 2 millimeters in height.

(B) The Air Index Label must be noticeable from a distance of 150 centimeters (59 inches) without any obstructions by equipment or engine parts, including all engine manufacturer or original equipment manufacturer (as applicable) available optional equipment. For engines that are installed in an engine compartment that is easily accessible to the ultimate purchaser, this subsection (l)(5)(B) may be satisfied by a generic label or hang tag stating "LOOK INSIDE THE ENGINE COMPARTMENT FOR IMPORTANT EMISSIONS INFORMATION," or by other means, subject to the Executive Officer's approval.

(C) The Air Index Label must be located in at least one of the following locations:

~~(i)~~1. included on the engine label;

~~(ii)~~2. included as an additional engine label, designed and intended for removal only by the ultimate purchaser; or

~~(iii)~~3. included as an engine or equipment hang-tag designed or intended for removal only by the ultimate purchaser;

(D) For engines 0-65 cc (up to 80 cc beginning with the 2005 model year), inclusive, the engine manufacturer must also arrange for a label with the engine family's Air Index to be attached to the equipment packaging.

(E) The Executive Officer, upon request, may waive or modify the form of the Air Index Label or may approve alternative forms, sizes or locations, provided that the intent of the Air Index Label requirement is met.

(6) The labeling and consumer information provisions of subsection (l) shall not apply to engines that are not the primary power source of the equipment in which they are installed or to engines that are installed in equipment that the engine or equipment manufacturer can demonstrate, to the Executive Officer's reasonable satisfaction, are used almost exclusively in commercial applications in which consumer information are not likely to affect a purchasing decision.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43017, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2405. Defects Warranty Requirements for 1995 and Later Small Off-Road Engines.

(a) Applicability. This section applies to 1995 and later small off-road engines. The warranty period begins on the date the engine or equipment is delivered to an ultimate purchaser.

(b) General Emissions Warranty Coverage. The manufacturer of each small off-road engine must warrant to the ultimate purchaser and each subsequent purchaser that the engine is:

(1) Designed, built, and equipped so as to conform with all applicable regulations adopted by the Air Resources Board pursuant to its authority in Chapters 1 and 2, Part 5, Division 26 of the Health and Safety Code; and

(2) Free from defects in materials and workmanship that cause the failure of a warranted part to be identical in all material respects to the part as described in the engine manufacturer's application for certification for a period of two years.

(c) The warranty on emissions-related parts will be interpreted as follows:

(1) Any warranted part that is not scheduled for replacement as required maintenance in the written instructions required by Subsection (d) must be warranted for the warranty period defined in Subsection (b)(2). If any such part fails during the period of warranty coverage, it must be repaired or replaced by the engine manufacturer according to Subsection (4) below. Any such part repaired or replaced under the warranty must be warranted for the remaining warranty period.

(2) Any warranted part that is scheduled only for regular inspection in the written instructions required by Subsection (d) must be warranted for the warranty period defined in Subsection (b)(2). A statement in such written instructions to the effect of "repair or replace as necessary" will not reduce the period of warranty coverage. Any such part repaired or replaced under warranty must be warranted for the remaining warranty period.

(3) Any warranted part that is scheduled for replacement as required maintenance in the written instructions required by Subsection (d) must be warranted for the period of time prior to the first scheduled replacement point for that part. If the part fails prior to the first scheduled replacement, the part must be repaired or replaced by the engine manufacturer according to Subsection (4) below. Any such part repaired or replaced under warranty must be warranted for the remainder of the period prior to the first scheduled replacement point for the part.

(4) Repair or replacement of any warranted part under the warranty provisions of this article must be performed at no charge to the owner at a warranty station.

(5) Notwithstanding the provisions of Subsection (4) above, warranty services or repairs must be provided at all manufacturer distribution centers that are franchised to service the subject engines.

(6) The owner must not be charged for diagnostic labor that leads to the determination that a warranted part is in fact defective, provided that such diagnostic work is performed at a warranty station.

(7) The engine manufacturer is liable for damages to other engine components proximately caused by a failure under warranty of any warranted part.

(8) Throughout the engine's warranty period defined in Subsection (b)(2), the engine manufacturer must maintain a supply of warranted parts sufficient to meet the expected demand for such parts.

(9) Any replacement part may be used in the performance of any warranty maintenance or repairs and must be provided without charge to the owner. Such use will not reduce the warranty obligations of the engine manufacturer.

(10) Add-on or modified parts that are not exempted by the Air Resources Board may not be used. The use of any non-exempted add-on or modified parts will be grounds for disallowing a warranty claim made in accordance with this article. The engine manufacturer will not be liable under this article to warrant failures of warranted parts caused by the use of a non-exempted add-on or modified part.

(11) The Executive Officer may request and, in such case, the engine manufacturer must provide, any documents that describe that manufacturer's warranty procedures or policies.

(d) Each manufacturer must include a copy of the following emission warranty parts list with each new engine, using those portions of the list applicable to the engine.

(1) Fuel Metering System

~~(i)~~(A) Carburetor and internal parts (and/or pressure regulator or fuel injection system).

~~(ii)~~(B) Air/fuel ratio feedback and control system.

~~(iii)~~(C) Cold start enrichment system.

(2) Air Induction System

~~(i)~~(A) Controlled hot air intake system.

~~(ii)~~(B) Intake manifold.

~~(iii)~~(C) Air filter.

(3) Ignition System

~~(i)~~(A) Spark Plugs.

~~(ii)~~(B) Magneto or electronic ignition system.

~~(iii)~~(C) Spark advance/retard system.

(4) Exhaust Gas Recirculation (EGR) System

~~(i)~~(A) EGR valve body, and carburetor spacer if applicable.

~~(ii)~~(B) EGR rate feedback and control system.

(5) Air injection System

~~(i)~~(A) Air pump or pulse valve.

~~(ii)~~(B) Valves affecting distribution of flow.

~~(iii)~~(C) Distribution manifold.

(6) Catalyst or Thermal Reactor System

~~(i)~~(A) Catalytic converter.

~~(ii)~~(B) Thermal reactor.

~~(iii)~~(C) Exhaust manifold.

(7) Particulate Controls

~~(i)~~(A) Traps, filters, precipitators, and any other device used to capture particulate emissions.

(8) Miscellaneous items Used in Above Systems

~~(i)~~(A) Vacuum, temperature, and time sensitive valves and switches.

~~(ii)~~(B) Electronic controls.

~~(iii)~~(C) Hoses, belts, connectors, and assemblies.

(e) Each manufacturer must furnish with each new engine written instructions for the maintenance and use of the engine by the owner. The instructions must be consistent with this article and applicable regulations contained herein.

(f) Each engine manufacturer must submit the documents required by Subsection (d) with the engine manufacturer's application for engine certification for approval by the Executive Officer. Approval by the Executive Officer of the documents required by Subsection (d) is a condition of certification. The Executive Officer will approve or disapprove the documents required by Subsection (d) within 90 days of the date such documents are received from the engine manufacturer. Any disapproval must be accompanied by a statement of the reasons thereof. In the event of disapproval, the engine manufacturer may file for an adjudicative hearing pursuant to Title 17, California Code of Regulations, Section 60040 et seq., to review the decision of the Executive Officer.

(g) In the application for engine certification, each engine manufacturer must include a statement regarding the maintenance of the engine for clean air. The statement must include, but not be limited to, information on carburetor adjustment, air filter care and replacement schedule, spark plug maintenance and inspection, proper fuel/oil ratio for low emissions, use of appropriate fuel, proper fueling and fuel mixing, proper method of disposing of oil and oil containers, engine maintenance, and a maintenance schedule to ensure that the owner returns to a servicing center to check for deposits, debris build-up, etc.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2405.1. Emission-related Defect Reporting Requirements.

(a) Applicability. This section applies to 2005 model year and later small off-road engines. The requirement to report emission-related defects affecting a given class or category of engines will remain applicable for five years from the end of the calendar year in which such engines were manufactured.

(b) A manufacturer must file a defect information report whenever, on the *basis of data obtained subsequent to the effective date of these regulations:*

(1) The manufacturer determines, in accordance with procedures established by the manufacturer to identify either safety-related or performance defects, that a specific emission-related defect exists; and

(2) A specific emission-related defect exists in 25 or more engines of a given engine family manufactured in the same Executive Order or model year.

(c) No report must be filed under this section for any emission-related defect corrected prior to the sale of the affected engines to ultimate purchasers.

(d) The manufacturer must submit defect information reports to Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar, El Monte, CA 91731, not more than 15 working days after an emission-related defect is found to affect 25 or more engines manufactured in the same Executive Order or model year. Information required by paragraph (e) of this section that is either not available within 15 working days or is significantly revised must be submitted the Executive Officer as it becomes available.

(e) Each defect report must contain the following information in substantially the format outlined below:

(1) The manufacturer's corporate name.

(2) A description of the defect and part number(s).

(3) A description of each class or category of engines potentially affected by the defect including make, model, model year, calendar year produced, and any other information required to identify the engines affected.

(4) For each class or category of engine described in response to paragraph (e)(3) of this section, the following must also be provided:

(A) The number of engines known or estimated to have the defect and an explanation of the means by which this number was determined.

(B) The address of the plant(s) at which the potentially defective engines were produced.

(5) An evaluation of the emissions impact of the defect and a description of any operational problems which a defective engine might exhibit.

(6) Emission data which relate to the defect.

(7) An indication of any anticipated manufacturer follow-up.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2405.2. Voluntary Emission Recall Program

(a) When any manufacturer initiates a voluntary emissions recall campaign involving 25 or more engines, the manufacturer must submit a report describing the manufacturer's voluntary emissions recall plan as prescribed by this section within 15 working days prior to the date owner notification was issued. The report must contain the following:

(1) A description of each class or category of engines recalled including the number of engines to be recalled, the model year, the make, the model, and such other information as may be required to identify the engines recalled;

(2) A description of the specific modifications, alterations, repairs, corrections, adjustments, or other changes to be made to correct the engines affected by the emission-related defect;

(3) A description of the method by which the manufacturer will notify engine owners and, if applicable, the method by which the manufacturer will determine the names and addresses of engine owners;

(4) A description of the proper maintenance or use, if any, upon which the manufacturer conditions eligibility for repair under the recall plan, an explanation of the manufacturer's reasons for imposing any such conditions, and a description of the proof to be required of an engine owner to demonstrate compliance with any such conditions;

(5) A description of the procedure to be followed by engine owners to obtain correction of the nonconformity. This may include designation of the date on or after which the owner can have the nonconformity remedied, the time reasonably necessary to perform the labor to remedy the defect, and the designation of facilities at which the defect can be remedied;

(6) A description of the class of persons other than dealers and authorized warranty agents of the manufacturer who will remedy the defect;

(7) When applicable, three copies of any letters of notification to be sent engine owners;

(8) A description of the system by which the manufacturer will assure that an adequate supply of parts is available to perform the repair under the plan, and that the supply remains both adequate and responsive to owner demand;

(9) Three copies of all necessary instructions to be sent to those persons who are to perform the repair under the recall plan;

(10) A description of the impact of the proposed changes on fuel consumption, performance, and safety of each class or category of engines to be recalled;

(11) A sample of any label to be applied to engines which participated in the voluntary recall campaign.

(b) The manufacturer must submit at least one report on the progress of the recall campaign. Such report must be submitted no later than 18 months from the date notification was begun and include the following information:

(1) The methods used to notify both engine owners, dealers and other individuals involved in the recall campaign;

(2) The number of engines known or estimated to be affected by the emission-related defect and an explanation of the means by which this number was determined;

(3) The number of engines actually receiving repair under the plan; and

(4) The number of engines determined to be ineligible for remedial action due to a failure to properly maintain or use such engines.

(c) Send the defect report, voluntary recall plan, and the voluntary recall progress report to: Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar Avenue, El Monte, CA 91731.

(d) Retain the information gathered by the manufacturer to compile the reports for not less than five years from the date of the manufacture of the engines. The manufacturer must make this information available to duly authorized officials of the ARB upon request.

(e) The filing of any report under the provisions of this section does not affect a manufacturer's responsibility to file reports or applications, obtain approval, or give notice under any provision of law.

(f) The act of filing an Emission Defect Information Report is inconclusive as to the existence of a defect subject to the warranty provided by section 2405.

(g) A manufacturer may include on each page of its Emission Defect Information Report a disclaimer stating that the filing of a Defect Information Report pursuant to these regulations is not conclusive as to the applicability of the warranty provided by section 2405.

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NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2405.3. Ordered Recalls.

(a) (1) If the Executive Officer determines that a substantial number of any class or category of engines, although properly maintained and used, do not conform to the regulations prescribed under Section 2400-2409, Chapter 1, Title 13 of the California Code of Regulations, when in actual use throughout their durability period (as defined under section 2403), the Executive Officer shall immediately notify the manufacturer of such nonconformity and require the manufacturer to submit a plan for remedying the nonconformity of the engines with respect to which such notification is given.

(A) The manufacturer's plan shall provide that the nonconformity of any such engines which are properly used and maintained will be remedied at the expense of the manufacturer.

(B) If the manufacturer disagrees with such determination of nonconformity and so advises the Executive Officer, the Executive Officer shall afford the manufacturer and other interested persons an opportunity to present their views and evidence in support thereof at a public hearing pursuant to Subchapter 1.25, Title 17, California Code of Regulations. Unless, as a result of such hearing, the Executive Officer withdraws such determination of nonconformity, the Executive Officer shall, within 60 days after the completion of such hearing, order the manufacturer to provide prompt notification of such nonconformity in accordance with paragraph (a)(2) of this section. The manufacturer shall comply in all respects with the requirements of this subpart.

(2) Any notification required to be given by the manufacturer under paragraph (a)(1) of this section with respect to any class or category of engines shall be given to dealers, ultimate purchasers, and subsequent purchasers (if known) in such manner and containing such information as required in section 2405.1(d).

(3) (A) Prior to an ARB ordered recall, the manufacturer may perform a voluntary emissions recall pursuant to regulations at section 2405.2. Such manufacturer is subject to the reporting and recordkeeping requirements of section 2405.2(c) and (d).

(B) Once ARB determines that a substantial number of engines fail to conform with the requirements of Section 2400-2409, Chapter 1, Title 13 of the California Code of Regulations, the manufacturer will not have the option of a voluntary recall.

(b) The manufacturer bears all cost obligation a dealer incurs as a result of a requirement imposed by paragraph (a) of this section. The transfer of any such cost obligation from a manufacturer to a dealer through franchise or other agreement is prohibited.

(c) Any inspection of an engine for purposes of paragraph (a)(1) of this section, after its sale to the ultimate purchaser, is to be made only if the owner of such engine voluntarily permits such inspection to be made, except as may be provided by any state or local inspection program.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2407. New Engine Compliance and Production Line Testing – New Small Off-Road Engine Selection, Evaluation, and Enforcement Action.

(a) Compliance Test Procedures.

(1) The Executive Officer may, with respect to any new engine family or subgroup being sold, offered for sale, or manufactured for sale in California, order an engine manufacturer to make available for compliance testing and/or inspection a reasonable number of engines, and may direct that the engines be delivered to the state board at the Haagen-Smit Laboratory, 9528 Telstar Avenue, El Monte, California or where specified by the Executive Officer. The Executive Officer may also, with respect to any new engine family or subgroup being sold, offered for sale, or manufactured for sale in California, have an engine manufacturer compliance test and/or inspect a reasonable number of engines at the engine manufacturer's facility under the supervision of an ARB Enforcement Officer. Engines must be selected at random from sources specified by the Executive Officer according to a method approved by the Executive Officer, that, insofar as practical, must exclude engines that would result in an unreasonable disruption of the engine manufacturer's distribution system.

A subgroup may be selected for compliance testing only if the Executive Officer has reason to believe that the emissions characteristics of that subgroup are substantially in excess of the emissions of the engine family as a whole.

(2) For all 1995 and subsequent small off-road engines selected for compliance testing, the selection and testing of engines and the evaluation of data must be made in accordance with the procedures set forth herein.

(3) These procedures are applicable, commencing with the 1995 calendar year, to any engine family or any subgroup within an engine family selected for compliance testing pursuant to this section.

(4) All testing must be conducted in accordance with the applicable calendar year (for 1995-1999) or model year (for 2000 and later) certification emission test procedures. Any adjustable engine parameters must be set to values or positions that are within the range available to the ultimate purchaser as determined by the ARB Enforcement Officer. For example, an engine carburetor with an adjustable idle fuel/air mixture must be compliance tested at any mixture position requested by the ARB Enforcement Officer that is within the range of adjustment available to the end-use operator. Engine service accumulation (i.e., break-in) before testing may be performed on test engines to the same extent it is performed on production line testing engines (See subsection (d)). No break-in or modifications, adjustments, or special preparation or maintenance will be allowed on engines chosen for compliance

testing without the written consent of the Executive Officer. Such consent must not be unreasonably withheld where such adjustment or alteration is required to render the engine testable and reasonably operative.

(5) If the engine manufacturer elects to specify a different break-in or adjustments, they will be performed by the engine manufacturer under the supervision of ARB personnel.

(6) Correction of damage or maladjustment that may reasonably be found to have resulted from shipment of the engine is permitted only after test of the engine, except where 100 percent of the engine manufacturer's production is given that inspection or maintenance by the engine manufacturer's own personnel. The engine manufacturer may request that the engine be repaired from shipping damage, and be retested. If the Executive Officer concurs, the engine may be retested, and the original test results may be replaced by the after-repair test results.

(7) Engine must be randomly chosen from the selected engine family or subgroup. Each chosen engine must be tested according to the "California Exhaust Emission Standards and Test Procedures for 1995-2004 ~~and Later~~ Small Off-Road Engines" ("Emission Standards and Test Procedures"), adopted March 20, 1992, and last amended ~~January 28, 2000~~ ________, or "California Exhaust Emission Standards and Test Procedures for 2005 and Later Small Off-Road Engines," adopted ________, as applicable, to determine its emissions. Unique specialty hardware and personnel normally necessary to prepare the engine for the performance of the test as set forth in the Procedures must be supplied by the engine manufacturer within seven days after the request for such speciality hardware or personnel. Failure to supply this unique specialty hardware or personnel may not be used by the engine manufacturer as a cause for invalidation of the subsequent tests.

(8) Engines must be tested in groups of five until a "Pass" or "Fail" decision is reached for each pollutant independently for the engine family or subgroup in accordance with the following table:

Number of Engines Tested	Decide "Fail" If "*U*" is greater than or equal to	Decide "Pass" If "*U*" is less than or equal to
5	2.18	-0.13
10	2.11	0.51
15	2.18	0.88
20	2.29	1.16

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where:

$$U = \frac{\sum_{i=1}^{n}(x_i - \mu_0)}{\sqrt{\sum_{i=1}^{n}(x_i - \mu_0)^2}}$$

x_i = the projected emissions of one pollutant for the ith engine tested.
μ_0 = the applicable calendar year emission standard for that pollutant.
n = the number of engines tested.

(9) The Executive Officer will find that a group of engines has failed the compliance testing pursuant to the above table if the Executive Officer finds that the average emissions of the engines within the selected engine family or subgroup exceed the applicable calendar year new engine emission standard for at least one pollutant.

(10) If no decision can be reached after 20 engines have been tested, the Executive Officer will not make a "Fail" decision for the selected engine family or subgroup on the basis of these 20 tests alone. Under these circumstances the Executive Officer will elect to test 10 additional engines. If the average emissions from the 30 engines tested exceed any one of the exhaust emission standards for which a "Pass" decision has not been previously made, the Executive Officer will render a "Fail" decision.

(11) If the Executive Officer determines, in accordance with the procedures set forth in Subsection (a) that an engine family or any subgroup within an engine family, exceeds the emission standards for one or more pollutants, the Executive Officer will:

(A) Notify the engine manufacturer that the engine manufacturer may be subject to revocation or suspension of the Executive Order authorizing sales and distribution of the noncompliant engines in the State of California, or enjoined from any further sales or distribution, of the noncompliant engines in the State of California pursuant to Section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or seeking to enjoin an engine manufacturer, the Executive Officer will consider production line test results, if any, and any additional test data or other information provided by the engine manufacturers and other interested parties, including the availability of emission reductions credits to remedy the failure.

(B) Notify the equipment manufacturer that the equipment manufacturer may be subject to being enjoined from any further sales, or distribution, of the equipment manufacturer's equipment product line(s) that are, or utilize engines that are, noncompliant with the applicable emission regulations pursuant to Section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or seeking to enjoin an equipment manufacturer, the Executive Officer will consider production line test results, if any, and any additional test data or other information provided by the equipment manufacturer and other interested parties, including the availability of emissions reduction credits to remedy the failure.

(12) Engines selected for inspection must be checked to verify the presence of those emissions-related components specified in the engine manufacturer's application for certification, and for the accuracy of any adjustments, part numbers and labels specified in that application. If any engine selected for inspection fails to conform to any applicable law in Part 5 (commencing with Section 43000) of Division 26 of the Health and Safety Code, or any regulation adopted by the state board pursuant thereto, other than an emissions standard applied to new engines to determine "certification" as specified in Chapter 9, the Executive Officer will:

(A) Notify the engine manufacturer and may seek to revoke or suspend the Executive Order authorizing sales and distribution or enjoin the engine manufacturer from any further sales, or distribution, of the applicable noncompliant engine families or subgroups within the engine families in the State of California pursuant to Section 43017 of the Health and Safety Code. Before revoking or suspending the Executive Order authorizing sales and distribution of the applicable noncompliant engine families or subgroups within the State of California, or seeking to enjoin an engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer and other interested parties, including the availability of emissions reductions credits to remedy the failure.

(B) Notify the equipment manufacturer and may seek to revoke or suspend the Executive Order authorizing sales and distribution or enjoin the equipment manufacturer from any further sales, or distribution, in the State of California of the equipment manufacturer's equipment product line(s) that are, or utilize engines that are, noncompliant with the applicable emission regulations pursuant to Section 43017 of the Health and Safety Code. Before revoking or suspending the Executive Order authorizing sales and distribution of the applicable noncompliant equipment, or seeking to enjoin an equipment manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer and other interested parties, including the availability of emissions reductions credits to remedy the failure.

(b) 1996 and Subsequent Calendar (Model) Year Quality-Audit Production Line Test Procedures.

(1) Small off-road engines produced in the 1996 and subsequent calendar (or model) years, that have been certified for sale in California, are subject to the quality-audit requirements specified in (b) and (d). Each engine manufacturer must use the quality-audit test procedures as specified in (b) and (d) unless it can satisfactorily provide an alternate method that shows an equivalent assurance of compliance. The purpose of providing alternate sampling, testing methods, and procedures is to help reduce sample size and

testing costs, while providing a reasonable assurance that production engines comply with the applicable emission standards. The engine manufacturer must submit the method of quality-audit to the Executive Officer for approval no later than 90 days prior to 1996 calendar year production, or any subsequent calendar or model year production, as applicable, if a change is proposed.

(2) Engine Sample Selection

(A) Except as provided in subsection (b)(3), the engine manufacturer must randomly select one percent of the California sales volume of engines from each engine family for quality-audit testing. Additional engine sample criteria appear in subsection (d)(3).

(B) The Executive Officer may, upon notice to the engine manufacturer, require the sample rate to be increased to a maximum of ten percent of production (not to exceed 30 additional engines or units of equipment) of the calendar quarterly production of any engine family.

(3) Alternate Quality-Audit Engine Selection Criteria For The 1996 Through 1999 Calendar Years

(A) An engine manufacturer may use the alternate engine selection method outlined in this Subsection.

(B) Engines or equipment must be randomly selected at a rate of 1.0 percent of engine family production at the beginning of production. When test results of the first 10 engines or units of equipment have been accumulated, an evaluation as indicated below must be made.

(C) Calculate the family mean and standard deviation of each pollutant (HC, CO, NO_x and PM, if applicable). Identify engines or units of equipment that have emission levels greater than three standard deviations above the mean. Eliminate these emission data points and recalculate the mean and standard deviation. Continue the calculation until there are no values greater than three standard deviations above the mean. Count the number of these data points greater than the emission standard (outliers). If the number of outliers is equal to or less than the allowable number in Table 1 for each pollutant, the engine family is eligible to continue to a second evaluation, shown in paragraph (D) below. Otherwise, sampling must continue at a rate of 1.0 percent of production for the rest of the month.

(D) If the allowable outlier criterion is met, the family mean standard deviation, and sample size determined for each contaminant before excluding any outliers, are substituted in the following expression:

$$\frac{(\text{emission standard} - \text{mean})\sqrt{(N)}}{(\text{standard deviation})}$$

(E) If the expression is greater than C in Table 2 below, and the engine manufacturer reasonably estimates that the quarterly engine family production will exceed 5,000 engines or units of equipment, the sampling rate for the remaining portion of the calendar month following the date of selection of the last of the 10 engines or equipment is 10 per month, applied on a prorated basis. If the expression is greater than C in Table 2 below, and the engine manufacturer reasonably estimates that the quarterly engine family production will be 5,000 engines or units of equipment or less, the sampling rate for the remaining portion of the calendar month following the date of selection of the last of the 10 engines or equipment is 5 per month, applied on a prorated basis. If the expression is equal to or less than C in Table 2, the sampling rate continues to be 1.0 percent of production for the remaining portion of the month in which selection of the 10 engines or equipment is completed. The value of C is a function of the coefficient of variation (standard deviation/mean). The coefficient of variation and "C" must be rounded to the number of decimal places shown in Table 2.

Table 1

Sample Size	*Allowable Outliers*	*Sample Size*	*Allowable Outliers*
1-32	1	430-478	11
33-68	2	479-528	12
69-107	3	529-578	13
108-149	4	579-629	14
150-193	5	630-680	15
194-238	6	681-731	16
239-285	7	732-783	17
286-332	8	784-835	18
333-380	9	836-887	19
381-429	10	888-939	20

Table 2

Coefficient of Variation	C
0.1	0.5
0.2	1.2
0.3	1.8
0.4	2.5
0.5	3.1
0.6	3.8
0.7	4.4
0.8	5.1
0.9	5.7

(F) At the conclusion of each month of quarterly engine family production, the emission test data must be evaluated in order to determine the sampling rate as set forth in Paragraphs C and D above. This evaluation must utilize all test data accumulated in the applicable quarter. The sample rate for the next month of production must be determined as follows: ten (10) engines per month when the engine manufacturer's estimated quantity of quarterly engine family production is greater than 5,000; five (5) engines per month when the engine manufacturer's estimated quantity of quarterly engine family production is equal to or less than 5,000; or, one (1) percent of the quarterly engine family production as determined by the sampling evaluation method set forth in Paragraphs D and E.

(G) For each subsequent quarter, the preceding sample selection method must be followed. The sample rate determination for the first month of each subsequent quarter must be based on the accumulated data from the previous quarter. The sample rate for the succeeding months of the quarter must be determined as previously set forth.

(H) If the start of production does not coincide with the first of a quarter, the sequence for sample rate determination must be followed, but references to remaining calendar months may not be appropriate.

(I) Where an engine manufacturer has sampled engines or equipment at a rate of 5 per month following a reasonable estimate that the quarterly engine family production will be 5,000 engines or units of equipment or less, and subsequently determines, or reasonably should determine based on information available to the engine manufacturer, that the quarterly engine family production will exceed 5,000 engines or units of equipment, the engine manufacturer must increase the sampling rate for the quarter such that the requirements of Paragraph D applicable to families reasonably estimated to exceed a quarterly production of 5,000 engines or units of equipment are satisfied.

(4) Compliance Evaluation

(A) Each engine manufacturer must review the test results of the first 10 test engines or equipment of each engine family, from each calendar quarter of production or from the start of calendar year production. It must also review the quarter's cumulative test results of each engine family at the end of each month. If 10 or more engines or units of equipment have been tested, the engine manufacturer must notify the Chief of the Mobile Source Operations Division, in writing within ten working days whenever an engine family exceeds an emission standard.

(B) At the end of the quarter, all of the data accumulated during the quarter are evaluated, and the compliance of the engine family with the family emission levels or emission standards, whichever is applicable, is determined. If a sample size for a particular production quarter is less than ten engines, the data from that quarter must be combined with all of the data from each successive quarter of the calendar year until data from at least ten engines that have been quality-audit tested are included in the quarterly evaluation. If the sample size for the first quarter's production for a calendar year does not contain at least ten engines, the data available for that quarter are evaluated. However, compliance of the engine family with the family emission levels or emission standards, whichever is applicable, is not determined until subsequent quarterly production data is available that includes evaluations of at least ten engines. If the sample size for the last final quarter's production for a calendar year does not

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contain at least ten engines, the data from the last final quarter must be combined with all the data from each preceding quarter of the calendar year until the sample size contains at least ten engines.

(C) When the average value of any pollutant that is rounded off to the same number of significant digits as is the standard, in accordance with ASTM E 29-93a (May 1993), exceeds the applicable family emission level or emission standard, whichever is applicable; or, when the engine manufacturer's submitted data reveal that the production line tests were performed improperly, the engine family may be determined to be in noncompliance. The Executive Officer will follow the manufacturer notification procedures in section (d)(5).

(D) A failed engine is one whose emission test results for a regulated pollutant exceeds the emission standard or FEL, as applicable.

(5) Reports

(A) Each engine manufacturer shall submit a written report to the ARB within 45 calendar days of the end of each calendar quarter.

(B) The quarterly report shall include the following:

~~(i)~~1. The total production and sample size for each engine family.

~~(ii)~~2. Engine identification numbers and explanation of the identification code.

~~(iii)~~3. The applicable emissions standards or Family Emission Levels for each engine family.

~~(iv)~~4. A description of each test engine or equipment (i.e., date of test, engine family, engine size, engine or equipment identification number, fuel system, dynamometer power absorber setting in horsepower or kilowatts, engine code or calibration number, and test location).

~~(v)~~5. The exhaust emission data for PM, CO, NO_x and HC for each test engine or equipment. The data reported shall provide two significant figures beyond the number of significant figures in the applicable emission standard.

~~(vi)~~6. The retest emissions data, as described in paragraph ~~(v)~~5 above for any engine or unit of equipment failing the initial test, and description of the corrective measures taken, including specific components replaced or adjusted.

~~(vii)~~7. A statistical analysis of the quality-audit test results for each engine family stating:

~~1~~a. Number of engines or units of equipment tested.

~~2~~b. Average emissions and standard deviations of the sample for HC, CO, NO_x and PM.

~~(viii)~~8. Every aborted test data and reason for the aborted test.

~~(ix)~~9. The applicable quarterly report shall include the date of the end of the engine manufacturer's calendar year (for 1995-1999) or model year (for 2000 and subsequent years) production for an engine family.

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~~(x)~~10. The required information for all engine families in production during the quarter regardless of sample size.

~~(xi)~~11. The start and stop dates of batch-produced engine family production.

(C) Each engine manufacturer shall submit a copy of the report that has been stored (e.g., computer discs), or may be transmitted, in an electronically digitized manner, and in a format that is specified by the Executive Officer. This electronically based submission is in addition to the written submission of the report.

(c) 2000 and Subsequent Model Cumulative Sum Production Line Test Procedures.

(1) The 2000 and subsequent model year small off-road engines, that have been certified for sale in California, are subject to production line testing performed according to either the Cumulative Sum requirements specified in (c) and (d), or to the Quality-Audit requirements specified in paragraph (b) and (d). At the time of certification, the engine manufacturer must designate which production line testing procedure, either Quality-Audit or Cumulative Sum, it will use for the model year. If an engine manufacturer uses the Cumulative Sum procedures, it must use the Cumulative Sum test procedures as specified herein.

(2) Engine Sample Selection

(A) At the start of each model year, the small off-road engine manufacturer will begin to randomly select engines from each engine family for production line testing, according to the criteria specified herein. Additional engine sample criteria appear in subsection (d)(3).

~~(i)~~1. For newly certified engine families: After two engines are tested, the manufacturer will calculate the required sample size for the model year according to the Sample Size Equation in paragraph (B) of this section.

~~(ii)~~2. For carry-over engine families: After one engine is tested, the manufacturer will combine the test with the last test result from the previous model year and then calculate the required sample size for the model year according to the Sample Size Equation in paragraph (B) of this section.

(B) ~~(i)~~1. Manufacturers will calculate the required sample size for the model year for each engine family using the Sample Size Equation below. N is calculated from each test result. The number N indicates the number of tests required for the model year for an engine family. N, is recalculated after each test. Test results used to calculate the variables in the Sample Size Equation must be final deteriorated test results as specified in paragraph (c)(4)(C).

$$\cancel{N=\left[\frac{(t_{95}\times\sigma)^2}{(x-FEL)}\right]+1}\quad N=\left[\frac{(t_{95}\times\sigma)}{(x-FEL)}\right]^2+1$$

where:

N = required sample size for the model year.

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t_{95} = 95% confidence coefficient. It is dependent on the actual number of tests completed, n, as specified in the table in paragraph (B)~~(ii)~~2. of this section. It defines one-tail, 95% confidence intervals.

σ = actual test sample standard deviation calculated from the following equation:

$$\sigma = \sqrt{\frac{\sum (X_i - x)^2}{n-1}}$$

X_i = emission test result for an individual engine

x = mean of emission test results of the actual sample

FEL = Family Emission Level, or emission standard if no Family Emission level is established

n = The actual number of tests completed in an engine family

~~(ii)~~2. Actual Number of Tests (n) & 1-tail Confidence Coefficients (t_{95})

n	t_{95}	n	t_{95}	n	t_{95}
2	6.31	12	1.80	22	1.72
3	2.92	13	1.78	23	1.72
4	2.35	14	1.77	24	1.71
5	2.13	15	1.76	25	1.71
6	2.02	16	1.75	26	1.71
7	1.94	17	1.75	27	1.71
8	1.90	18	1.74	28	1.70
9	1.86	19	1.73	29	1.70
10	1.83	20	1.73	30	1.70
11	1.81	21	1.72	∞	1.645

~~(iii)~~3. A manufacturer must distribute the testing of the remaining number of engines needed to meet the required sample size N, evenly throughout the remainder of the model year.

~~(iv)~~4. After each new test, the required sample size, N, is recalculated using updated sample means, sample standard deviations and the appropriate 95% confidence coefficient.

~~(v)~~5. A manufacturer must continue testing and updating each engine family's sample size calculations according to paragraphs (B)~~(i)~~1. through (B)~~(iv)~~4. of this section until a decision is made to stop testing as described in paragraph (B)~~(vi)~~6. of this section or a noncompliance decision is made pursuant to paragraph (c)(3)(A)~~(v)~~5. of this section.

~~(vi)~~6. If, at any time throughout the model year, the calculated required sample size, N, for an engine family is less than or equal to the actual sample size, n, and the sample mean, x, for each regulated pollutant is less than or equal to the emission standard (or FEL, as applicable) for that pollutant, the manufacturer may stop testing that engine family except as required by paragraph (c)(3)(A)~~(vi)~~6.

~~(vii)~~7. If, at any time throughout the model year, the sample mean, x, for any regulated pollutant is greater than the emission standard (or FEL, as applicable), the manufacturer must continue testing that engine family at the appropriate maximum sampling rate.

~~(viii)~~8. The maximum required sample size for an engine family (regardless of the required sample size, N, as calculated in paragraph (B)~~(i)~~1 of this section) is thirty tests per model year.

~~(ix)~~9. Manufacturers may elect to test additional randomly chosen engines. All additional randomly chosen engines tested in accordance with the testing procedures specified in the Emission Standards and Test Procedures must be included in the Sample Size and Cumulative Sum equation calculations as defined in paragraphs (B)~~(i)~~1. and (c)(3)(A)~~(i)~~1. of this section, respectively.

(C) The manufacturer must produce and assemble the test engines using its normal production and assembly process for engines to be distributed into commerce.

(D) No quality control, testing, or assembly procedures will be used on any test engine or any portion thereof, including parts and subassemblies, that have not been or will not be used during the production and assembly of all other engines of that family, unless the Executive Officer approves the modification.

(3) Calculation of the Cumulative Sum Statistic

(A) Each engine manufacturer must review the test results using the following procedure:

~~(i)~~1. Manufacturers must construct the following Cumulative Sum Equation for each regulated pollutant for each engine family. Test results used to calculate the variables in the Cumulative Sum Equation must be final deteriorated test results as defined in paragraph (c)(4)(C).

$$C_i = \max\,[0 \text{ or } (C_{i-1} + X_i - (\text{FEL} + \text{F}))]$$

where:

C_i = The current Cumulative Sum statistic

C_{i-1} = The previous Cumulative Sum statistic. Prior to any testing, the Cumulative Sum statistic = 0 (i.e. $C_0 = 0$)

X_i = The current emission test result for an individual engine

FEL = Family Emission Level, or emission standard if no Family Emission level is established

F = $0.25 \times \sigma$

After each test, C_i is compared to the action limit, H, the quantity that the Cumulative Sum statistic must exceed, in two consecutive tests, before the engine family may be determined to be in noncompliance for purposes of paragraphs (c)(3)(A)~~(iv)~~4. and (c)(3)(A)~~(v)~~5.

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H = The Action Limit. It is 5.0 x σ, and is a function of the standard deviation, σ,.

σ = is the sample standard deviation and is recalculated after each test.

~~(ii)~~2. After each engine is tested, the Cumulative Sum statistic must be promptly updated according to the Cumulative Sum Equation in paragraph ~~(i)~~1 of this section.

~~(iii)~~3. If, at any time during the model year, a manufacturer amends the application for certification for an engine family as specified in Part I, Sections 28 and 29 of the 1995-2004 Emission Standards and Test Procedures, or Subpart B, §90.120 and §90.122 of the 2005 and Later Emission Standards and Test Procedures, as applicable, by performing an engine family modification (i.e., a change such as a running change involving a physical modification to an engine, a change in specification or setting, the addition of a new configuration, or the use of a different deterioration factor), all previous sample size and Cumulative Sum statistic calculations for the model year will remain unchanged.

~~(iv)~~4. A failed engine is one whose final deteriorated test results pursuant to paragraph (c)(4)(C), for a regulated pollutant exceeds the emission standard or the FEL, as applicable, for that pollutant.

~~(v)~~5. An engine family may be determined to be in noncompliance, if at any time throughout the model year, the Cumulative Sum statistic, C_i, for, a regulated pollutant is greater than the action limit, H, for two consecutive tests.

~~(vi)~~6. The engine manufacturer must perform a minimum of two tests per engine family per quarter, regardless of whether the conditions of paragraph (c)(2)(B)~~(iv)~~4 have been met.

~~(vii)~~7. All results from previous quarters of the same model year must be included in the on-going Cumulative Sum analysis, provided that the engine family has not failed (e.g., if three engines of a family were tested in the first quarter, the first test of the second quarter would be considered as the fourth test).

~~(viii)~~8. If the Cumulative Sum analysis indicates that an engine family has failed, the engine manufacturer must notify the Chief of the Mobile Source Operations Division, in writing and by telephone, within ten working days. Corrective action will be taken as noted in paragraph (d)(5), below.

~~(ix)~~9. If a manufacturer performs corrective action on a failed engine family and then resumes production, all previous tests will be void, and Cumulative Sum analysis will begin again with the next test.

(B) At the end of the quarter, or when the Cumulative Sum analysis indicates that a decision has been made, the manufacturer must provide all the data accumulated during the quarter.

(4) Calculation and Reporting of Test Results.

(A) Initial test results are calculated following the applicable test procedure specified in "California Exhaust Emission Standards and Test Procedures for 1995-2004 ~~and Later~~ Small Off-Road Engines" or "California Exhaust Emission Standards and Test Procedures for 2005 and Later Small

Off-Road Engines," as applicable. The manufacturer rounds these results, in accordance with ASTM E29-93a, to the number of decimal places contained in the applicable emission standard expressed to one additional significant figure. (ASTM E29-93a has been incorporated by reference)

(B) Final test results are calculated by summing the initial test results derived in paragraph (A) of this section for each test engine, dividing by the number of tests conducted on the engine, and rounding in accordance with ASTM E29-93a to the same number of decimal places contained in the applicable standard expressed to one additional significant figure.

(C) The final deteriorated test results for each test engine are calculated by applying the appropriate deterioration factors, derived in the certification process for the engine family, to the final test results, and rounding in accordance with ASTM E29-93a to the same number of decimal places contained in the applicable standard expressed to one additional significant figure.

(D) If, at any time during the model year, the Cumulative Sum statistic exceeds the applicable action limit, H, in two consecutive tests, the engine family may be determined to be in noncompliance and the manufacturer must notify the Chief of the Mobile Source Operations Division and the Manager of the ~~New Vehicle Audit~~ Off-Road Certification/Audit Section, 9528 Telstar Avenue, El Monte, CA, 91731, within ten working days of such exceedance by the Cumulative Sum statistic.

(E) Within 45 calendar days of the end of each quarter, each engine manufacturer must submit to the Executive Officer a report that includes the following information unless the Executive Officer has approved the omission of some of the information:

~~(i)~~1. The location and description of the manufacturer's or other's exhaust emission test facilities that were utilized to conduct testing reported pursuant to this section;

~~(ii)~~2. Total production and sample sizes, N and n, for each engine family;

~~(iii)~~3. The applicable emissions standards or Family Emissions Levels for each engine family;

~~(iv)~~4. A description of the process to obtain engines on a random basis;

~~(v)~~5. A description of the test engines or equipment (i.e., date of test, engine family, engine size, engine or equipment identification number, fuel system, dynamometer power absorber setting in horsepower or kilowatts, engine code or calibration number, and test location);

~~(vi)~~6. The date of the end of the engine manufacturer's model year production for each engine family;

~~(vii)~~7. For each test conducted,

~~1~~a. A description of the test engine, including:

~~(I)~~(i.) Configuration and engine family identification,

~~(II)~~(ii.) Year, make, and build date,

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~~(III)~~(iii.) Engine identification number and explanation of the identification code, and
~~(IV)~~(iv.) Number of hours of service accumulated on engine prior to testing;

~~2~~b. Location where service accumulation was conducted and description of accumulation procedure and schedule;

~~3~~c. Test number, date, test procedure used, initial test results before and after rounding, and final test results for all exhaust emission tests, whether valid or invalid, and the reason for invalidation, if applicable;

4d. The exhaust emission data for PM, CO, NO_x and HC (or NMHC, as applicable) for each test engine or equipment. The data reported must provide two significant figures beyond the number of significant figures in the applicable emission standard;

~~5~~e. The retest emissions data, as described in Paragraph 4 above for any engine or unit of equipment failing the initial test, and description of the corrective measures taken, including specific components replaced or adjusted;

~~6~~f. A complete description of any adjustment, modification, repair, preparation, maintenance, and/or testing that was performed on the test engine, was not reported pursuant to any other part of this article, and will not be performed on all other production engines;

~~7~~g. A Cumulative Sum analysis, as required in paragraph (c)(3), of the production line test results for each engine family;

~~8~~h. Any other information the Executive Officer may request relevant to the determination whether the new engines being manufactured by the manufacturer do in fact conform with the regulations with respect to which the Executive Order was issued;

~~(viii)~~8. For each failed engine as defined in paragraph (c)(3)(A)~~(iv)~~4., a description of the remedy and test results for all retests;

~~(ix)~~9. Every aborted test data and reason for the aborted test;

~~(x)~~10. The start and stop dates of batch-produced engine family production;

~~(xi)~~11. The required information for all engine families in production during the quarter regardless of sample size; and

(F) Each manufacturer must submit a copy of the report that has been stored (e.g., computer disc), or may be transmitted, in an electronically digitized manner, and in a format that is specified by the Executive Officer. This electronically based submission is in addition to the written submission of the report.

(d) Procedures Applicable to All Production Line Testing.

(1) Standards and Test Procedures. The emission standards, exhaust sampling and analytical procedures are those described in the Emission Standards and Test Procedures, and are applicable to engines tested only for

exhaust emissions. The production line test procedures are specified in conjunction with the Emission Standards and Test Procedures. An engine is in compliance with these production line standards and test procedures only when all portions of these production line test procedures and specified requirements from the Emission Standards and Test Procedures are fulfilled, except for the provisions as follows:

(A) A handheld equipment engine manufacturer, (or~~, for the 2000 and subsequent model year~~, a manufacturer of 2000 through 2004 model year engines 65 cc or below, or a manufacturer of 2005 and subsequent model years engines 80 cc or below,) may request that the Executive Officer allow the values of rated engine power and speed determined in the engine family certification be used in lieu of the determination of the engine power and speed of a production line engine. This request must include a specification of the particular power absorption device (e.g., dynamometer, water brake, etc.) used to apply the test load to the production engines. An engine manufacturer must request and must receive approval from the Executive Officer for this allowance before the production line tests are conducted. The engine manufacturer should establish equivalent assurance of compliance by providing emission data from a statistically valid sample of engines for comparison between the proposed procedures and the required procedures.

(B) Any adjustable engine parameters must be set to any value or position that is within the range available to the ultimate purchaser.

(2) Air Resources Board (ARB) personnel and mobile laboratories must have access to engine or equipment assembly plants, distribution facilities, and test facilities for the purpose of engine selection, testing, and observation. Scheduling of access must be arranged with the designated engine manufacturer's representative and must not unreasonably disturb normal operations (See Section 31 of the 1995-2004 Emission Standards and Test Procedures or Section 90.126 of the 2005 and Later Emission Standards and Test Procedures, as applicable).

(3) Engine Sample Selection

(A) The engine manufacturer must randomly select engines according to (b)~~(3)~~(2) or (c)(2), as applicable, from each engine family for production line testing. The engines must be representative of the engine manufacturer's California sales. Each engine will be selected from the end of the assembly line. All engine models within the engine family must be included in the sample pool. Each selected engine for quality-audit testing must pass the inspection test, by being equipped with the appropriate emission control systems certified by the ARB. The procedure for randomly selecting engines or units of equipment must be submitted to the Chief, Mobile Source Operations Division, 9528 Telstar Avenue, El Monte, CA, 91731, prior to the start of production for the first year of production.

(B) ~~(i)~~1. Prior to the beginning of the 2000 model year, if an engine manufacturer cannot provide actual California sales data, it must provide

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its total production and an estimate of California sales at the end of the model year. The engine manufacturer must also provide supporting material for its estimate.

~~(ii)~~2. For the 2000 and later model years, engine manufacturers must provide actual California sales, or other information acceptable to the Executive Officer, including, but not limited to, an estimate based on market analysis and federal production or sales.

(4) Engine Preparation and Preconditioning

(A) No emissions tests may be performed on an engine prior to the first production line test.

(B) The engine or unit of equipment must be tested after the engine manufacturer's recommended break-in period. The engine manufacturer must submit to the Executive Officer the schedule for engine break-in and any changes to the schedule with each quarterly report. This schedule must be adhered to for all production line testing within an engine family and subgroup or engine family and assembly plant as appropriate.

(C) If an engine or unit of equipment is shipped to a remote facility for production line testing, and adjustment or repair is necessary because of such shipment, the engine manufacturer must perform the necessary adjustments or repairs only after the initial test of the engine or equipment. Engine manufacturers must report to the Executive Officer in the quarterly report, all adjustments or repairs performed on engines or equipment prior to each test. In the event a retest is performed, a request may be made to the Executive Officer, within ten days of the production quarter, for permission to substitute the after-repair test results for the original test results. The Executive Officer will either affirm or deny the request by the engine manufacturer within ten working days from receipt of the request.

(D) If an engine manufacturer determines that the emission test results of an engine or unit of equipment are invalid, the engine or equipment must be retested. Emission results from all tests must be reported. The engine manufacturer must include a detailed report on the reasons for each invalidated test in the quarterly report.

(5) Manufacturer Notification of Failure

(A) The Executive Officer will notify the engine manufacturer that the engine manufacturer may be subject to revocation or suspension of the Executive Order authorizing sales and distribution of the noncompliant engines in the State of California, or being enjoined from any further sales, or distribution, of the noncompliant engines in the State of California pursuant to Section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or seeking to enjoin an engine manufacturer, the Executive Officer will consider all information provided by the engine manufacturer, and other interested parties, including, but not limited to corrective actions applied to the noncompliant engine family, and for 2000 and subsequent model year engines, the availability of emissions reduction credits to remedy the failure.

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(B) The Executive Officer will notify the equipment manufacturer that the equipment manufacturer may be subject to revocation or suspension of the Executive Order authorizing sales and distribution, or being enjoined from any further sales, or distribution, of the equipment manufacturer's equipment product line(s) that are, or utilize engines that are, noncompliant with the applicable emission regulations pursuant to Section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or seeking to enjoin an equipment manufacturer, the Executive Officer will consider all information provided by interested parties, including, but not limited to corrective actions applied to the noncompliant engine family, and for 2000 and subsequent model year engines, the availability of emissions reduction credits to remedy the failure.

(6) Suspension and Revocation of Executive Orders.

(A) The Executive Order is automatically suspended with respect to any engine failing pursuant to paragraph (c)(3)(A)~~(iv)~~4. or (b)(4)(D) effective from the time that testing of that engine is completed.

(B) The Executive Officer may suspend the Executive Order for an engine family that is determined to be in noncompliance pursuant to paragraph (c)(3)(A)~~(v)~~5. or (b)(4)(C). This suspension will not occur before fifteen days after the engine family is determined to be in noncompliance. Before revoking or suspending the Executive Order authorizing sales and distribution of the applicable noncompliant engine families or subgroups within the State of California, or seeking to enjoin an engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer and other interested parties, including the availability of emissions reductions credits to remedy the failure.

(C) If the results of testing pursuant to these regulations indicate that engines of a particular family produced at one plant of a manufacturer do not conform to the regulations with respect to which the Executive Order was issued, the Executive Officer may suspend the Executive Order with respect to that family for engines manufactured by the manufacturer at all other plants.

(D) Notwithstanding the fact that engines described in the application for certification may be covered by an Executive Order, the Executive Officer may suspend such Executive Order immediately in whole or in part if the Executive Officer finds any one of the following infractions to be substantial:

~~(i)~~1. The manufacturer refuses to comply with any of the requirements of this section;

~~(ii)~~2. The manufacturer submits false or incomplete information in any report or information provided to the Executive Officer under this section;

~~(iii)~~3. *The manufacturer renders inaccurate any test data* submitted under this section;

~~(iv)~~4. An ARB enforcement officer is denied the opportunity to conduct activities authorized in this section and a warrant or court order is presented to the manufacturer or the party in charge of the facility in question;

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~~(v)~~5. An ARB enforcement officer is unable to conduct activities authorized in paragraph (d)(2) of this section because a manufacturer has located its facility in a foreign jurisdiction where local law prohibits those activities.

(E) The Executive Officer will notify the manufacturer in writing of any suspension or revocation of an Executive Order in whole or in part. A suspension or revocation is effective upon receipt of the notification or fifteen days from the time an engine family is determined to be in noncompliance pursuant to paragraph (c)(3)(A)~~(v)~~5. or (b)(4)(C), whichever is later, except that the Executive Order is immediately suspended with respect to any failed engines as provided for in paragraph (A) of this section.

(F) The Executive Officer may revoke an Executive Order for an engine family after the Executive Order has been suspended pursuant to paragraph (B) or (C) of this section if the proposed remedy for the nonconformity, as reported by the manufacturer to the Executive Officer, is one requiring a design change or changes to the engine and/or emission control system as described in the application for certification of the affected engine family.

(G) Once an Executive Order has been suspended for a failed engine, as provided for in paragraph (A) of this section, the manufacturer must take the following actions before the Executive Order is reinstated for that failed engine:

~~(i)~~1. Remedy the nonconformity;

~~(ii)~~2. Demonstrate that the engine conforms to the emission standards by retesting the engine in accordance with these regulations; and

~~(iii)~~3. Submit a written report to the Executive Officer, after successful completion of testing on the failed engine, that contains a description of the remedy and test results for each engine in addition to other information that may be required by this part.

(H) Once an Executive Order for a failed engine family has been suspended pursuant to paragraph (B), (C) or (D) of this section, the manufacturer must take the following actions before the Executive Officer will consider reinstating the Executive Order:

~~(i)~~1. Submit a written report to the Executive Officer that identifies the reason for the noncompliance of the engines, describes the proposed remedy, including a description of any proposed quality control and/or quality assurance measures to be taken by the manufacturer to prevent future occurrences of the problem, and states the date on which the remedies will be implemented; and

~~(ii)~~2. Demonstrate that the engine family for which the Executive Order has been suspended does in fact comply with the regulations of this part by testing as many engines as needed so that the Cumulative Sum statistic, as calculated in paragraph (c)(3)(A)~~(i)~~1., falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(4)(C) remains below the emission standard or FEL, as applicable. Such testing must comply with the provisions of this section. If the manufacturer elects to continue testing individual engines after suspension of an Executive Order, the

Executive Order is reinstated for any engine actually determined to be in conformance with the emission standards through testing in accordance with the applicable test procedures, provided that the Executive Officer has not revoked the Executive Order pursuant to paragraph (F) of this section.

(I) Once the Executive Order has been revoked for an engine family, if the manufacturer desires to continue introduction into commerce of a modified version of that family, the following actions must be taken before the Executive Officer may issue an Executive Order for that modified family:

~~(i)~~1. If the Executive Officer determines that the proposed change(s) in engine design may have an effect on emission performance deterioration, the Executive Officer will notify the manufacturer, within five working days after receipt of the report in paragraph (H)~~(i)~~1. of this section, whether subsequent testing under this section will be sufficient to evaluate the proposed change or changes or whether additional testing will be required; and

~~(ii)~~2. After implementing the change or changes intended to remedy the nonconformity, the manufacturer must demonstrate that the modified engine family does in fact conform with the regulations of this section by testing as many engines as needed from the modified engine family so that the Cumulative Sum statistic, as calculated in paragraph (c)~~(6)~~(3)(A)~~(i)~~1. falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(4)~~(C)~~ remains below the emission standard or FEL, as applicable. When both of these requirements are met, the Executive Officer will reissue the Executive Order or issue a new Executive Order, as the case may be, to include that family. As long as the Cumulative Sum statistic remains above the action limit, or the average emissions from the Quality-Audit testing exceeds the emission standard or FEL, as applicable, the revocation remains in effect.

(J) At any time subsequent to a suspension of an Executive Order for a test engine pursuant to paragraph (A) of this section, but not later than 15 days (or such other period as may be allowed by the Executive Officer) after notification of the Executive Officer's decision to suspend or revoke an Executive Order in whole or in part pursuant to paragraphs (B), (C), or (F) of this section, a manufacturer may request a hearing as to whether the tests have been properly conducted or any sampling methods have been properly applied.

(K) Any suspension of an Executive Order under paragraph (D) of this section:

~~(i)~~1. must be made only after the manufacturer concerned has been offered an opportunity for a hearing conducted in accordance with all applicable requirements and;

~~(ii)~~2. need not apply to engines no longer in the possession of the manufacturer.

(L) After the Executive Officer suspends or revokes an Executive Order pursuant to this section and prior to the commencement of a hearing, if the manufacturer demonstrates to the Executive Officer's satisfaction that the decision to suspend or revoke the Executive Order was based on erroneous information, the Executive Officer will reinstate the Executive Order.

(M) To permit a manufacturer to avoid storing non-test engines while conducting subsequent testing of the noncomplying family, a manufacturer may request that the Executive Officer conditionally reinstate the Executive Order for that family. The Executive Officer may reinstate the Executive Order subject to the following condition: the manufacturer must commit to recall all engines of that family produced from the time the Executive Order is conditionally reinstated if the Cumulative Sum statistic does not fall below the action limit, or the average emissions from the Quality-Audit testing remains above the emission standard or FEL, as applicable, and must commit to remedy any nonconformity at no expense to the owner.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2408. Emission Reduction Credits – Certification Averaging, Banking, and Trading Provisions.

(a) Applicability. The requirements of this section are applicable to all small off-road engines produced in the 2000 and later model years. Engines certified to the voluntary standards in subsection 2403(b)(2) are not eligible for participation in this program. Participation in the averaging, banking and trading program is voluntary, but if a manufacturer elects to participate, it must do so in compliance with the regulations set forth in this section. The provisions of this section are limited to $HC+NO_x$ (or $NMHC+NO_x$, as applicable) and Particulate Matter emissions.

(b) General provisions.

(1) The certification averaging, banking, and trading provisions for $HC+NO_x$ and Particulate Matter emissions from eligible engines are described in this section.

(2) An engine family may use the averaging, banking and trading provisions for $HC+NO_x$ and $NMHC+NO_x$ and Particulate Matter emissions if it is subject to regulation under this article with certain exceptions specified in paragraph (3) of this section. $HC+NO_x$ and Particulate Matter credits are interchangeable subject to the limitations on credit generation, credit usage, cross-class averaging and other provisions described in this section.

(3) A manufacturer must not include in its calculation of credit generation and may exclude from its calculation of credit usage, any new engines that are exported from California, or that are not destined for California, unless the manufacturer has reason or should have reason to believe that such engines have been or will be imported in a piece of equipment.

(4) For an engine family using credits, a manufacturer may, at its option, include its entire production of that engine family in its calculation of credit usage for a given model year.

(5) A manufacturer may certify engine families at Family Emission Limits (FELs) above or below the applicable emission standard subject to the limitation in paragraph (6) of this section, provided the summation of the manufacturer's projected balance of credits from all credit transactions for each engine class in a given model year is greater than or equal to zero, as determined under paragraph (f).

(A) A manufacturer of an engine family with an FEL exceeding the applicable emission standard must obtain positive emission credits sufficient to address the associated credit shortfall via averaging, banking, or trading.

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(B) An engine family with an FEL below the applicable emission standard may generate positive emission credits for averaging, banking, or trading, or a combination thereof.

(C) In the case of a production line test failure, credits may be used to cover subsequent production of engines for the family in question if the manufacturer elects to recertify to a higher FEL. Credits may be used to remedy a nonconformity determined by production line testing or new engine compliance testing, at the discretion of the Executive Officer.

(D) In the case of a production line testing failure pursuant to section 2407, a manufacturer may revise the FEL based upon production line testing results obtained under section 2407 and upon Executive Officer approval. The manufacturer may use certification credits to cover both past production and subsequent production as needed.

(6) No engine family may have an FEL that is greater than the emission levels in the table below.

~~(A) 180 g/bhp-hr HC+NO~~$_x$ ~~for engines 0-65 cc, inclusive,~~

~~(B) 24.1 g/bhp-hr HC+NO~~$_x$ ~~for engines greater than 65 cc and less than 225 cc, or~~

~~(C) 20 g/bhp-hr HC+NO~~$_x$ ~~for engines greater than 225 cc.~~

Model Year	Displacement Category	$HC+NO_x$ level	
		g/kW-hr	g/bhp-hr
2000-2004	0-65 cc, inclusive		180
	> 65 cc - < 225 cc		24.1
	≥ 225 cc		20
2005 and subsequent	< 50 cc	241.4	
	50-80 cc, inclusive	186	
2005-2006	> 80 cc- < 225 cc	32.3	
	≥ 225 cc	26.8	
2007	> 80 cc- < 225 cc	16.1	
	≥ 225 cc	26.8	
2008 and subsequent	> 80 cc- < 225 cc	16.1	
	≥ 225 cc	12.1	

(7) Manufacturers must demonstrate compliance under the averaging, banking, and trading provisions for a particular model year by 270 days after the end of the model year. An engine family generating negative credits for which the manufacturer does not obtain or generate an adequate number of positive credits by that date from the same or previous model year engines will violate the conditions of the Executive Order. The Executive Order may be voided *ab initio* for this engine family.

(c) Averaging.

(1) Negative credits from engine families with FELs above the applicable emission standard must be offset by positive credits from engine

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families having FELs below the applicable emission standard, as allowed under the provisions of this section. Averaging of credits in this manner is used to determine compliance under paragraph (f)(2).

(2) Subject to the limitations above, credits used in averaging for a given model year may be obtained from credits generated in the same model year by another engine family, credits banked in previous model years, or credits of the same or previous model year obtained through trading. The restrictions of this paragraph notwithstanding, credits from a given model year may be used to address credit needs of previous model year engines as allowed under paragraph (f)(3).

(d) Banking.

(1) Beginning with the 1999 model year, a manufacturer of an engine family with an FEL below the applicable emission standard for 2006 and subsequent years may bank credits in that model year for use in averaging and trading. Negative credits may be banked only according to the requirements of paragraph (f)(3) of this section.

(2) A manufacturer may bank emission credits only after the end of the model year and after ARB has reviewed the manufacturer's end-of-year reports. During the model year and before submittal of the end-of-year report, credits originally designated in the certification process for banking will be considered reserved and may be redesignated for trading or averaging in the end-of-year report and final report.

(3) Credits declared for banking from the previous model year that have not been reviewed by ARB may be used in averaging or trading transactions. However, such credits may be revoked at a later time following ARB review of the end-of-year report or any subsequent audit actions.

(e) Trading.

(1) An engine manufacturer may exchange emission credits with other engine manufacturers in trading.

(2) Credits for trading can be obtained from credits banked in previous model years or credits generated during the model year of the trading transaction.

(3) Traded credits can be used for averaging or banking.

(4) Traded credits are subject to the limitations on use for past model years, and the use of credits from early banking as set forth in paragraph (c)(2).

(5) In the event of a negative credit balance resulting from a transaction, both the buyer and the seller are liable, except in cases involving fraud. The Executive Officer may void Executive Orders of all engine families participating in a negative trade *ab initio*.

(f) Credit calculation and manufacturer compliance with emission standards.

(1) For each engine family, $HC+NO_x$ and Particulate Matter certification emission credits (positive or negative) are to be calculated according to the following equation and rounded to the nearest gram. Consistent units are to be used throughout the equation.

Credits = (Standard – FEL) x Sales x Power x EDP x Load Factor

Where:
Standard = the current and applicable small off-road engine $HC+NO_x$ ($NMHC+NO_x$) or Particulate Matter emission standard ~~in grams per brake-horsepower hour~~ as determined in Section 2403.
FEL = the family emission limit for the engine family in grams per brake-horsepower hour or g/kW-hr as applicable.
Sales = eligible sales as defined in section 2401. Annual sales projections are used to project credit availability for initial certification. Actual sales volume is used in determining actual credits for end-of-year compliance determination.
Power = the sales weighted maximum modal power, in horsepower or kilowatts as applicable. This is determined by multiplying the maximum modal power of each configuration within the family by its eligible sales, summing across all configurations and dividing by the eligible sales of the entire family. Manufacturers may use an alternative if approved by the Executive Officer.
EDP = the Emissions Durability Period for which the engine family was certified.
Load Factor = For Test Cycle A and Test Cycle B, the Load Factor = 47% (i.e., 0.47). For Test Cycle C, the Load Factor = 85% (i.e.,0.85). For approved alternate test procedures, the load factor must be calculated according to the following formula:

$$\sum_{i=1}^{n}(\%\text{MTT mode}_i)\times(\%\text{MTS mode}_i)\times(\text{WF mode}_i)$$

Where:
$\%\text{MTT mode}_i$ = percent of the maximum torque for mode i
$\%\text{MTS mode}_i$ = percent of the maximum engine rotational speed for mode i
WF mode_i = the weighting factor for mode i

(2) Manufacturer compliance with the emission standard is determined on a corporate average basis at the end of each model year. A manufacturer is in compliance when the sum of positive and negative emission

credits it holds is greater than or equal to zero, except that the sum of positive and negative credits for a given class may be less than zero as allowed under paragraph (3) of this section.

(3) If, as a result of production line testing as required in section 2407, an engine family is determined to be in noncompliance, the manufacturer may raise its FEL for past and future production as necessary. Further, a manufacturer may carry a negative credit balance (known also as a credit deficit) for the subject class and model year forward to the next model year. The credit deficit may be no larger than that created by the nonconforming family. If the credit deficit still exists after the model year following the model year in which the nonconformity occurred, the manufacturer must obtain and apply credits to offset the remaining credit deficit at a rate of 1.2 grams for each gram of deficit within the next model year. The provisions of this paragraph are subject to the limitations in paragraph (4) of this section.

(4) Regulations elsewhere in this section notwithstanding, if an engine manufacturer experiences two or more production line testing failures pursuant to the regulations in section 2407 of this article in a given model year, the manufacturer may raise the FEL of previously produced engines only to the extent that such engines represent no more than 10% of the manufacturer's total eligible sales for that model year. For any additional engines determined to be in noncompliance, the manufacturer must conduct offsetting projects approved in advance by the Executive Officer.

(5) If, as a result of production line testing under section 2407, a manufacturer desires to lower its FEL, it may do so subject to Executive Officer approval and demonstration that the family would meet the new FEL in the production line testing using the existing data.

(6) Except as allowed at paragraph (c) of this section, when a manufacturer is not in compliance with the applicable emission standard by the date 270 days after the end of the model year, considering all credit calculations and transactions completed by then, the manufacturer will be in violation of these regulations and the Executive Officer may, void *ab initio* the Executive Orders of engine families for which the manufacturer has not obtained sufficient positive emission credits.

(g) Certification Using Credits.

(1) In the application for certification a manufacturer must:

(A) Submit a statement that the engines for which certification is requested will not, to the best of the manufacturer's belief, cause the manufacturer to be in noncompliance under paragraph (f)(2) when all credits are calculated for all the manufacturer's engine families.

(B) Declare an FEL for each engine family for $HC+NO_x$ ($NMHC+NO_x$) and Particulate Matter, if applicable. The FEL must have the same number of significant digits as the emission standard.

(C) Indicate the projected number of credits generated/needed for this family; the projected applicable eligible sales volume and the values required to calculate credits as given in paragraph (f).

(D) Submit calculations in accordance with paragraph (f) of projected emission credits (positive or negative) based on production projections for each family.

(E) ~~(i)~~1. If the engine family is projected to generate negative emission credits, state specifically the source (manufacturer/engine family or reserved) and quantity of the credits necessary to offset the credit deficit according to projected production.

~~(ii)~~2. If the engine family is projected to generate credits, state specifically the recipient (manufacturer/engine family or reserved) and quantity of the credits used to offset a deficit, banked, or traded, according to where the projected credits will be applied.

(2) The manufacturer may supply the information required above in subparagraphs (C), (D), and (E) by use of a spreadsheet detailing the manufacturer's annual production plans and the credits generated or consumed by each engine family.

(3) All Executive Orders issued are conditional upon manufacturer compliance with the provisions of this section both during and after the model year of production.

(4) Failure to comply with all provisions of this section will be considered to be a failure to satisfy the conditions upon which the Executive Order was issued, and the Executive Order may be determined to be void *ab initio*.

(5) The manufacturer bears the burden of establishing to the satisfaction of the Executive Officer that the conditions upon which the Executive Order was issued were satisfied or waived.

(6) Projected credits based on information supplied in the certification application may be used to obtain an Executive Order. However, any such credits may be revoked based on review of end-of-year reports, follow-up audits, and any other verification steps considered appropriate by the Executive Officer.

(h) Maintenance of records.

(1) The manufacturer must establish, maintain, and retain the following adequately organized and indexed records for each engine family:

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(A) ARB engine family identification code,

(B) Family Emission Limit (FEL) or FELs where FEL changes have been implemented during the model year,

(C) Maximum modal power for each configuration sold or an alternative approved by the Executive Officer.

(D) Projected sales volume for the model year, and

(E) Records appropriate to establish the quantities of engines that constitute eligible sales for each power rating for each FEL.

(2) Any manufacturer producing an engine family participating in trading reserved credits must maintain the following records on a quarterly basis for each such engine family:

(A) The engine family,

(B) The actual quarterly and cumulative applicable production/sales volume,

(C) The values required to calculate credits as given in paragraph (f),

(D) The resulting type and number of credits generated/required,

(E) How and where credit surpluses are dispersed, and

(F) How and through what means credit deficits are met.

(3) The manufacturer must retain all records required to be maintained under this section for a period of eight years from the due date for the end-of-model year report. Records may be retained as hard copy or reduced to microfilm, diskettes, and so forth, depending on the manufacturer's record retention procedure; provided, that in every case all information contained in the hard copy is retained.

(4) Nothing in this section limits the Executive Officer's discretion in requiring the manufacturer to retain additional records or submit information not specifically required by this section.

(5) Pursuant to a request made by the Executive Officer, the manufacturer must submit to the Executive Officer the information that the manufacturer is required to retain.

(6) ARB may void ab initio the Executive Order for an engine family for which the manufacturer fails to retain the records required in this section or to provide such information to the Executive Officer upon request.

(i) End-of-year and final reports.

(1) End-of-year and final reports must indicate the engine family, the actual sales volume, the values required to calculate credits as given in paragraph (f), and the number of credits generated/required. Manufacturers must also submit how and where credit surpluses were dispersed (or are to be

banked) and/or how and through what means credit deficits were met. Copies of contracts related to credit trading must be included or supplied by the broker, if applicable. The report must include a calculation of credit balances to show that the credit summation for each class of engines is equal to or greater than zero (or less than zero in cases of negative credit balances as permitted in paragraph (f)(3).

(2) The calculation of eligible sales (as defined in section 2401) for end-of-year and final reports must be based on the location of the point of first retail sale (for example, retail customer or dealer) also called the final product purchase location. Upon advance written request, the Executive Officer will consider other methods to track engines for credit calculation purposes, such as shipments to distributors of products intended for sale in California, that provide high levels of confidence that eligible sales are accurately counted.

(3) (A) End-of-year reports must be submitted within 90 days of the end of the model year to: Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar, El Monte, CA 91731.

(B) Unless otherwise approved by the Executive Officer, final reports must be submitted within 270 days of the end of the model year to: Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar, El Monte, CA 91731.

(4) Failure by a manufacturer to submit any end-of-year or final reports in the specified time for any engines subject to regulation under this section is a violation of Section 2403 for each engine.

(5) A manufacturer generating credits for banking only who fails to submit end-of-year reports in the applicable specified time period (90 days after the end of the model year) may not use the credits until such reports are received and reviewed by ARB. Use of projected credits pending ARB review is not permitted in these circumstances.

(6) Errors discovered by ARB or the manufacturer in the end-of-year report, including errors in credit calculation, may be corrected in the final report.

(7) If ARB or the manufacturer determines that a reporting error occurred on an end-of-year or final report previously submitted to ARB under this section, the manufacturer's credits and credit calculations must be recalculated. Erroneous positive credits will be void except as provided in paragraph (h) of this section. Erroneous negative credit balances may be adjusted by ARB.

(8) If within 270 days of the end of the model year, ARB review determines a reporting error in the manufacturer's favor (that is, resulting in an increased credit balance) or if the manufacturer discovers such an error within

270 days of the end of the model year, ARB must restore the credits for use by the manufacturer.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2409. Emission Reduction Credits – Production Credit Program for New Engines.

(a) Applicability. The 1998 model year and later small off-road engines subject to the provisions of this article are eligible to participate in the production emission credit program described in this section for HC $+NO_x$ (or $NMHC+NO_x$, as applicable) and Particulate Matter emissions.

(b) General provisions.

(1) The production credit program for eligible small off-road engines is described in this section. Participation in this program is voluntary.

(2) Any 2000 model year or later engine family subject to the provisions of this article is eligible to participate in the production credit program described in this section. Any 1998 or 1999 model year engine family subject to the provisions of this article is eligible to participate in the production emissions credit program described in this section provided it conforms with the requirements of section 2403.

(3) Credits generated and used in the certification averaging, banking, and trading program pursuant to the provisions of section 2408 may not be used in the production credit program.

(4) An engine family with a compliance level, as determined by production line testing pursuant to section 2407, below the applicable FEL to which the engine family is certified may generate emission credits for averaging, banking, or trading in the production credit program.

(5) Positive credits generated in a given model year may be used in that model year and/or in any subsequent model year.

(c) Averaging.

(1) A manufacturer may use averaging across engine families to demonstrate a zero or positive credit balance for a model year. Positive credits to be used in averaging may be obtained from credits generated by another engine family of the same model year, credits banked in previous model years, or credits obtained through trading.

(2) ~~Credits used to demonstrate a zero or positive credit balance must be used at a rate of 1.1 grams to 1 gram.~~ Production emission credits used for the certification emission credit program must be discounted 1.1 grams to 1 gram.

(d) Banking.

(1) A manufacturer of an engine family with a production compliance level below the FEL to which the engine family is certified for a given model year may bank positive production credits for that model year for use in certification averaging, trading, or, at the Executive Officer's discretion, to remedy noncompliance of another engine family.

(2) Unless otherwise approved by the Executive Officer, a manufacturer that generates positive production credits must wait 30 days after it has both completed production testing for the model year for which the credits were generated and submitted the report required by paragraph (g)(1) before it may bank credits for use in future averaging or trading. During the 30 day period, the Executive Officer will work with the manufacturer to correct any error in calculating banked credits, if necessary.

(e) Trading.

(1) An engine manufacturer may exchange positive production emission credits with other engine manufacturers through trading.

(2) Production credits for trading can be obtained from credits banked for model years prior to the model year of the engine family requiring production credits.

(3) Traded production credits can be used for certification averaging or banking.

(4) Unless otherwise approved by the Executive Officer, a manufacturer that generates positive production credits must wait 30 days after it has both completed production testing for the model year for which the credits were generated and submitted the report required by paragraph (g)(1) before it may transfer credits to another manufacturer or broker.

(5) In the event of a negative credit balance resulting from a transaction, both the buyer and the seller are liable, except in cases involving fraud. Engine families participating in a trade that leads to a negative credit balance may be subject to suspension or revocation of the Executive Order if the engine manufacturer having the negative credit balance is unable or unwilling to obtain sufficient credits in the time allowed.

(f) Credit calculation. For each participating engine family, and for each regulated pollutant ($HC+NO_x$ ($NMHC+NO_x$)~~, CO~~ and Particulate Matter) emission credits (positive or negative) are to be calculated according to the following equation and rounded to the nearest gram. Consistent units are to be used throughout the equation:

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Credits = (FEL – CL) × Sales × Power × EDP × Load Factor

Where:

FEL = The applicable Family Emission level to which the engine family was certified.

CL = compliance level of the deteriorated production line testing results for the subject pollutant in g/bhp-hr or g/kW-hr as applicable.

Sales = sales or eligible sales as defined in section 2401.

Power = *the sales weighted maximum modal power, in horsepower* or kilowatts as applicable, as calculated from the applicable test procedure as described in Section 2403. This is determined by multiplying the maximum modal power of each configuration within the family by its eligible sales, summing across all configurations and dividing by the eligible sales of the entire family. Where testing is limited to certain configurations designated by the Executive Officer, the maximum modal power for the individual configuration(s) must be used. Manufacturers may use an alternative if approved by the Executive Officer.

EDP = the Emissions Durability Period for which the engine family was certified.

Load Factor = For Test Cycle A and Test Cycle B, the Load Factor = 47% (i.e., 0.47). For Test Cycle C, the Load Factor = 85% (i.e.,0.85). For approved alternate test procedures, the load factor must be calculated according to the Load Factor formula found in paragraph (f)(1) of section 2408.

(g) Maintenance of records.

(1) Any manufacturer that is participating in the production credit program set forth in this section must establish, maintain, and retain the records required by paragraph (h) of Section 2408 with respect to its participation in the production credit program.

(2) The Executive Officer may void ab initio an Executive Order for an engine family for which the manufacturer fails to retain the records required under this section or to provide such information to the Executive Officer upon request.

(h) Reporting requirements.

(1) Any manufacturer who participates in the production credit program is required to submit a production credit report with the end of the model year production testing report required under Section 2407 within 90 days of the *end of the production testing of a given model year's engine families.* This report must show the calculation of credits from all the production testing conducted by the manufacturer for a given model year's engines. Such report must show the applications of credits, the trading of credits, the discounting of credits that are

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used and the final credit balance. The manufacturer may submit corrections to such end of model year reports in a final report for a period of up to 270 days after the end of the production testing of a given model year's engine families.

(2) The calculation of eligible sales (as defined in section 2401) for end-of-year and final reports must be based on the location of the point of first retail sale (for example, retail customer or dealer) also called the final product purchase location. Upon advance written request, the Executive Officer will consider other methods to track engines for credit calculation purposes, such as shipments to distributors of products intended for sale in California, that provide high levels of confidence that eligible sales are accurately counted.

(3) Reports must be submitted to: Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar, El Monte, CA 91731.

(4) A manufacturer that fails to submit a timely end of year report as required in paragraph (h)(1) of this section will be considered ineligible to have participated in the production credit program.

(5) If the Executive Officer or the manufacturer determines that a reporting error occurred on an end of model year report previously submitted under this section, or an engine family production testing report submitted under section 2407, the manufacturer's credits and credit calculations will be recalculated. Erroneous positive credits will be void. Erroneous negative credits may be adjusted by the Executive Officer. An update of previously submitted "point of first retail sale" information is not considered an error and no increase in the number of credits will be allowed unless an actual error occurred in the calculation of credits due to an error in the "point of first retail sale" information from the time of the original end of model year report.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

APPENDIX B: PROPOSED AMENDMENTS TO THE EXHAUST EMISSION TEST PROCEDURES

PART I

State of California
AIR RESOURCES BOARD

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1995-2004 ~~AND LATER~~ SMALL OFF-ROAD ENGINES

Adopted: March 20, 1992
Amended: April 8, 1993
Amended: August 29, 1994
Amended: May 26, 1995
Amended: May 23, 1998
Amended: January 28, 2000
Amended: ____________

NOTE: This document is printed in a style to indicate changes from the existing provisions.

All existing language in Part I-VI is indicated by plain type. All proposed additions to language in parts I-VI are indicated by underlined text. All proposed deletions to language are indicated by ~~strikeout~~. Only those portions containing the suggested modifications from the existing language are included. All other portions remain unchanged and are indicated by the symbol "* * * * *" for reference.

The numbering convention employed in this document, in order of priority, is: I.1.a.1.i.A.

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CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1995-2004 ~~AND LATER~~ SMALL OFF-ROAD ENGINES

Part I. Emission Regulations for 1995-2004 ~~and Later~~ New Small Off-Road Engines, General Provisions.

1. General Applicability.

(a) Parts I-V of these provisions apply to spark-ignition small off-road engines produced on or after January 1, 1995 and through the 2004 model year, and any equipment that uses such engines produced on or after January 1, 1995. Despite the use of the term "spark-ignition engine", Parts I-V of these provisions apply to compression-ignition small off-road engines produced on or after January 1, 1995 and prior to the 2000 model year, and any equipment that uses such engines produced on or after January 1, 1995 and prior to the 2000 model year. These provisions do not apply to all engines and equipment that fall within the scope of the preemption of Section 209(e)(1)(A) of the Federal Clean Air Act, as amended, and as defined by regulation of the Environmental Protection Agency.

* * * * *

9. Exhaust Emission Standards For 1995-2004 ~~and Later~~ Small Off-Road Engines.

(a) This section applies to small off-road engines produced on or after January 1, 1995 and through the 2004 model year.

(b) Exhaust emissions from small off-road engines manufactured for sale, sold, offered for sale, introduced, delivered or imported into California for introduction into commerce, must not exceed:

Exhaust Emission Standards
grams per brake horsepower-hour
[grams per kilowatt-hour]

Calendar Year	Engine Class(1)	Hydrocarbon plus Oxides of Nitrogen(2)	Hydrocarbon(2)	Carbon Monoxide	Oxides of Nitrogen	Particulate
1995	I	12.0	—	300	—	0.9(3)
	II	10.0	—	300	—	0.9(3)
	III(4)	—	220	600	4.0	—
	IV(4)	—	180	600	4.0	—
	V(4)	—	120	300	4.0	—
1996 to1999	I	12.0(5)	—	350	—	0.9(3)
	II	10.0(5)	—	350	—	0.9(3)
	III(4)	—	220(5)	600	4.0(5)	—
	IV(4)	—	180(5)	600	4.0(5)	—
	V(4)	—	120(5)	300	4.0(5)	—

Exhaust Emission Standards for Spark-Ignition Engines
grams per brake horsepower-hour
[grams per kilowatt-hour]

Model Year	Engine Class~~(1)~~	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen(2)	Carbon Monoxide	Particulate
2000-2001(5)	~~SI~~ 0-65 cc, inclusive	50/125/300	54 [72]	400 [536]	1.5(4) [2.0]
	~~SI~~ >65 cc - <225 cc	NA	12.0 [16.1]	350 [467]	
	~~SI~~ ≥225 cc	NA	10.0 [13.4]	350 [467]	
2002-200~~5~~4(5)	~~SI~~ 0-65 cc, inclusive	50/125/300	54 [72]	400 [536]	1.5(4) [2.0]
	~~SI~~ >65 cc - <225 cc Horizontal-Shaft Engine	125/250/500	12.0 [16.1]	410 [549]	
	~~SI~~ >65 cc - <225 cc Vertical-Shaft Engine	NA	12.0 [16.1]	350 [467]	
	~~SI~~ ≥225 cc	125/250/500	9.0 [12.0]	410 [549]	
~~2006 and subsequent(5)~~	~~SI~~ ~~0-65 cc, inclusive~~	~~50/125/300~~	~~54 [72]~~	~~400 [536]~~	~~1.5(4) [2.0]~~
	~~SI~~ ~~>65 cc - <225 cc~~	~~125/250/500~~	~~12.0 [16.1]~~	~~410 [549]~~	
	~~SI~~ ~~≥ 225 cc~~	~~125/250/500~~	~~9.0 [12]~~	~~410 [549]~~	

(1) "Class I" means small off-road engines greater than 65 cc to less than 225 cc in displacement.
"Class II" means small off-road engines greater than or equal to 225 cc in displacement.
"Class III" means small off-road engines less than 20 cc in displacement.
"Class IV" means small off-road engines 20 cc to less than 50 cc in displacement.
"Class V" means small off-road engines greater than or equal to 50 cc to 65 cc in displacement.

(2) The Executive Officer may allow gaseous-fueled (i.e., propane, natural gas) engine families, that satisfy the requirements of the regulations, to certify to either the hydrocarbon plus oxides of nitrogen or hydrocarbon emission standard, as applicable, on the basis of the non-methane hydrocarbon (NMHC) portion of the total hydrocarbon emissions.

(3) Applicable to all diesel-cycle engines.

(4) Applicable to all two-stroke engines.

(5) Engines used exclusively in snowthrowers and ice augers need not certify to or comply with the HC and NOx standards or the crankcase requirements at the option of the manufacturer.

* * * * *

APPENDIX B: PROPOSED AMENDMENTS TO THE EXHAUST EMISSION TEST PROCEDURES

PART II

State of California
AIR RESOURCES BOARD

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2005 AND LATER SMALL OFF-ROAD ENGINES

Adopted: ___________

NOTE: This document incorporates by reference 40 Code of Federal Regulations (CFR) part 90, subparts A, B, D, and E, including Appendix A and B to subpart D, and Appendix A and B to subpart E, as amended April 25, 2000, and 40 CFR Part 86, Subparts D and portions of N, as amended October 21, 1997. All language is new and set forth in standard type. Sections that have been included in their entirety are set forth with the section number and title. California provisions that replace specific federal language provisions are denoted by the words "DELETE" for the federal language and "REPLACE WITH" or "ADD" for the California language. The symbols "* * * * *" and "..." mean that the remainder of the CFR text for a specific section is not shown in these procedures but has been incorporated by reference, unchanged. CFR sections that are not listed are not part of the test procedures. If there is any conflict between the provisions of this document and the California Health and Safety Code, Division 26, or Title 13 of the California Code of Regulations, the Health and Safety Code and Title 13 apply.

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CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2005 AND LATER SMALL OFF-ROAD ENGINES

The following provisions of Part 90, Title 40, Code of Federal Regulations, as adopted or amended by the United State Environmental Protection Agency on the date listed, are adopted and incorporated herein by this reference for 2005 model year and later small off-road engines as the California Exhaust Emission Standards and Test Procedures for 2005 and Later Small Off-Road Engines, except as altered or replaced by the provisions set forth below.

PART 90 – CONTROL OF EMISSIONS FROM NONROAD SPARK-IGNITION ENGINES

SOURCE: 65 FR 24306, April 25, 2000, unless otherwise noted.

Subpart A – General

§ 90.1 Applicability.

DELETE,
REPLACE WITH:

(a) These provisions apply to 2005 and later model year spark-ignition small off-road engines, and any equipment that use such engines. These provisions do not apply to all engines and equipment that fall within the scope of the preemption of Section 209(e)(1)(A) of the Federal Clean Air Act, as amended, and as defined by regulation of the Environmental Protection Agency.

(b) Every new small off-road engine that is manufactured for sale, sold, offered for sale, introduced or delivered or imported into California for introduction into commerce and that is subject to any of the standards prescribed herein is required to be covered by an Executive Order issued pursuant to Article 1, Chapter 9, Title 13, California Code of Regulations.

§ 90.2 Effective dates.

DELETE,
REPLACE WITH:
This subpart applies to small off-road engines at or below 19 kW.

§ 90.3 Definitions.

* * * * *

ADD:
The definitions in Section 2401, Chapter 9, Title 13 of the California Code of Regulations apply with the following additions:

Act DELETE.

* * * * *

Administrator DELETE,
REPLACE WITH:
Administrator means the Executive Officer of the Air Resources Board or a designee of the Executive Officer.

* * * * *

ADD:
Certificate of Conformity means an Executive Order issued in accordance with the California Health and Safety Code, Division 26, Part 5.

Certification DELETE,
REPLACE WITH:
Certification means, with respect to new small off-road engines, obtaining an executive order for an engine family complying with the small off-road engine emission standards and requirements specified in the California Code of Regulations, Title 13, Chapter 9, Sections 2400-2409.

* * * * *

ADD:
Clean Air Act or the *Act* means California Health and Safety Code, Division 26, and corresponding regulations, except where the context indicates otherwise.

ADD:
Displacement class or *Class*, see Section 90.116(a).

* * * * *

Eligible production or U.S. production DELETE.

* * * * *

ADD:
EPA means Air Resources Board.

EPA enforcement officer DELETE,

REPLACE WITH:
EPA enforcement officer means an "ARB enforcement officer," which means any employee of the Air Resources Board so designated in writing by the Executive Officer's designee.

ADD:
Executive Order means an order issued by the Executive Officer of the Air Resources Board certifying engines for sale in California.

* * * * *

Handheld equipment engine DELETE.

ADD:
Hang-up means the situation whereby hydrocarbon molecules are absorbed, condensed, or otherwise removed from the sample flow prior to the instrument detector; and any subsequent desorption of the molecules into the sample flow when such molecules are assumed to be absent.

* * * * *

Nonroad engine DELETE,
REPLACE WITH:
Nonroad engine means an off-road engine as defined in this section.

Nonroad vehicle DELETE,
REPLACE WITH:
Nonroad vehicle means a vehicle that is powered by an off-road engine as defined in this section and that is not a motor vehicle or a vehicle used solely for competition. Nonroad vehicle also includes equipment powered by off-road engines.

* * * * *

ADD:
Off-road engine means:
(1) Except as discussed in paragraph (2) of this definition, any internal combustion engine:

(i) In or on a piece of equipment that is self-propelled or serves a dual purpose by both propelling itself and performing another function (such as garden tractors, off-highway mobile cranes, and bulldozers); or

(ii) In or on a piece of equipment that is intended to be propelled while performing its function (such as lawnmowers and string trimmers); or

(iii) That, by itself or in or on a piece of equipment, is portable or transportable, meaning designed to be and capable of being carried or moved from one location to another. Indicia of transportability include, but are not limited to, wheels, skids, carrying

handles, dolly, trailer, or platform.
(2) An internal combustion engine is not an off-road engine if:

(i) The engine is used to propel a vehicle subject to the emissions standards contained in Title 13, California Code of Regulations, Sections 1950-1978, or a vehicle used solely for competition, or is subject to standards promulgated under section 202 of the federal Clean Air Act (42 U.S.C; or

(ii) The engine is regulated by a federal New Source Performance Standard promulgated under section 111 of the 1990 Clean Air Act (42 U.S.C. 7511); or

(iii) The engine otherwise included in paragraph (1)(iii) of this definition remains or will remain at a location for more than 12 consecutive months or a shorter period of time for an engine located at a seasonal source. A location is any site at a building, structure, facility, or installation. Any engine (or engines) that replaces an engine at a location and that is intended to perform the same or similar function as the engine replaced will be included in calculating the consecutive time period. An engine located at a seasonal source is an engine that remains at a seasonal source during the full annual operating period of the seasonal source. A seasonal source is a stationary source that remains in a single location on a permanent basis (i.e., at least two years) and that operates at that single location approximately three months (or more) each year. This paragraph does not apply to an engine after the engine is removed from the location.

ADD:
Oxides of nitrogen means the sum of the nitric oxide and nitrogen dioxide contained in a gas sample as if the nitric oxide were in the form of nitrogen dioxide.

Phase 1 engine DELETE.

Phase 2 engine DELETE,
REPLACE WITH:
Phase 2 engine means any small off-road engine subject to the 2005 or later emission standards listed in Title 13, California Code of Regulations, Section 2403.

* * * * *

Small volume engine family DELETE.

Small volume engine manufacturer DELETE,
REPLACE WITH:
Small volume engine manufacturer means any engine manufacturer whose total eligible California production of small off-road engines are projected at the time of certification of a given model year to be no more than 500 engines.

Small volume equipment manufacturer DELETE.

Small volume equipment model DELETE.

ADD:
Span gas means a gas of known concentration that is used routinely to set the output level of any analyzer.

* * * * *

§ 90.4 Treatment of confidential information.

DELETE,
REPLACE WITH:
Any manufacturer may assert that some or all of the information submitted pursuant to Title 13, California Code of Regulations, Division 3, Chapter 9, Article 1 (Small Off-Road Engines) is entitled to confidential treatment as provided by Title 17, California Code of Regulations, Sections 91000-91022.

§ 90.5 Acronyms and abbreviations.

* * * * *

ADD:
C – Celsius
cc – Cubic centimeter(s)

* * * * *

ADD:
cm – Centimeter(s)

* * * * *

ADD:
EGR – Exhaust gas recirculation

* * * * *

ADD:
hr – hour

* * * * *

ADD:
in. – inch(es)
K – Kelvin
kg – Kilogram(s)

kPa – Kilopascals
kW – Kilowatt
lb – Pound(s)
m – Meter(s)

* * * * *

ADD:
N – Newton

* * * * *

ADD:
No. – Number

* * * * *

ADD:
PM – Particulate

* * * * *

ADD:
ppm – parts per million by volume
psi – Pounds per square inch
RPM – Revolutions per minute

* * * * *

ADD:
° – Degree(s)
% – Percent

§ 90.6 Table and figure numbering; position.

* * * * *

§ 90.7 Reference materials.

* * * * *

Subpart B – Emission Standards and Certification Provisions

§ 90.101 Applicability.

* * * * *

§ 90.102 Definitions.

* * * * *

§ 90.103 Exhaust emission standards.

(a) DELETE,
REPLACE WITH:
(a) (1) Exhaust emissions from small off-road spark-ignition engines manufactured for sale, sold, offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce, must not exceed:

Exhaust Emission Standards for Spark-Ignition Engines
(grams per kilowatt-hour)

Model Year	Displacement Category	Durability Periods (hours)	Hydrocarbon plus Oxides of Nitrogen(1)(3)	Carbon Monoxide	Particulate
2005 and subsequent	<50 cc	50/125/300	50	536	2.0(2)
	50-80 cc, inclusive	50/125/300	72	536	2.0(2)
2005	>80 cc - <225 cc Horizontal-shaft Engine	125/250/500	16.1	549	
	>80 cc - <225 cc Vertical-shaft Engine	NA	16.1	467	
	≥225 cc	125/250/500	12.1	549	
2006	>80 cc - <225 cc	125/250/500	16.1	549	
	≥ 225 cc	125/250/500	12.1	549	
2007	>80 cc - <225 cc	125/250/500	8.0	549	
	≥ 225 cc	125/250/500	12.1	549	
2008 and subsequent	>80 cc - <225 cc	125/250/500	8.0	549	
	≥ 225 cc	125/250/500/1000	6.0	549	

(1) The Executive Officer may allow gaseous-fueled (i.e., propane, natural gas) engine families, that satisfy the requirements of the regulations, to certify to either the hydrocarbon plus oxides of nitrogen or hydrocarbon emission standard, as applicable, on the basis of the non-methane hydrocarbon (NMHC) portion of the total hydrocarbon emissions.
(2) Applicable to all two-stroke engines.
(3) Engines used exclusively to power products which are used exclusively in wintertime, at the option of the engine manufacturer, may comply with the provisions in section 90.103(a)(2)(ii).

(a) (2) (i) Two-stroke engines used to power snowthrowers may meet the emission standards for engines at or less than 80 cc in displacement.

(ii) Engines used exclusively to power products which are used exclusively in wintertime, such as snowthrowers and ice augers, at the option of the engine manufacturer, need not certify to or comply with standards regulating emissions of $HC+NO_x$ or $NMHC+NO_x$, as applicable. If the manufacturer exercises the option to certify to standards regulating such emissions, such engines must meet such standards. If the engine is to be used in any equipment or vehicle other than an exclusively wintertime product such as a snowthrower or ice auger, it must be certified to the applicable standard regulating emissions of $HC+NO_x$ or $NMHC+NO_x$ as applicable.

(a) (3) Low-emitting Blue Sky Series engine requirements.

(i) *Voluntary standards.* Engines may be designated "Blue Sky Series" engines by meeting the following voluntary exhaust emission standards, which apply to all certification and compliance testing. Blue Sky Series engines shall not be included in the averaging, banking, and trading program.

Voluntary Emission Standards
(grams per kilowatt-hour)

Model Year	Displacement Category	Hydrocarbon plus Oxides of Nitrogen	Carbon Monoxide	Particulate*
2005 and subsequent	<50 cc	25	536	2.0
	50 - 80 cc, inclusive	36	536	2.0
2007 and subsequent	>80 cc - <225 cc	4.0	549	
2008 and subsequent	≥225 cc	3.0	549	

* Applicable to all two-stroke engines

(ii) *Additional standards.* Blue Sky Series engines are subject to all provisions that would otherwise apply under this part.

* * * * *

§ 90.104 Compliance with emission standards.

* * * * *

(a) DELETE.

(b) DELETE.

(c) DELETE.

* * * * *

(f) DELETE,
REPLACE WITH:
Each engine manufacturer must comply with all provisions of the averaging, banking, and trading program outlined in Title 13, California Code of Regulations, Sections 2408-2409, for each engine family participating in that program.

(g) (1) DELETE,
REPLACE WITH:
Small volume engine manufacturers may, at their option, take deterioration factors for $HC+NO_x$ ($NMHC+NO_x$) and CO from Table 1 or Table 2 of this paragraph (g) or they may calculate deterioration factors for $HC+NO_x$ ($NMHC+NO_x$) and CO according to the process described in paragraph (h) of this section. For technologies that are not addressed in Table 1 or Table 2 of this paragraph (g), the manufacturer may ask the Executive Officer to assign a deterioration factor prior to the time of certification.

(2) DELETE,
REPLACE WITH:
Table 1 follows:

TABLE 1: ENGINES GREATER THAN 80 CC $HC+NO_x$ ($NMHC+NO_x$) AND CO ASSIGNED DETERIORATION FACTORS FOR SMALL VOLUME ENGINE MANUFACTURERS

Displacement category	Side valve engines		Overhead valve engines		Engines with aftertreatment
	$HC+NO_x$ ($NMHC+NO_x$)	CO	$HC+NO_x$ ($NMHC+NO_x$)	CO	
>80 cc-<225 cc	2.1	1.1	1.5	1.1	Dfs must be calculated using the formula in Section 90.104(g)(4)
≥ 225 cc	1.6	1.1	1.4	1.1	

(3) DELETE,
REPLACE WITH:
Table 2 follows:

TABLE 2. ENGINES AT OR BELOW 80 CC HC+NOx (NMHC+NOx) AND CO

ASSIGNED DETERIORATION FACTORS FOR SMALL VOLUME ENGINE MANUFACUTURERS

Displacement category	Two-stroke engines[1]		Four-stroke engines		Engines with aftertreatment
	$HC+NO_x$ ($NMHC+NO_x$)	CO	$HC+NO_x$ ($NMHC+NO_x$)	CO	
0-80 cc, inclusive	1.1	1.1	1.5	1.1	Dfs must be calculated using the formula in Section 90.104(g)(4)

[1] Two-stroke technologies to which these assigned deterioration factors apply include conventional two-strokes, compression wave designs, and stratified scavenging designs.

* * * * *

(h) (2) DELETE,
REPLACE WITH:
For engines not using assigned dfs from Table 1 or Table 2 of paragraph (g) of this section, dfs shall be determined as follows:

(i) The new prototype engine must be emissions tested at break-in with all emission control systems (e.g., EGR, catalysts, etc.) installed.

(ii) The engine must be aged on the emissions durability cycle to the first test point. The manufacturer may choose its test points provided that, the points are equally divided (same number of hours ± 2 hours). An emissions test is conducted at half the emissions durability period ± 2 hours.

(iii) The prototype engine must be emissions tested at each test point. Following testing the durability cycle must be continued to the next point.

(iv) Only specified maintenance may be performed during durability cycle testing.

(v) When the prototype engine has been aged on the durability cycle to the full emissions durability cycle, a final emissions test must be conducted.

(vi) For each pollutant, a line must be fitted to the data points treating the initial test as occurring at hour=0, and using the method of least-squares. The deterioration factor is the calculated emissions at the end of the emissions durability period divided by the calculated emissions at zero hours.

(vii) The product of the zero-hour (break-in) results from the engine multiplied by the deterioration factor is the emissions certification value for that engine family and pollutant.

* * * * *

§ 90.105 Useful life periods for Phase 2 engines.

* * * * *

(a) (1) DELETE,
REPLACE WITH:
For engines greater than 80 cc in displacement: Manufacturers shall select a useful life category from Table 1 of this section at the time of certification.

(2) DELETE,
REPLACE WITH:
Table 1 follows:

TABLE 1: USEFUL LIFE CATEGORIES FOR ENGINES GREATER THAN 80 CC IN DISPLACEMENT (HOURS)

Engine class	Durability Periods (hours)			
>80 cc - <225 cc	125	250	500	–
≥ 225 cc	125	250	500	1000*

* Applicable to engines certifying to the 2008 and later model year emission standards, as specified in section 90.103(a)(1).

(3) DELETE,
REPLACE WITH:
For engines less than or equal to 80 cc in displacement: Manufacturers shall select a useful life category from Table 2 of this section at the time of certification.

(4) DELETE,
REPLACE WITH:
Table 2 follows:

TABLE 2: USEFUL LIFE CATEGORIES FOR ENGINES LESS THAN OR EQUAL TO 80 CC IN DISPLACEMENT (HOURS)

Engine class	Durability Periods (hours)		
0-80 cc, inclusive	50	125	300

* * * * *

§ 90.106 Certificate of conformity.

(a) (1) DELETE,
REPLACE WITH:
Every manufacturer of a new small off-road engine must obtain an Executive Order covering the engine family. The Executive Order must be obtained from the Executive Officer prior to selling, offering for sale, introducing into commerce, or importing into California the new small off-road engine for each model year.

(2) DELETE,
REPLACE WITH:
The Executive Officer may request notification, sixty (60) days prior to the initial model year submission of an engine manufacturer's certification application(s), of the engine manufacturer's intent to seek engine family certification (i.e., a letter of intent) so that the Executive Officer can adequately allocate resources required for reviewing such certification applications in a timely manner. Such letters of intent must provide the engine manufacturer's best estimate of general information for the applicable model-year certification, such as identification of each engine family, date of expected submission, etc.

* * * * *

(b) (3) DELETE.

* * * * *

(e) DELETE.

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§ 90.107 Application for certification.

* * * * *

(d) (11) (i) DELETE,
REPLACE WITH:
A statement indicating whether the manufacturer intends to include the engine family in a corporate average, and, if so, the engine family's expected Family Emission Levels and an estimate of the overall corporate average emissions for that model year.

* * * * *

ADD:
(d) (12) Projected California sales data of the engine family for which certification is requested. Such estimated sales data must include an explanation of the method used to make the estimate.

(e) DELETE.

* * * * *

(h) DELETE.

§ 90.108 Certification.

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(c) DELETE,
REPLACE WITH:
For certificates issued for engine families included in the averaging, banking the trading program as described in Title 13, California Code of Regulations, Sections 2408-2409.

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§ 90.109 Requirement of certification – closed crankcase.

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§ 90.110 Requirement of certification – prohibited controls.

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§ 90.111 Requirement of certification – prohibition of defeat devices.

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§ 90.112 Requirement of certification – adjustable parameters.

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(c) DELETE,
REPLACE WITH:
For engines with adjustable parameters, manufacturers must test the engines at both extremes of the adjustment, as applicable.

§ 90.113 In-use testing program for Phase 1 engines.

DELETE.

§ 90.114 Requirement of certification – engine information label.

DELETE,
REPLACE WITH:
The label shall meet the requirements specified in Section 2404, Title 13 of the California Code of Regulations.

§ 90.115 Requirement of certification – supplying production engines upon request.

* * * * *

§ 90.116 Certification procedure – determining engine displacement, engine class, and engine families.

(a) DELETE,
REPLACE WITH:
Engine displacement must be calculated using nominal engine values and rounded to the nearest whole cubic centimeter in accordance with ASTM E29-93a (May 1993). This procedure has been incorporated by reference. See section 90.7. Engines will be divided into displacement categories by the following:

(1) Engines less than 50 cc in displacement,
(2) Engines 50 cc and greater, but less than or equal to 80 cc in displacement,
(3) Engines greater than 80 cc but less than 225 cc in displacement, and
(4) Engines 225 cc in displacement and greater.

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(d) (5) DELETE,
REPLACE WITH:
The engine displacement category. Engines of different displacements that are within fifteen percent of the largest displacement may be included within the same engine family provided the engine displacement category requirement is satisfied.

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ADD:
(d) (11) The exhaust port(s) and cylinder design of two-stroke engines.

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§ 90.117 Certification procedure – test engine selection.

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ADD:
(c) Each Manufacturer shall provide to the Executive Officer the reason for its engine choice. The Executive Officer will approve or disapprove the documents within ten days of the date such documents are received from the engine manufacturer. Any disapproval must be accompanied by a statement of the reasons thereof. In the event of disapproval, the manufacturer may petition the California Air Resources Board to review the decision of the Executive Officer.

§ 90.118 Certification procedure – service accumulation and usage of deterioration factors.

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§ 90.119 Certification procedure – testing.

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(a) (1) (i) DELETE,
REPLACE WITH:
Engines greater than 80 cc displacement volume must use Test Cycle A described in subpart E of this part, except that engine families in which 100 percent of the engines sold operate only at rated speed may use Test Cycle B described in Subpart E of this part.

(ii) DELETE,
REPLACE WITH:
Engines less than or equal to 80 cc displacement volume must use Test Cycle C described in subpart E of this part.

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§ 90.120 Certification procedure – use of special test procedures.

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§ 90.121 Certification procedure – recordkeeping.

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(a) (2) DELETE.

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§ 90.122 Amending the application and certificate of conformity.

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§ 90.123 Denial, revocation of certificate of conformity.

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§ 90.124 Request for hearing.

DELETE,
REPLACE WITH:
A manufacturer may request a hearing on an Executive Officer's decision regarding

certification, as specified in Title 17, California Code of Regulations, Division 3, Chapter 1, Subchapter 1.25, Articles 1 and 2.

§ 90.125 Hearing procedures.

DELETE,
REPLACE WITH:
The hearing procedures set forth in Subchapter 1.25, Title 17, California Code of Regulations, Section 60040, et seq. apply to this subpart.

§ 90.126 Right of entry and access.

DELETE,
REPLACE WITH:
(a) Any engine manufacturer affected by these regulations, upon receipt of prior notice must admit or cause to be admitted during operating hours any ARB Enforcement Officer that has presented proper credentials to any of the following:

(1) Any facility where tests or procedures or activities connected with such tests or procedures are or were performed.

(2) Any facility where any new small off-road engine is present and is being, has been, or will be tested.

(3) Any facility where a manufacturer constructs, assembles, modifies, or builds-up an engine into a certification engine that will be tested for certification.

(4) Any facility where any record or other document relating to any of the above is located.

(b) Upon admission to any facility referred to in paragraph (c)(1) of this Section, any ARB Enforcement Officer must be allowed:

(1) To inspect and monitor any part or aspect of such procedures, activities, and testing facilities, including, but not limited to, monitoring engine preconditioning, emissions tests and break-in, maintenance, and engine storage procedures.

(2) To verify correlation or calibration of test equipment; and,

(3) To inspect and make copies of any such records, designs, or other documents; and,

(4) To inspect and/or photograph any part or aspect of any such certification engine and any components to be used in the construction thereof.

(c) To permit an ARB determination whether production small off-road engines conform in all material respects to the design specifications that apply to those engines described in the Executive Order certifying such engines and to standards prescribed herein. Engine manufacturers must, upon receipt of prior notice, admit any ARB Enforcement Officer, upon presentation of credentials, to:

(1) Any facility where any document design, or procedure relating to the translation of the design and construction of engines and emission related components

described in the application for certification or used for certification testing into production engines is located or carried on; and,

(2) Any facility where any small off-road engines to be introduced into commerce are manufactured or assembled.

(3) Any California retail outlet where any small off-road engine is sold.

(d) On admission to any such facility referred to in this Section, any ARB Enforcement Officer must be allowed:

(1) To inspect and monitor any aspects of such manufacture or assembly and other procedures;

(2) To inspect and make copies of any such records, documents or designs; and,

(3) To inspect and photograph any part or aspect of any such new small off-road engines and any component used in the assembly thereof that are reasonably related to the purpose of the Enforcement Officer's entry.

(e) Any ARB Enforcement Officer must be furnished by those in charge of a facility being inspected with such reasonable assistance as may be necessary to discharge any function listed in this paragraph. Each applicant for or recipient of certification is required to cause those in charge of a facility operated for its benefit to furnish such reasonable assistance without charge to the ARB irrespective of whether or not the applicant controls the facility.

(f) The duty to admit or cause to be admitted any ARB Enforcement Officer applies whether or not the applicant owns or controls the facility in question and applies both to domestic and foreign engine manufacturers and facilities. The ARB will not attempt to make any inspections that it has been informed that local law forbids. However, if local law makes it impossible to insure the accuracy of data generated at a facility, no informed judgment that an engine is certifiable or is covered by an Executive Order can properly be based on the data. It is the responsibility of the engine manufacturer to locate its testing and manufacturing facilities in jurisdictions where this situation will not arise.

(g) For purposes of this Section:

(1) "Presentation of credentials" means a display of a document designating a person to be an ARB Enforcement Officer.

(2) Where engine, component, or engine storage areas or facilities are concerned, "operating hours" means all times during which personnel are at work in the vicinity of the area or facility and have access to it.

(3) Where facilities or areas other than those covered by paragraph (g)(2) of this Section are concerned, "operating hours" means all times during which an assembly line is in operation or during which testing, maintenance, break-in procedure, production or compilation of records, or any other procedure or activity is being conducted related to certification testing, translation of designs from the test stage to the production stage, or engine manufacture or assembly.

(4) "Reasonable assistance" includes, but is not limited to, providing clerical, copying, interpretation and translation services; making personnel available upon request to inform the ARB Enforcement Officer of how the facility operates and to answer questions; and performing requested emissions tests on any engine that is being, has been, or will be used for certification testing. Such tests must be nondestructive, but may require appropriate break-in. The engine manufacturer must be compelled to cause the personal appearance of any employee at such a facility before an ARB Enforcement Officer, upon written request from the Executive Officer for the appearance of any employee of a facility, and service of such request upon the engine manufacturer. Any such employee who has been instructed by the engine manufacturer to appear will be entitled to be accompanied, represented, and advised by counsel.

Subpart D – Emission Test Equipment Provisions

§ 90.301 Applicability.

* * * * *

(d) DELETE,
REPLACE WITH:
For gaseous-fueled engines greater than 80 cc displacement volume, the following sections from 40 CFR Part 86 are applicable to this subpart. The requirements of the following sections from 40 CFR Part 86 which pertain specifically to the measurement and calculation of non-methane hydrocarbon (NMHC) exhaust emissions from otto cycle heavy-duty engines must be followed when determining the NMHC exhaust emissions from gaseous-fueled engines greater than 80 cc displacement volume. Those sections are: 40 CFR 86.1306-90 Equipment required and specifications; overview, 40 CFR 86.1309-90 Exhaust gas sampling system; otto-cycle engines, 40 CFR 86.1311-94 Exhaust gas analytical system; CVS bag sampling, 40 CFR 86.1313-94(e) Fuel Specification – Natural gas-fuel, 40 CFR 86.1313-94(f) Fuel Specification – Liquified petroleum gas-fuel, 40 CFR 86.1314-94 Analytical gases, 40 CFR 86.1316-94 Calibrations; frequency and overview, 40 CFR 86.1321-94 Hydrocarbon analyzer calibration, 40 CFR 86.1325-94 Methane analyzer calibration, 40 CFR 86.1327-94 Engine dynamometer test procedures, overview, 40 CFR 86.1340-94 Exhaust sample analysis, 40 CFR 86.1342-94 Calculations; exhaust emissions, 40 CFR 86.1344-94(d) Required information – Pre-test data, 40 CFR 86.1344-94(e) Required information – Test data.

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§ 90.302 Definitions.

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§ 90.303 Symbols, acronyms, abbreviations.

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§ 90.304 Test equipment overview.

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§ 90.305 Dynamometer specifications and calibration accuracy.

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§ 90.306 Dynamometer torque cell calibration.

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§ 90.307 Engine cooling system.

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§ 90.308 Lubricating oil and test fuels.

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(b) (1) DELETE,
REPLACE WITH:
(b) (1) (i) The certification test fuel used for emission testing must be consistent with the fuel specifications as outlined in the California Code of Regulations, Title 13, Section 1960.1, and the latest amendment of the "California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles", incorporated by reference herein. The test fuel specification should remain consistent from batch to batch. If a particular engine requires a different octane (or cetane) fuel, test records should indicate the fuel used.

(ii) Alcohol-based fuels. Alcohol-based fuels must be allowed for emission test purposes when the appropriate emission standards with respect to such fuels are a part of these provisions. Such fuels must be as specified in subparagraph (b)(1)(i) above.

(c) DELETE,
REPLACE WITH:
Test fuels--service accumulation and aging.

(1) Gasoline.

(i) Unleaded gasoline representative of commercial gasoline generally available through retail outlets must be used in service accumulation and aging for gasoline-fueled spark-ignition engines. As an alternative, the certification test fuels specified under paragraph (b) of this section may be used for engine service accumulation and aging. Leaded fuel may not be used during service accumulation or aging.

(ii) The octane rating of the gasoline used must be no higher than 4.0 Research Octane Numbers above the minimum recommended by the engine manufacturer when a certification fuel is not used for service accumulation, and must have a minimum sensitivity of 7.5 Octane Numbers. Sensitivity is the Research Octane Number minus the Motor Octane Number.

(iii) The Reid Vapor Pressure of a gasoline must be characteristic of the engine fuel during the season in which the service accumulation takes place in the outdoors, or must be characteristic of the engine fuel appropriately suited to the ambient conditions of an indoor test cell in which the entire service accumulation takes place.

(2) Alternative fuels

(i) Liquefied petroleum gas meeting the ASTM D1835 (11/10/1997) or NGPA HD-5 (1970) specifications must be used for service accumulation.

(ii) Natural gas representative of commercial natural gas that is available locally to the manufacturer's test site may be used in service accumulation. The manufacturer must provide the Executive Officer with detail of how the commercial natural gas differs from the certification test fuel specifications.

§ 90.309 Engine intake air temperature measurement.

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§ 90.310 Engine intake air humidity measurement.

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§ 90.311 Test conditions.

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§ 90.312 Analytical gases.

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§ 90.313 Analyzers required.

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§ 90.314 Analyzer accuracy and specifications.

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§ 90.315 Analyzer initial calibration.

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§ 90.316 Hydrocarbon analyzer calibration.

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§ 90.317 Carbon monoxide analyzer calibration.

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§ 90.318 Oxides of nitrogen analyzer calibration.

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§ 90.319 NO_x converter check.

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§ 90.320 Carbon dioxide analyzer calibration.

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§ 90.321 NDIR analyzer calibration.

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§ 90.322 Calibration of other equipment.

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§ 90.323 Analyzer bench checks.

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§ 90.324 Analyzer leakage check.

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§ 90.325 Analyzer interference checks.

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§ 90.326 Pre- and post-test analyzer calibration.

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§ 90.327 Sampling system requirements.

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§ 90.328 Measurement equipment accuracy/calibration frequency table.

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§ 90.329 Catalyst thermal stress test.

DELETE.

APPENDIX A TO SUBPART D OF PART 90–TABLES

TABLE 1–SYMBOLS USED IN SUBPART D

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TABLE 3–TEST FUEL SPECIFICATIONS

DELETE,
REPLACE WITH:
See section 90.308.

APPENDIX B TO SUBPART D OF PART 90–FIGURES

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Subpart E – Gaseous Exhaust Test Procedures

§ 90.401 Applicability.

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(c) DELETE.

(d) DELETE,
REPLACE WITH:
For gaseous-fueled engines greater than 80 cc displacement volume, the following sections from 40 CFR Part 86 are applicable to this subpart. The requirements of the following sections from 40 CFR Part 86 which pertain specifically to the measurement and calculation of non-methane hydrocarbon (NMHC) exhaust emissions from otto cycle heavy-duty engines must be followed when determining the NMHC exhaust emissions from gaseous-fueled engines greater than 80 cc displacement volume. Those sections are: 40 CFR 86.1327-94 Engine dynamometer test procedures, overview, 40 CFR 86.1340-94 Exhaust sample analysis, 40 CFR 86.1342-94 Calculations; exhaust emissions, 40 CFR 86.1344-94(d) Required information – Pre-test data, and 40 CFR 86.1344-94(e) Required information – Test data.

§ 90.402 Definitions.

* * * * *

§ 90.403 Symbols, acronyms, and abbreviations.

* * * * *

§ 90.404 Test procedure overview.

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(b) DELETE,
REPLACE WITH:
The test is designed to determine the brake-specific emissions of hydrocarbons, carbon monoxide, carbon dioxide, and oxides of nitrogen and fuel consumption. For gaseous-fueled engines greater than 80 cc displacement volume the test is also designed to determine the brake-specific emissions of non-methane hydrocarbons. The test consists of three different test cycles which are application specific for engines which span the typical operating range of small off-road engines. Two cycles exist for engines greater than 80 cc displacement volume and one is for engines less than or equal to 80 cc displacement volume. The test cycles for engines greater than 80 cc displacement volume consist of one idle mode and five power modes at one speed (rated or intermediate). The test cycle for engines less than or equal to 80 cc displacement

volume consists of one idle mode at idle speed and one power mode at rated speed. These procedures require the determination of the concentration of each pollutant, fuel flow, and the power output during each mode. The measured values are weighted and used to calculate the grams of each pollutant emitted per brake kilowatt hour (g/kW-hr).

* * * * *

ADD:
(e) For PM testing, engine manufacturers must use the particulate sampling test procedure specified in International Organization for Standardization (ISO) test procedure 8178-1 RIC engines - Exhaust emissions measurement, Part I: Test bed measurement of gaseous and particulate exhaust emission from RIC engines, Version N124, *November 11, 1992; or any similar procedure that has been approved by the* Executive Officer. For two-stroke engines, engine manufacturers will be allowed, in lieu of testing, to determine PM emissions through the following equation:

$$PM_{est} = \frac{HC}{\text{Fuel to oil ratio}}$$

Where HC = weighted hydrocarbons in g/kW-hr, and
Fuel to oil ratio = the fuel to oil ratio used in the test engine.
Engine manufacturers may report this estimate as PM_{est}, and indicate that the PM emissions were estimated as per this paragraph.

§ 90.405 Recorded information.

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§ 90.406 Engine parameters to be measured and recorded.

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§ 90.407 Engine inlet and exhaust systems.

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§ 90.408 Pre-test procedures.

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(b) (2) (i) DELETE,
REPLACE WITH:
Operate the engine on the dynamometer measuring the fuel consumption (fuel consumption required only for raw gas sampling method) and torque before and after the emission sampling equipment is installed, including the sample probe, using the modes specified in the following table.

Engine class	Test cycle	Operating mode
(A) Engines greater than 80 cc displacement volume	A	6
(B) Engines greater than 80 cc displacement volume	B	1
(C) Engines less than or equal to 80 cc displacement volume	C	1

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§ 90.409 Engine dynamometer test run.

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(a) (3) DELETE,
REPLACE WITH:
For engines greater than 80 cc displacement volume equipped with an engine speed governor, the governor must be used to control engine speed during all test cycle modes except for Mode 1 or Mode 6, and no external throttle control may be used that interference with the function of the engine's governor; a controller may be used to adjust the governor setting for the desired engine speed in Modes 2-5 or Modes 7-10; and during Mode 1 or Mode 6 fixed throttle operation may be used to determine the 100 percent torque value.

* * * * *

(b) (6) DELETE,
REPLACE WITH:
For engines greater than 80 cc displacement volume, during the maximum torque mode calculate the torque corresponding to 75, 50, 25, and 10 percent of the maximum observed torque (see Table in Appendix A to this subpart).

* * * * *

(c) (6) DELETE,
REPLACE WITH:
If, during the emission measurement portion of a mode, the value of the gauges downstream of the NDIR analyzer(s) G3 or G4 (see Figure 1 in Appendix B of Subpart E), differs by more than ±0.5kPa from the pretest value, the test mode is void.

* * * * *

§ 90.410 Engine test cycle.

(a) DELETE,
REPLACE WITH:
Follow the appropriate 6-mode test cycle for engines greater than 80 cc displacement

volume and 2-mode test cycle for engines less than or equal to 80 cc displacement volume when testing spark ignition engines (see Table 2 in Appendix A of this subpart).

(b) DELETE,
REPLACE WITH:
For engines not equipped with an engine speed governor, during each non-idle mode, hold both the specified speed and load within ± five percent of point. During the idle mode, hold speed within ± ten percent of the manufacturer's specified idle engine speed. For engines greater than 80 cc displacement volume equipped with an engine speed governor, during Mode 1 or Mode 6 hold both the specified speed and load within ± five percent of point, during Modes 2-3, Modes 7-8 hold the specified load with ± five percent of point, during Modes 4-5 or Modes 9-10, hold the specified load within the larger range provided by +/- 0.27 Nm (+/- 0.2 lb-ft), or +/- ten (10) percent of point, and during the idle mode hold the specified speed within ± ten percent of the manufacturer's specified idle engine speed (see Table 1 in Appendix A of this subpart for a description of test Modes). The use of alternative test procedures is allowed if approved in advance by the Executive Officer.

(c) DELETE,
REPLACE WITH:
If the operating conditions specified in paragraph (b) of this section for engines greater than 80 cc displacement volume using Mode Points 2, 3, 4, and 5 cannot be maintained, the Executive Officer may authorize deviations from the specified load conditions. Such deviations may not exceed 10 percent of the maximum torque at the test speed. The minimum deviations, above and below the specified load, necessary for stable operation shall be determined by the manufacturer and approved by the Executive Officer prior to the test run.

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§ 90.411 Post-test analyzer procedures.

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(a) (1) DELETE,
REPLACE WITH:
Introduce a zero gas or room air into the sample probe or valve V2 (see Figure 1 in Appendix B of Subpart E) to check the "hang-up zero" response. Simultaneously start a time measurement.

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§ 90.412 Data logging.

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§ 90.413 Exhaust sample procedure–gaseous components.

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§ 90.414 Raw gaseous exhaust sampling and analytical system description.

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§ 90.415 Raw gaseous sampling procedures.

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§ 90.416 Intake air flow measurement specifications.

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§ 90.417 Fuel flow measurement specifications.

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§ 90.418 Data evaluation for gaseous emissions.

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§ 90.419 Raw emission sampling calculations–gasoline fueled engines.

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§ 90.420 CVS *concept of exhaust gas sampling* system.

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§ 90.421 Dilute gaseous exhaust sampling and analytical system description.

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§ 90.422 Background sample.

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§ 90.423 Exhaust gas analytical system – CVS grab sample.

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§ 90.424 Dilute sampling procedures – CVS calibration.

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§ 90.425 CVS calibration frequency.

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§ 90.426 Dilute emission sampling calculations–gasoline fueled engines.

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§ 90.427 Catalyst thermal stress resistance evaluation.

DELETE.

APPENDIX A TO SUBPART E OF PART 90–TABLES

TABLE 1–PARAMETERS TO BE MEASURED OR CALCULATED AND RECORDED

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TABLE 2– DELETE,
REPLACE WITH:
SPARK-IGNITION ENGINE TEST CYCLES

Mode Speed	1	2	3	4	5	6	7	8	9	10	11
	Rated Speed					Intermediate Speed					Idle
Mode Points – A Cycle	....	....	....	....	....	1	2	3	4	5	6
Load Percent – A Cycle	....	....	....	....	....	100	75	50	25	10	0
Weighting (%)	....	....	....	....	....	9	20	29	30	7	5
Mode Points – B Cycle	1	2	3	4	5	....	....	....	....	....	6
Load Percent – B Cycle	100	75	50	25	10	....	....	....	....	....	0
Weighting (%)	9	20	29	30	7	....	....	....	....	....	5
Mode Points – C Cycle	1	....	....	....	....	....	....	....	....	....	2
Load Percent – C Cycle	100	....	....	....	....	....	....	....	....	....	0
Weighting (%)	85	....	....	....	....	....	....	....	....	....	15

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APPENDIX B TO SUBPART E OF PART 90–FIGURES

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APPENDIX C: PROPOSED EVAPORATIVE EMISSION REQUIREMENTS FOR OFF-ROAD EQUIPMENT

Proposed Regulation Order

Adopt new Chapter 15 – Off-Road Vehicles and Engines Pollution Control Devices, Article 1, Division 3, sections 2750-2773, title 13, California Code of Regulations (CCR), to read as follows:

Chapter 15. Off-Road Vehicles and Engines Pollution Control Devices

Article 1. Evaporative Emission Requirements for Off-Road Equipment

§2750. Purpose.

The purpose of these regulations is to set performance standards for new equipment utilizing gasoline-fueled, spark-ignited small off-road engines rated at less than 25 horsepower, and equipment utilizing such engines.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2751. Applicability.

(a) For the model year engines or equipment subject to this Article, no person shall:

(1) manufacture for sale or lease for use or operation in California, or

(2) sell or lease or offer for sale or lease for use or operation in California, or

(3) deliver or import into California for introduction into commerce in California, or

(4) use or operate in California equipment that use small off-road engines subject to this Article,

without an evaporative emission control system that has been certified and labeled pursuant to this Article.

(b) This Article does not apply to engines or equipment that use compression-ignition engines, or engines or equipment powered with compressed natural gas (CNG), propane, liquefied petroleum gas (LPG), or liquefied natural gas (LNG).

(c) This Article does not apply to engines or equipment that use small off-road engines manufactured in California for sale and use outside of California.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2752. Definitions.

(a) The definitions in section 2401 (a), Chapter 9, Title 13 of the California Code of Regulations, apply to this Article with the following additions:

(1) "Coextruded Multilayer Fuel Tank" means a multi-layered high-density polyethylene fuel tank with a continuous nylon or ethylene vinyl alcohol layer(s) present within the walls of the tank.

(2) "CP-901" means "Certification and Approval Procedures for Small Off-Road Engine Fuel Tanks", adopted **[insert date of adoption]**.

(3) "CP-902" means "Certification and Approval Procedures for Evaporative Emission Control Systems", adopted **[insert date of adoption]**.

(4) "Diurnal Emissions" means evaporative emissions resulting from the daily cycling of ambient temperatures and include resting losses, and permeation emissions.

(5) "Equivalent Fuel Tank" means a metal or coextruded multilayer fuel tank used on a small off-road engine. The volume of an equivalent tank must be less than or equal to a nominal tank. An equivalent tank must be functionally equivalent to a nominal tank.

(6) "Equivalent Fuel Line" means a fuel line meeting SAE J30 R9, SAE J30 R11-A, SAE J30 R-12-A (Revised, June 1998), or SAE J2260 (Issued Nov. 1996) Category 1 surface vehicle permeation standards.

(7) "Evaporative Emissions" means emissions that result from the evaporation of reactive organic gases into the atmosphere.

(8) "Evaporative Emission Control System" means the fuel system and associated components that are designed to control evaporative emissions.

(9) "Evaporative Family" means a class of off-road engines or equipment that are grouped together based on similar fuel system characteristics as they relate to evaporative emissions. For equipment less than or

equal to 80 cc, the engine family and evaporative family are considered equivalent.

(10) "Executive Order of Certification" means an order signed by the Executive Officer that documents certification evaporative of emission control systems on engines or equipment to the performance standards of this Article.

(11) "Holder" means the person to whom the Executive Order of Certification is issued.

(12) "Hot Soak Emissions" means evaporative emissions that occur for the one-hour period following the termination of engine operation.

(13) "Hydrocarbon" means a molecule composed entirely of carbon and hydrogen atoms.

(14) "Manufacturer" means either an engine manufacturer or equipment manufacturer.

(15) "Nominal Capacity" means the volume of fuel indicated by the manufacturer that represents the maximum recommended fill level.

(16) "Nominal Fuel Tank" means the fuel tank that is used by an engine manufacturer to certify the evaporative emissions control system on a small off-road engine.

(17) "Nominal Fuel Line" means the fuel line that is used by an engine manufacturer to certify the evaporative emissions control system on a small off-road engine.

(18) "Permeation Emissions" means evaporative emissions that result from reactive organic gas molecules penetrating through the walls of fuel system components and evaporating on outside surfaces. Permeation emissions are a component of diurnal emissions.

(19) "Permeation Rate" means the total mass of reactive organic gas molecules passing through the internal surface area of a fuel tank in a 24-hour period.

(20) "Person" means any individual, association, partnership, limited liability company, or corporation.

(21) "Reactive Organic Gases (ROG)" means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid,

metallic carbides or carbonates, and ammonium carbonate, and excluding the following:

		CAS*
(1)	methane;	[74-82-8]
	methylene chloride (dichloromethane);	[75-09-2]
	1,1,1-trichloroethane (methyl chloroform);	[71-55-6]
	trichlorofluoromethane (CFC-11);	[75-69-4]
	dichlorodifluoromethane (CFC-12);	[75-71-8]
	1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113);	[76-13-1]
	1,2-dichloro-1,1,2,2-tetrafluoroethane (CFC-114);	[76-14-2]
	chloropentafluoroethane (CFC-115);	[76-15-3]
	chlorodifluoromethane (HCFC-22);	[75-45-6]
	1,1,1-trifluoro-2,2-dichloroethane (HCFC-123);	[306-83-2]
	2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124);	[2837-89-0]
	1,1-dichloro-1-fluoroethane (HCFC-141b);	[1717-00-6]
	1-chloro-1,1-difluoroethane (HCFC-142b);	[75-68-3]
	trifluoromethane (HFC-23);	[75-46-7]
	pentafluoroethane (HFC-125);	[354-33-6]
	1,1,2,2-tetrafluoroethane (HFC-134);	[359-35-3]
	1,1,1,2-tetrafluoroethane (HFC-134a);	[811-97-2]
	1,1,1-trifluoroethane (HFC-143a);	[420-46-2]
	1,1-difluoroethane (HFC-152a);	[75-37-6]
	cyclic, branched, or linear completely methylated siloxanes;	[various]
	the following classes of perfluorocarbons:	[various]

(A) cyclic, branched, or linear, completely fluorinated alkanes;
(B) cyclic, branched, or linear, completely fluorinated ethers with no unsaturations;
(C) cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and
(D) sulfur-containing perfluorocarbons with no unsaturations and with the sulfur bonds only to carbon and fluorine; and

(2) the following low-reactive organic compounds which have been exempted by the U.S. EPA:

acetone;	[67-64-1]
ethane;	[74-84-0]
methyl acetate;	[79-20-9]
perchloroethylene; and	[127-18-4]
parachlorobenzotrifluoride (1-chloro-4-trifluoromethyl benzene).	[98-56-6]

* NOTE: Chemical Abstract Service (CAS) identification numbers have been included in brackets [ ] for convenience.

(22) "SHED" (Sealed Housing Evaporative Determination) means the enclosure and associated equipment used to determine evaporative emissions. A SHED must meet the design specifications in 40 Code of Federal Regulations Part 86.107-96.

(23) "Structurally Integrated Nylon Fuel Tank" means a fuel tank having the following characteristics:

(A) The fuel tank is made of a polyamide material which:

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1. does not contain more than 50 percent by weight of a reinforcing glass fiber and/or mineral filler; and
2. does not contain more than 10 percent by weight of impact modified polyamides which use rubberized agents such as EPDM rubber

(B) The fuel tank must be:

1. used in a chainsaw; or

2. of a pre-existing design that is substantially similar to a current production fuel tank used by the same manufacturer that is integrated into a major structural member where, as a single component, the fuel tank material is a primary structural/stress member for other major components such as the engine, transmission or cutting attachment.

(24) "TP-901" means "Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks", adopted **[insert date of adoption]**.

(25) "TP-902" means "Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines", adopted **[insert date of adoption]**.

(26) "Total Hydrocarbons" means the total mass of open chain and cyclic hydrocarbon molecules.

(27) "Walk-Behind Mower" means a grass-cutting product which has:

(A) A gasoline powered vertical or horizontal shaft engine with a blade stop or brake mechanism;

(B) an engine displacement greater than 80 cc and less than 225 cc;

(C) a horizontally fixed blade and/or string directly attached to the crankshaft of a vertical shaft engine.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2753. Certification Requirements and Procedures.

(a) Certification

Small off-road engines or equipment that use small off-road engines subject to this Article must contain evaporative emission control systems. The evaporative emission control systems must be certified annually to the performance-based standards set out in sections 2754 through 2757 by the Air Resources Board. An Executive Order of Certification for such engines or equipment must be obtained prior to the sale or lease, or the offering for sale or lease, for use or operation in California or the delivery or importation for introduction into commerce in California or the use or operation of such engines or equipment in California. Engine or equipment manufacturers may apply for an Executive Order of Certification. Applicants must follow the certification procedures outlined in CP-901, adopted **[insert date of adoption]** or CP-902, adopted **[insert date of adoption]**, as applicable, which are incorporated by reference herein.

(b) Certification of Complete Systems

Certification of a complete evaporative emission control system is required. An applicant for certification of a evaporative emission control system must submit diurnal evaporative emission data for an engine that exhibits the highest evaporative emission characteristics for an evaporative family as part of the certification application. TP-902, adopted **[insert date of adoption]**, is used to determine the evaporative emissions from engines or equipment with complete evaporative emission control systems.

(c) Modifications to the Evaporative Emission Control System

Manufacturers are allowed to replace the nominal fuel tank and/or nominal fuel line of a certified evaporative emission control system with an equivalent fuel tank and/or equivalent fuel line. All other evaporative emission control components must be identical in design and function to those components used to certify the control system.

Modification of certified evaporative emission control systems in any manner other than replacement of the nominal tanks and/or fuel lines with equivalent fuel tanks and/or fuel lines invalidates the certification of the control system. When an evaporative emission control system's certification is invalidated due to an unapproved modification, a new certification is required per CP-902, adopted **[insert date of adoption]**.

Manufacturers are required to notify the Executive Officer in writing of any modification of a certified evaporative emission control system. The notification must include a statement citing the basis for the equivalent fuel tank and/or fuel line determination.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2754. Evaporative Emission Performance Standards.

On or after the model year set out herein, diurnal evaporative emissions from any small off-road engine or equipment that use small off-road engines subject to this section with a displacement greater than 80 cubic centimeters ("cc") must not exceed the following evaporative emission standards:

Diurnal Evaporative Emission Standards
(grams per 24-hour diurnal test)

Model Year	**Applicability**	**Requirement** Hydrocarbons
2007 and Later	All Walk-Behind Mowers That Use Small Off-Road Engines With Displacements >80 cc to < 225 cc	Diurnal Emissions Shall Not Exceed 1.0 Grams Hydrocarbons Per Day As Determined By TP-902.
2007 and Later	All Equipment That Use Small Off-Road Engines With Displacements > 80 cc to < 225 cc Except Walk-Behind Mowers	Diurnal Emissions Shall Not Exceed (0.21*Tank Volume Gallons+0.95) Grams Hydrocarbons Per Day As Determined By TP-902.
2008 and Later	All Equipment That Use Small Off-Road Engines With Displacements ≥ 225 cc	Diurnal Emissions Shall Not Exceed 2.0 Grams Hydrocarbons Per Day As Determined By TP-902.

(a) The evaporative emission control system must be fully operational when the engine and/equipment is shut down. The mechanism to activate the control system must be tied to the engine kill switch, engine brake, blade stop, or other similar device that does not require a operator to actuate separate levers or switches other than those required to normally turn off the engine.

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(b) Data documenting the evaporative emission performance of equipment when operated on certification fuel specified in "California Exhaust Emissions Standards for 1995 and Later Small Off-Road Engines", adopted March 20, 1992, and last amended **[insert date of amendment]**, must be included in a certification application.

(c) The test procedure for determining compliance with the evaporative emission standards from new equipment that use small off-road engines are set forth in "Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines, TP-902, " adopted **[insert date of adoption]**, which is incorporated by reference herein.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2755. Permeation Emissions Performance Standard.

On or after the model year set out herein, fuel tanks used on equipment subject to this section must not exceed the following permeation rates:

Permeation Rate Standard
(grams per meter^2 per day)

Model Year	Applicability	Requirement Tank Permeation
2007 and Later	New Equipment That Use Gasoline Powered Small Off-Road Engines With Displacements $\leq$ 80 cc	Fuel Tank Permeation Emissions Shall Not Exceed 2.0 Grams Per Square Meter Per Day As Determined By TP-901.

(a) Data documenting the permeation rate of fuel tanks must be included in a certification application.

(b) The test procedure for determining compliance with the standards for permeation rates from new small off-road engine fuel tanks are set forth in "Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks, TP-901, " adopted **[insert date of adoption]**, which is incorporated by reference herein.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2756. Fuel Cap Performance Standard.

On or after the model year set out herein, no person shall sell, supply, offer for sale or manufacture for sale fuel caps for fuel tanks for small off-road engines or equipment that use small off-road engines with displacements ≥80 cc subject to this Article that do not meet the following performance standards:

Fuel Cap Performance Standards

(a) Fuel cap must be permanently tethered to the tank, equipment, or engine; and

(b) fuel cap must be designed to provide physical and/or audible feedback to the user that a fuel tank vapor seal is established.

The following table defines equipment subject to the fuel cap performance standards of this Section:

Equipment Subject to the Fuel Cap Performance Standards

Model Year	Applicability
2007	Fuel Caps For ALL SORE Equipment With Small Off-Road Engines >80 cc to < 225 cc
2008	Fuel Caps For ALL SORE Equipment With Small Off-Road Engines ≥ 225 cc

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2757. Optional Performance Standards.

The Air Resources Board recognizes that evaporative emissions can be further reduced by incorporating advanced fuel system designs that reduce or eliminate carburetor emissions. These optional performance standards are emission targets that are more stringent than the performance standards set out in section 2754. These optional performance standards will be part of a statewide clean air-labeling program. Upon implementation, a manufacturer certifying to an optional performance standard would be allowed to affix a “California Clean Air Label” on their equipment.

Optional Evaporative Emission Standards
(Grams per 24-hour diurnal test)

Model Year	Applicability	Requirement Total Hydrocarbons
2007 and Later	All Walk-Behind Mowers With Small Off-Road Engines >80 cc To < 225 cc	Diurnal Emissions Shall Not Exceed 0.5 Grams Hydrocarbons Per Day As Determined By TP-902.
2007 and Later	All Equipment That Use Small Off-Road Engines With Displacements > 80 cc To < 225 cc	Diurnal Emissions Shall Not Exceed 0.5 Grams Total Hydrocarbons Per Day As Determined By TP-902.
2008 and Later	All Equipment That Use Small Off-Road Engines With Displacements ≥ 225 cc	Diurnal Emissions Shall Not Exceed 1.0 Grams Total Hydrocarbons Per Day As Determined By TP-902.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2758. Test Procedures.

(a) Testing to determine compliance with section 2754 of this Article shall be performed using TP-902, adopted **[insert date of adoption]**, which is incorporated by reference herein.

(b) Testing to determine compliance with section 2755 of this Article shall be performed using TP-901, adopted **[insert date of adoption]**, which is incorporated by reference herein.

(c) Testing to determine compliance with section 2757 of this Article shall be performed using TP-902, adopted **[insert date of adoption]**.

Test procedures referred to in this Article may be obtained from the California Air Resources Board at P.O. Box 2815, Sacramento, California 95812 or over the Internet at http:\\www.arb.ca.gov.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2759. Equipment and Component Labeling.

(a) Purpose. The Air Resources Board recognizes that certain emissions-critical and/or emissions-related parts must be properly labeled in order to identify equipment that meets applicable evaporative emission standards. These specifications require equipment and/or engine manufacturers to affix a certification label (or labels) on each production equipment (or engine, as applicable).

(b) Applicability. These specifications apply to:

(1) Engines or equipment that have been certified to the applicable evaporative emission standards in this Article.

(2) Equipment manufacturers who use an engine certified under this Article if their equipment obscures the emissions control label of such certified engine.

(c) Certification Label Content and Location.

(1) A plastic or metal label must be welded, riveted or otherwise permanently attached by the equipment or engine manufacturer to an area on the engine or equipment in such a way that it will be readily visible.

(2) In selecting an acceptable location, the possibility of accidental damage must be considered (e.g. possibility of tools or sharp instruments coming in contact with the label). Each certification label must be affixed in such a manner that it cannot be removed without destroying or defacing the label, and must not be affixed to any engine (or equipment, as applicable) component that is easily detached from the engine.

(3) The equipment label information must be written in the English language and use block letters and numerals (i.e., sans serif, upper-case characters) that must be of a color that contrasts with the background of the label.

(4) The equipment label must contain the following information:

(A) The label heading must read: "IMPORTANT EMISSIONS INFORMATION." When combined with an exhaust label, "EMISSIONS" relates to both exhaust and evaporative emissions.

(B) The full corporate name or trademark of the engine or equipment manufacturer.

1. A manufacturer may request approval to delete its name and trademark, and substitute the name and trademark of another manufacturer, original equipment manufacturer, or third-party distributor.

2. Such an approval does not relieve the manufacturer of complying with the requirements imposed by this Article.

(C) Identification of the evaporative emission control system. Abbreviations are allowed if they are submitted as part of the certification application.

(D) The date of engine manufacture (month and year) for evaporative emission control systems certified by the engine manufacturer or the date of equipment manufacture (month and year) for evaporative emission control systems certified by the equipment manufacturer.

(E) An unconditional statement of compliance with the appropriate calendar year (for 2007-2008) or model year (for 2007 and later) California regulations; for example, "THIS ENGINE MEETS 200x CALIFORNIA EXHAUST AND EVAPORATIVE EMISSION REQUIREMENTS FOR SMALL OFF-ROAD ENGINES."

(F) Engine displacement in cubic centimeters.

(G) Evaporative emissions family. Attachment 1 of the Certification Procedures, CP-902, adopted **[insert date of adoption]**, contains the classification criteria for determining an evaporative family for engines greater than 80 cc. For equipment less than or equal to 80 cc, the engine family and evaporative family are considered equivalent.

(d) Conformance with Federal Requirements. A label may state that the equipment conforms to any applicable federal evaporative emission standards for new equipment; or any other information that the manufacturer deems necessary for, or useful to, the proper operation and satisfactory maintenance of the engine.

(e) Label Visibility. As used in these specifications, readily visible to the average person means that a label is readable from a distance of 46 centimeters (18 inches) without any obstructions from equipment or engine parts (including all original equipment manufacturer or engine manufacturer (as applicable) available optional equipment) except for flexible parts (e.g., vacuum hoses, ignition wires) that can be moved out of the way without disconnection. Alternatively, information required by these specifications to be printed on the equipment and/or engine (as applicable) must be no smaller than 2 millimeters in height provided that no equipment or engine parts (including all manufacturer available optional equipment), except for flexible parts, obstruct the label(s).

(f) Label Durability. The labels and any adhesives used must be designed to withstand, for the equipment's useful life, typical equipment environmental conditions in the area where the labels required by this section are attached. Typical equipment environmental conditions include, but are not limited to, exposure to engine fuels, lubricants and coolants (e.g., gasoline, motor oil, water, and ethylene glycol). The engine or equipment manufacturer must submit, with its certification application, a statement attesting that its labels comply with these requirements.

(g) Sample Label Submission. Samples of all actual production labels used within an evaporative family must be submitted to the Executive Officer within thirty days after the start of production. Engine manufacturers must provide samples of their own applicable production labels, and samples of applicable production labels of the equipment manufacturer that are accessible to the engine manufacturers due to any direct market arrangement between such manufacturers.

(h) The Executive Officer may approve alternate label locations or may, upon request, waive or modify the label content requirements provided that the intent of these specifications is met. Such approval may be conditioned upon providing such information in the owner's manual as the Executive Officer deems appropriate.

(i) Labeling Enforcement

(1) Use of labels that are different from those approved will be grounds for revocation or suspension of the Executive Order of Certification

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2760. Defects Warranty Requirements for Small Off-Road Engines.

(a) Applicability. This section applies to 2007 model year and later small off-road engines or equipment that use small off-road engines subject to the performance standards in this Article. The warranty period begins on the date the engine or equipment is delivered to an ultimate purchaser.

(b) General Evaporative Emissions Warranty Coverage. The engine or equipment must be warranted to the ultimate purchaser and any subsequent owner that the evaporative emission control system when installed was:

(1) Designed, built, and equipped so as to conform with all applicable regulations; and

(2) Free from defects in materials and workmanship that causes the failure of a warranted part for a period of two years.

(c) The warranty on evaporative emissions-related parts will be interpreted as follows:

(1) Any warranted part that is not scheduled for replacement as required maintenance in the written instructions required by subsection (d) must be warranted for the warranty period defined in subsection (b)(2). If any such part fails during the period of warranty coverage, it must be repaired or replaced by the manufacturer issuing the warranty according to subsection (4) below. Any such part repaired or replaced under the warranty must be warranted for a time not less than the remaining warranty period.

(2) Any warranted part that is scheduled only for regular inspection in the written instructions required by subsection (d) must be warranted for the warranty period defined in subsection (b)(2). A statement in such written instructions to the effect of "repair or replace as necessary" will not reduce the period of warranty coverage. Any such part repaired or replaced under warranty must be warranted for a time not less than the remaining warranty period.

(3) Any warranted part that is scheduled for replacement as required maintenance in the written instructions required by subsection (d) must be warranted for the period of time prior to the first scheduled replacement point for that part. If the part fails prior to the first scheduled replacement, the part must be repaired or replaced by the manufacturer according to subsection (4) below. Any such part repaired or replaced under warranty must be warranted for a time not less than the remainder of the period prior to the first scheduled replacement point for the part.

(4) Repair or replacement of any warranted part under the warranty provisions of this article must be performed at no charge to the owner at a warranty station.

(5) Notwithstanding the provisions of subsection (4) above, warranty services or repairs must be provided at distribution centers that are franchised to service the subject engines or equipment.

(6) The owner must not be charged for diagnostic labor that leads to the determination that a warranted part is in fact defective, provided that such diagnostic work is performed at a warranty station.

(7) Throughout the evaporative emission control system's warranty period set out in subsection (b)(2), the manufacturer issuing the warranty must maintain a supply of warranted parts sufficient to meet the expected demand for such parts.

(8) Any replacement part may be used in the performance of any warranty maintenance or repairs and must be provided without charge to the owner. Such use will not reduce the warranty obligations of the manufacturer issuing the warranty.

(9) The use of any add-on or modified parts will be grounds for disallowing a warranty claim made in accordance with this article. The manufacturer issuing the warranty will not be liable under this Article to warrant failures of warranted parts caused by the use of an add-on or modified part.

(10) The manufacturer issuing the warranty shall provide any documents that describe that manufacturer's warranty procedures or policies within five working days of request by the Executive Officer.

(d) A copy of the following evaporative emission warranty parts list must be included with each new engine or equipment subject to this Article, using those portions of the list applicable to the engine or equipment.

(1) Fuel Tank*
(2) Fuel Cap
(3) Fuel Line
(4) Fuel Line Fittings
(5) Clamps
(6) Pressure Relief Valves
(7) Control Valves
(8) Control Solenoids

(9) Electronic Controls
(10) Vacuum Control Diaphragms
(11) Control Cables
(12) Control Linkages
(13) Purge Valves
(14) Vapor Hoses
(15) Liquid/Vapor Separator
(16) Carbon Canister
(17) Canister Mounting Brackets
(18) Carburetor Purge Port Connector

*Note: The parts list for equipment less than or equal to 80 cc only includes the fuel tank.

(e) Written instructions for the maintenance and use of the evaporative emissions control system by the owner shall be furnished with each new engine or equipment subject to this Article. The instructions must be consistent with this article and applicable regulations contained herein.

(f) The documents required by subsection (d) must be submitted with the application for evaporative emission control system certification for approval by the Executive Officer. Approval by the Executive Officer of the documents required by subsection (d) is a condition of certification. The Executive Officer will approve or disapprove the documents required by subsection (d) within 90 days of the date such documents are received.

(g) The application for evaporative emission control system certification must also include a statement regarding the maintenance of the evaporative emission control system. The statement must include, but not be limited to, information on evaporative emission control system maintenance, and a maintenance schedule.

§2761. Emission-related Defect Reporting Requirements.

(a) Applicability. This Section applies to 2007 model year and later small off-road engines and equipment that use small off-road engines. The requirement to report evaporative emission-related defects affecting a given class or category of engines or equipment will remain applicable for five years from the end of the calendar year in which such engines or equipment were manufactured.

(b) A manufacturer must file a defect information report whenever, on the basis of data obtained subsequent to the effective date of these regulations:

(1) The manufacturer determines, in accordance with procedures established by the manufacturer to identify either safety-related or performance defects, that a specific evaporative emission-related defect exists; and

(2) A specific evaporative emission-related defect exists in 25 or more tanks, engines or equipment of a given evaporative family manufactured in the same Executive Order or model year.

(c) No report must be filed under this Section for any evaporative emission-related defect corrected prior to the sale of the affected engines or equipment to ultimate purchasers.

(d) The manufacturer must submit defect information reports to Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar, El Monte, CA 91731, not more than 15 working days after an emission-related defect is found to affect 25 or more engines manufactured in the same Executive Order or model year. Information required by paragraph (d) of this section that is either not available within 15 working days or is significantly revised must be submitted the Executive Officer as it becomes available.

(e) Each defect report must contain the following information:

(1) The manufacturer's corporate name.

(2) A description of the defect.

(3) A description of each class or category of engines potentially affected by the defect including make, model, model year, calendar year produced, and any other information required to identify the engines affected.

(4) For each class or category of engine described in response to paragraph (d) of this section, the following must also be provided:

(A) The number of engines or equipment known or estimated to have the defect and an explanation of the means by which this number was determined.

(B) The address of the plant(s) at which the potentially defective engines or equipment were produced.

(5) An evaluation of the evaporative emissions impact of the defect and a description of any operational problems that a defective engine or equipment might exhibit.

(6) Available evaporative emission data that relate to the defect.

(7) An indication of any anticipated manufacturer follow-up.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2762. Voluntary Emission Recall Program

(a) When any manufacturer initiates a voluntary emissions recall campaign *involving 25 or more tanks, engines, or equipment, the manufacturer must* submit a report describing the manufacturer's voluntary emissions recall plan as prescribed by this section within 15 working days of the date owner notification began. The report must contain the following:

(1) A description of each class or category of engines or equipment recalled including the number of tanks, engines or equipment to be recalled, the model year, the make, the model, and such other information as may be required to identify the engines recalled;

(2) A description of the specific modifications, alterations, repairs, *corrections, adjustments, or other changes to be made to correct* the tanks, engines, or equipment affected by the emission-related defect;

(3) A description of the method by which the manufacturer will notify engine or equipment owners and, if applicable, the method by which the manufacturer will determine the names and addresses of engine or equipment owners;

(4) A description of the proper maintenance or use, if any, upon which the manufacturer conditions eligibility for repair under the recall *plan, an explanation of the manufacturer's reasons for imposing* any such conditions, and a description of the proof to be required of an engine or equipment owner to demonstrate compliance with any such conditions;

(5) A description of the procedure to be followed by engine or equipment owners to obtain correction of the nonconformity. This may include designation of the date on or after which the owner can have the nonconformity remedied, the time reasonably necessary to perform the labor to remedy the defect, and the designation of facilities at which the defect can be remedied;

(6) A description of the class of persons other than dealers and authorized warranty agents of the manufacturer who will remedy the defect;

(7) When applicable, three copies of any letters of notification to be sent engine owners;

(8) A description of the system by which the manufacturer will assure that an adequate supply of parts is available to perform the repair under the plan, and that the supply remains both adequate and responsive to owner demand;

(9) Three copies of all necessary instructions to be sent to those persons who are to perform the repair under the recall plan;

(10) A description of the impact of the proposed changes on fuel consumption, performance, and safety of each class or category of engines or equipment to be recalled;

(11) A sample of any label to be applied to engines or equipment that participated in the voluntary recall campaign.

(b) The manufacturer must submit at least one report on the progress of the recall campaign. Such report must be submitted no later than 18 months from the date notification was begun and include the following information:

(1) The methods used to notify both engine or equipment owners, dealers and other individuals involved in the recall campaign;

(2) The number of engines or equipment to be affected by the emission-related defect and an explanation of the means by which this number was determined;

(3) The number of engines or equipment actually receiving repair under the plan; and

(4) The number of engines or equipment determined to be ineligible for remedial action due to a failure to properly maintain or use such engines.

(c) Send the defect report, voluntary recall plan, and the voluntary recall progress report to: Chief, Mobile Source Operations Division, Air Resources Board, 9528 Telstar Avenue, El Monte, CA, 91731.

(d) Retain the information gathered by the manufacturer to compile the reports for not less than five years from the date of the manufacture of the engines. The manufacturer must make this information available to duly authorized officials of the ARB upon request.

(e) The filing of any report under the provisions of this section does not affect a manufacturer's responsibility to file reports or applications, obtain approval, or give notice under any provision of law.

(f) The act of filing an Emission Defect Information Report is inconclusive as to the existence of a defect subject to the warranty provided by section 2764 of this Article.

(g) A manufacturer may include on each page of its Emission Defect Information Report a disclaimer stating that the filing of a Defect Information Report pursuant to these regulations is not conclusive as to the applicability of the warranty provided by section 2764 of this Article.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2763. Ordered Recalls.

(a) (1) If the Executive Officer determines that a substantial number of any class or category of engines or equipment, although properly maintained and used, do not meet the performance standards prescribed under this Article, when in actual use throughout their useful life, the Executive Officer shall immediately notify the responsible manufacturer of such nonconformity and require the manufacturer to submit a plan for remedying the nonconformity.

The manufacturer's plan shall provide that the nonconformity of any such engines or equipment that are properly used and maintained will be remedied at the expense of the manufacturer.

If the manufacturer disagrees with such determination of nonconformity, the manufacturer may appeal such determination pursuant to section 2770.

(2) Any notification required to be given by the manufacturer under paragraph (a)(1) of this section with respect to any class or category of engines or equipment shall be given to dealers, ultimate purchasers, and subsequent purchasers (if known) in such manner and containing such information as required in section 2761 of this Article.

(3) (A) Prior to an ARB ordered recall, the manufacturer may perform a voluntary emissions recall pursuant to section 2762 of this

Article. Such manufacturer is subject to the reporting and record keeping requirements of section 2762 paragraphs (c) and (d) of this Article.

(B) Once ARB determines that a substantial number of engines or equipment fail to conform to the requirements of this Article, the manufacturer will not have the option of a voluntary recall.

(b) The manufacturer bears all cost obligation a dealer incurs as a result of a requirement imposed by paragraph (a) of this section. The transfer of any such cost obligation from a manufacturer to a dealer through franchise or other agreement is prohibited.

(c) Any inspection of an engine or equipment for purposes of paragraph (a)(1) of this section, after its sale to the ultimate purchaser, is to be made only if the owner of such engine or equipment voluntarily permits such inspection to be made, except as may be provided by any state or local inspection program.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2764. Evaporative Emission Control Warranty Statement.

(a) Any application for an evaporative emission control system certification must include a copy of the following statement:

CALIFORNIA EVAPORATIVE EMISSION CONTROL WARRANTY STATEMENT

YOUR WARRANTY RIGHTS AND OBLIGATIONS

The California Air Resources Board (and manufacturer's name, optional) is pleased to explain the evaporative emission control system's warranty on your (year(s)) (equipment type). In California, new equipment that use small off-engines must be designed, built, and equipped to meet the State's stringent anti-smog standards. (Manufacturer's name) must warrant the evaporative emission control system on your (equipment type) for the period listed below provided there has been no abuse, neglect or improper maintenance of your equipment.

Your evaporative emission control system may include parts such as: carburetors, fuel tanks, fuel lines, fuel caps, valves, canisters, filters, vapor hoses, clamps, connectors, and other associated components.

A combined exhaust and evaporative warranty statement is acceptable.

MANUFACTURER'S WARRANTY COVERAGE:

This evaporative emission control system is warranted for two years. If any evaporative emission-related part on your equipment is defective, the part will be repaired or replaced by (manufacturer's name).

OWNER'S WARRANTY RESPONSIBILITIES:

- As the (equipment type) owner, you are responsible for performance of the required maintenance listed in your owner's manual. (Manufacturer's name) recommends that you retain all receipts covering maintenance on your (equipment type), but (manufacturer's name) cannot deny warranty solely for the lack of receipts.
- As the (equipment type) owner, you should however be aware that the (manufacturer's name) may deny you warranty coverage if your (equipment type) or a part has failed due to abuse, neglect, or improper maintenance or unapproved modifications.
- You are responsible for presenting your (equipment type) to a (manufacturer's name) distribution center or service center as soon as the problem exists. The warranty repairs should be completed in a reasonable amount of time, not to exceed 30 days. If you have a question regarding your warranty coverage, you should contact (Insert chosen manufacturer's contact) at 1-XXX-XXX-XXXX.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2765. New Equipment Compliance Testing

(a) Compliance Test Procedures.

(1) The Executive Officer may order an engine or equipment manufacturer to make available for compliance testing and/or inspection five tanks, engines, or equipment units. Unless otherwise directed by the Executive Officer, the tanks, engines, or equipment units shall be delivered to the Haagen-Smit Laboratory, 9528 Telstar Avenue, El Monte, California. Tanks, engines or equipment units must be selected at random from sources specified by the Executive Officer according to a method approved by the Executive Officer, that, insofar as practical, must exclude engines or equipment that would result in an unreasonable disruption of the manufacturer's distribution system.

(2) The method for selection and testing of the tanks, engines or equipment and the evaluation of test data must be made in accordance with the procedures set forth herein.

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(3) Air Resources Board personnel shall have access to the tank, engine, or equipment assembly plants, or distribution facilities for the purposes of tank, engine, or equipment selection and testing. Scheduling of access shall be arranged with the representative designated in the application for certification.

(4) All testing must be conducted in accordance with the applicable model year evaporative emission test procedures. Any evaporative emission control system parameters must be set to values or positions that are within the range available to the ultimate purchaser as determined by ARB. No break-in or modifications, adjustments, or special preparation or maintenance will be allowed on engines or equipment units chosen for compliance testing without the written consent of the Executive Officer.

(5) Correction of damage or maladjustment that may reasonably be found to have resulted from shipment of the engine or equipment is permitted only after an initial test of the engine or equipment, except where 100 percent of the manufacturer's production is given that inspection or maintenance by the manufacturer's own personnel. The manufacturer may request that the engine or equipment be repaired from shipping damage, and be retested. If the Executive Officer concurs, the engine or equipment may be retested, and the original test results may be replaced by the after-repair test results.

(6) Engines or equipment must be randomly chosen from the selected evaporative family or subgroup.

(7) Five tanks, engines or equipment of the same model within an evaporative family or subgroup will be selected for testing per the applicable test procedure. An evaporative family or subgroup will be deemed to have failed the compliance testing if the upper 95% confidence limit of the five samples is greater than 150%, 130%, or 110% of the applicable performance standards specified in sections 2754 through 2757 of this Article per the following table:

Test Category	"Pass" If "U" is less than or equal to	"Fail" If "U" is greater than
Ist Year of Production of Evaporative Families	1.5*Applicable Standard	1.5*Applicable Standard
2nd Year of Production of Evaporative Families	1.3*Applicable Standard	1.3*Applicable Standard
3rd and Subsequent Years of Production of Evaporative Families	1.1*Applicable Standard	1.1*Applicable Standard

Where:

$$U = \bar{x} + 2.776 * \frac{s}{\sqrt{n}}$$

$$\bar{x} = \frac{\sum_{i=1}^{n} sample_i}{n}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}$$

$$n = 5$$

(8) If any group of tanks, engines, or equipment units selected for inspection fails an evaporative emission test as determined by subsection (a)(7), or fails to conform to the labeling requirements of section 2759, the Executive Officer shall notify the manufacturer in accordance with subsection (b).

(b) Notification of Failure

If compliance testing identifies engines or equipment units that do not meet the standards set out in (a)(7) above, the Executive Officer will notify the Holder of the Executive Order of Certification covering the engines or equipment. The Executive Officer shall also notify such Holder that the Executive Order of Certification may be suspended or revoked. The Holder of the Executive Order of Certification shall have fourteen calendar days in which to notify the Executive Officer of their intent to provide additional information and/or independent test results for five tanks, engines, or equipment that document compliance of the evaporative family.

(c) Suspension and Revocation of Executive Orders.

(1) The Executive Officer shall not revoke or suspend the Executive Order of Certification, without considering any information provided by the holder of such certification pursuant to (b) above.

(2) If the results of the compliance testing indicate that the failed tanks, engines, or equipment units of a particular evaporative family or subgroup are produced at one plant, the Executive Officer may elect to suspend the Executive Order of Certification with respect to that evaporative family for engines or equipment manufactured at that plant.

(3) Notwithstanding the foregoing, the Executive Officer may suspend an Executive Order of Certification , in whole or in part, effective upon written notice to the Holder if the Executive Officer finds that :

(A) The Holder of the Executive Order of Certification has refused to comply with any of the requirements of this section; or

(B) The Holder has submitted false or incomplete information in any report or information provided to the Executive Officer under this section;

(C) The Holder has rendered inaccurate any test data submitted under this section;

(D) That ARB personnel have been denied the opportunity to conduct activities authorized under this Section after a warrant or court order is presented to the Holder;

(E) That ARB personnel were unable to conduct activities authorized in this Article because the facility is located in a foreign jurisdiction where local law prohibits those activities.

(4) The Executive Officer may revoke an Executive Order of Certification for an evaporative family after the Executive Order of Certification has been suspended pursuant to paragraph (1) or (2) of this Section if the proposed remedy for the nonconformity, as reported by the Holder to the Executive Officer, is one requiring a design change or changes to the evaporative emission control system as described in the application for certification of the affected evaporative family or subgroup.

(5) Once an Executive Order of Certification has been suspended for a failed tank, engine, or equipment, as provided for in paragraph (1) of this section, the Holder must take the following actions before the Executive Order of Certification can be reinstated:

(A) Remedy the nonconformity;
(B) Demonstrate that the tank, engine, or equipment conforms to the evaporative emission standards by retesting the tank, engine, or equipment in accordance with these regulations; and
(C) Submit a written report to the Executive Officer, after successful completion of testing on the failed tank, engine, or equipment that contains a description of the remedy and test results for each tank, engine, or equipment in addition to other information that may be required by this part.

(6) Once an Executive Order of Certification for a failed evaporative family or subgroup has been suspended pursuant to paragraph (1), (2) or (3) of this section, the Holder must take the following actions before the Executive Officer will consider reinstating the Executive Order of Certification:

(A) Submit a written report to the Executive Officer that identifies the reason for the noncompliance of the tanks, engines, or equipment, describes the proposed remedy, including a description of any proposed quality control and/or quality assurance measures to be taken by the Holder to prevent future occurrences of the problem, and states the date on which the remedies will be implemented; and
(B) Demonstrate that the evaporative family or subgroup for which the Executive Order of Certification has been suspended does in fact comply with the regulations of this part by testing no fewer than five tanks, engines, or equipment. The results must meet the "Pass" criteria in subsection (a)(7). Such testing must comply with the provisions of this Section.

(7) Once the Executive Order of Certification has been revoked for an evaporative family or subgroup, if the Holder desires to continue introduction into commerce of a modified version of that evaporative family or subgroup, the Holder must :

After implementing the change or changes intended to remedy the nonconformity, demonstrate that the modified evaporative family does in fact conform to the applicable standards of this Article by testing five engines or equipment from the modified evaporative family unless such testing is waived by the Executive Officer.

(8) To permit a Holder to avoid storing non-test engines or equipment while conducting subsequent testing of the noncomplying evaporative family, a Holder may request that the Executive Officer

conditionally reinstate the Executive Order of Certification for that evaporative family.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2766. Exemptions.

(a) Structurally Integrated Tanks - Structurally integrated nylon fuel tanks on SORE equipment with engine displacements $\leq$ 80 cc are specifically exempt from all Sections in this Article.

(b) Small Volume Equipment - Any equipment manufacturer that sells 400 or fewer units per year of equipment that use an identical fuel tank design is exempt from all Sections of this Article if the equipment contains the following:

(1) An evaporative emission control system certified by an engine manufacturer that uses an actively purged carbon canister, an equivalent fuel line, and a sealed tethered fuel cap; or

(2) An evaporative emission control system that passively vents fuel tank vapors to a carbon canister with a minimum butane working capacity of 2 grams per liter of tank volume, an equivalent fuel line, and a sealed tethered fuel cap.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2767. Innovative Products

(a) The Executive Officer can make a determination that fuel tanks that have undergone special treatment or that have been manufactured from a unique material are "equivalent fuel tanks" if it can be demonstrated that they meet the permeation standard in section 2755 of this Article when using TP-901, **[insert date of adoption]**. Tanks deemed equivalent augment "equivalent fuel tanks" already defined in section 2752 of this Article.

(b) A manufacturer must apply in writing to the Executive Officer for an innovative product equivalency claimed under subsection (a). The application must include the supporting documentation that quantifies the emissions from at least 30 samples of the innovative product, including the test methods used to generate the data. The test methods shall include criteria for reproducibility, accuracy, and sampling and laboratory procedures. In addition, the applicant must provide any information to enable the Executive Officer to establish conditions for making a determination of "equivalency". All information, including proprietary data submitted by a manufacturer pursuant to this section, shall be handled in accordance with the procedures specified in title 17, California Code of Regulations, sections 91000-91022.

(c) Within 30 days of receipt of the application, the Executive Officer shall determine whether an application is complete.

(d) Within 90 days after an application has been deemed complete, the Executive Officer will determine whether, under what conditions, and to what extent, a determination of "equivalency" will be permitted. The applicant and the Executive Officer may mutually agree to a longer time period for reaching a decision. An applicant may submit additional supporting documentation before a decision has been reached. The Executive Officer will notify the applicant of the decision in writing and specify such terms and conditions that are necessary to ensure that emissions from use of the product will meet the emissions reductions specified in subsection (a).

(e) In granting an "equivalency" determination for a fuel tank, the Executive Officer shall specify the test method(s) for determining conformance to the conditions established.

(f) For any fuel tank for which an innovative product "equivalency" has been granted pursuant to this section, the manufacturer shall notify the Executive Officer in writing at least 30 days before the manufacturer changes a product's design, connections, or other factors that may effect the ROG emissions during recommended usage. The manufacturer must also notify the Executive Officer within 30 days after the manufacturer learns of any information that would alter the emissions estimates submitted to the Executive Officer in support of the "equivalency" application.

(g) If the permeation standards are amended for a product category, all innovative "equivalency" determinations granted for products in the product category, except as provided in subsection (h), have no force and effect as of the effective date of the amended permeation standards.

(h) If the Executive Officer believes that a fuel tank for which an "equivalency" determination has been granted no longer meets the criteria for an innovative product specified in subsection (a), the Executive Officer may hold a public hearing in accordance with the procedures specified in title 17, California Code of Regulations, subchapter 1.25, to determine if the "equivalency" determination should be modified or revoked.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2768. Variances.

(a) Any manufacturer of small off-road engines or equipment that use small off-road engines or fuel tanks subject to this Article that cannot meet the requirements set forth in sections 2754 through 2757 of this Article, due to extraordinary reasons beyond the manufacturer's reasonable control, may apply in writing for a variance. The variance application must set forth:

(1) The provisions of the regulations for which a variance is sought;

(2) the specific grounds upon which the variance is sought;

(3) the proposed date(s) by which compliance will be achieved; and

(4) a compliance plan detailing the method(s) that will achieve compliance.

(b) Within 75 calendar days of receipt of a variance application containing the information required in subsection (a), the Executive Officer or his nominee shall hold a public hearing to determine whether, under what conditions, and to what extent, a variance is necessary and should be allowed. Notice of the time and place of the hearing must be sent to the applicant by certified mail not less than 30 days before to the hearing. Notice of the hearing must also be submitted for publication in the California Regulatory Notice Register and sent to every person who requests such a notice, not less than 30 days before the hearing. The notice must state that the parties may, but not need to be, represented by counsel at the hearing. At least 30 days before the hearing, the variance application must be made available to the public for inspection. Interested members of the public must be allowed a reasonable opportunity to testify at the hearing and their testimony must be considered.

(c) No variance may be granted unless all of the following findings are made:

(1) that, due to reasons beyond the reasonable control of the applicant, compliance would result in extraordinary economic hardship;

(2) that the public interest in mitigating the extraordinary hardship to the applicant by issuing the variance outweighs the public interest in avoiding any increased emissions of air contaminants that would result from issuing the variance;

(3) that the compliance plan proposed by the applicant can reasonably be implemented, and will achieve compliance as expeditiously as possible; and

(4) that the applicant has mitigated the noncompliance to the maximum extent feasible.

(d) Any variance order shall specify a final date by which compliance will be achieved. Any variance order shall contain a condition that specifies increments of progress necessary to assure timely compliance, and such other conditions that the Executive Officer, in consideration of the testimony received at the hearing, finds necessary to carry out the purposes of Division 26 of the Health and Safety Code.

(e) A variance shall cease to be effective upon failure of the party to whom the variance was granted to comply with any term or condition of the variance.

(f) Upon the application of any person, the Executive Officer may review, and for good cause, modify or revoke a variance from requirements of sections 2753 through 2756 or section 2759 after holding a public hearing in accordance with the provisions of subsection (b).

(g) In no event shall a variance be granted for more than one model year.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2769. Inspection.

The Executive Officer, or an authorized representative of the Executive Officer, may periodically inspect manufacturers of equipment, manufacturers of engines, or manufacturers of evaporative emission control components, technology, or systems subject to this Article as deemed necessary to ensure compliance with these regulations. Failure of a manufacturer, distributor, or retailer or other person subject to this Article to allow access for inspection purposes shall be grounds for suspension or revocation of an Executive Order of Certification.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2770. Denial, Suspension or Revocation of Certification.

(a) The Executive Officer for just cause may deny, suspend or revoke an Executive Order of Certification in any of the following circumstances:

An applicant or Holder has materially misrepresented the meaning, findings, effect or any other material aspect of the certification application, including submitting false or incomplete information in its application for certification regardless of the applicant's personal knowledge of the falsity or incompleteness of the information;

An applicant or Holder that uses a label other than the approved label on any engine or equipment, or the label used otherwise fails to comply with the requirements of this Article.

(b) An applicant or Holder may be denied certification or be subject to a suspension or revocation action pursuant to this section based upon the actions of an agent, employee, licensee, or other authorized representative.

(c) The Executive Officer shall notify the applicant or Holder by certified mail of any action taken by the Executive Officer to deny, suspend or revoke *any certification granted under this Article. The notice shall set forth the* reasons for and evidence supporting the action(s) taken. A suspension or revocation is effective upon receipt of the notification.

(d) A Holder may request that the suspension or revocation be stayed pending a hearing under section 2771. In determining whether to grant the stay, the Executive Officer shall consider the harm the Holder will likely suffer if the stay is not granted. The Executive Officer shall deny the stay if the adverse effects of the stay on the public health, safety, and welfare outweigh the harm to the Holder if the stay is not granted.

(e) Once an Executive Order of Certification has been suspended pursuant to (a) above, the Holder must satisfy and correct all noted reasons for the suspension and submit a written report to the Executive Officer advising him or her of all such steps taken by the Holder before the Executive Officer will consider reinstating the Executive Order of Certification.

(f) Nothing in this Section shall prohibit the Executive Officer from taking any other action provided for by law for violations of the Health and Safety Code.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2771. Appeals.

Any person whose application for Executive Order of Certification has been denied, suspended, or revoked may request a hearing to review the action as provided herein. Any such request shall be made within fifteen working days of the date the action for which review is sought became final.

(a) Hearing Procedure.

Except as provided for in subsection (b) below, any appeal pursuant to this section shall be conducted in accordance with the Administrative Hearing Procedures for Petitions for Review of Executive Officer Decisions, title 17, California Code of Regulations, Division 3. Chapter 1 Article 2, commencing with section 60055.1.

(b) Review by written submission.

(1) In lieu of the hearing procedure set forth in (a) above, a manufacturer may request that a review of the Executive Officer's decision be conducted by a hearing officer solely by written submission.

(2) A manufacturer may request a review of the Executive Officer's decision to deny, suspend or revoke a certification no later than 20 days from the date of issuance of the notice of the denial, suspension, or revocation. Such request shall include, at a minimum, the following:

(A) name of the manufacturer, the name, address and telephone number of the person representing the manufacturer and a statement signed by a senior officer of the manufacturer warranting that the representative has full authority to bind the manufacturer as to all matters regarding the appeal;

(B) copy of the Executive Order granting certification and the *written notification of denial;*

(C) a statement of facts and explanation of the issues to be raised setting forth the basis for challenging the denial, suspension, or revocation (conclusory allegations will not suffice) together with all documents relevant to those issues; and

(D) the signature of the representative named in (A) above.

(3) Upon receipt of a request for review, the request shall be referred to the administrative hearing office of the state board for assignment of a hearing officer.

(4) Within 15 days of appointment of a hearing officer ARB staff shall submit a written response to the manufacturer's submission and documents in support of the Executive Officer's action no later than 10 days after receipt of the manufacturer's submission;

(5) within 7 days of receipt of the ARB response, the manufacturer may submit one rebuttal statement which shall be limited to the issues raised in the ARB rebuttal;

(6) if the manufacturer submits a rebuttal, ARB staff may, within 7 days of receipt of the manufacturer's rebuttal, submit one rebuttal statement which shall be limited to the issues raised in the manufacturer's rebuttal; and

(7) the hearing officer shall receive all statements and documents and render a written decision. The hearing officer's decision shall be mailed to the manufacturer no later than 60 working days after the final deadline for submission of papers.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2772. Penalties.

In addition to suspension or revocation of an Executive Order of Certification as provided in this Article, the Executive Officer may seek civil or criminal penalties as provided for by law and/or such equitable relief deemed appropriate for any violation of these regulations.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

§2773. Severability.

Each part of this article is severable, and in the event that any part of this article is held to be invalid, the remainder of this article remains in full force and effect.

NOTE: Authority cited: Sections 39600, 39601, and 43013 Health and Safety Code. Reference: Section Health and Safety Code 43013.

APPENDIX D: PROPOSED SMALL OFF-ROAD ENGINE EVAPORATIVE EMISSIONS TEST PROCEDURES

California Environmental Protection Agency

Air Resources Board

Small Off-Road Engine Evaporative Emissions Test Procedure

TP - 901

Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks

Proposed: August 8, 2003

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Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks

A set of definitions common to all Certification and Test Procedures are in Title 13, California Code of Regulations (CCR), Section 2752 et seq.

For the purpose of this procedure, the term "CARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the CARB Executive Officer, or his or her authorized representative or designate.

1. APPLICABILITY

This Test Procedure, TP-901, is used by the Air Resources Board to determine the permeation rate from fuel tanks of equipment that use spark ignited small off-road engines with displacements of less than or equal to 80 cc. Small off-road engines (SORE) are defined in Title 13, California Code of Regulations (CCR), section 2401 et seq. This Test Procedure is proposed pursuant to Section 43824 of the California Health and Safety Code (CH&SC) and is applicable in all cases where equipment with fuel tanks subject to the maximum allowable permeation performance standard are sold, supplied, offered for sale, or manufactured for use in the State of California.

1.1 Requirement to Comply with All Other Applicable Codes and Regulations

Certification or approval of an equipment fuel tank by the Executive Officer does not exempt the fuel tank from compliance with other applicable codes and regulations such as state and federal safety codes and regulations.

1.2 Safety

This test procedure involves the use of flammable materials and operations and should only be used by or under the supervision of those familiar and experienced in the use of such materials and operations. Appropriate safety precautions should be observed at all times while performing this test procedure.

2. PERFORMANCE STANDARDS

The minimum performance standards for certification of evaporative emission control systems on small off-road engines or equipment that use small off-road engines is defined in CCR Title 13, Chapter 15, Article 1, Section 2755.

3. PRINCIPLE AND SUMMARY OF TEST PROCEDURE

Prior to permeation testing of the fuel tank, durability testing is performed. Durability testing exposes the fuel tank to pressure and vacuum extremes, and fuel sloshing. After durability testing, the fuel tank outlet(s) are sealed and the tank is then filled with Phase II California Reformulated Certification (CERT) fuel. Once filled, the tank is allowed to precondition at ambient temperature and pressure for a minimum of 20 weeks or until equilibrium is reached. Once preconditioning is complete, the tank is emptied, immediately refilled with CERT fuel, and allowed to equilibrate at 40 °C.

After the fuel temperature reaches 40 °C +/- 2 °C, an additional HDPE coupon is fusion welded over the tank inlet in place of the fuel cap. The tank is then leak tested, weighed, and subjected to a constant (40 °C) temperature. At the end of each 24-hour period, the tank is re-weighed and the weight loss in grams is calculated. The permeation rate is defined as the average steady state weight loss over time divided by the tank's internal surface area.

4. BIASES AND INTERFERENCES

To accurately quantify the losses attributable solely to permeation, each tank tested must be completely sealed. Tanks incorrectly sealed will emit evaporative emissions, which can affect the final weight loss calculations.

To ensure the losses attributed to permeation are accurately quantified during this test procedure, the tanks must remain exposed to the constant 40 °C temperature for each 24-hours ± 30 minutes period.

CERT fuel is required for both preconditioning and testing. Currently, CERT fuel does not contain alcohol. Fuels containing alcohol can significantly bias permeation results.

Relative humidity greater than 20% can bias the permeation results for certain plastics such as nylon. Where these types of plastics are tested, the relative humidity must be controlled to accurately quantify the losses attributable solely to permeation.

5. SENSITIVITY AND RANGE

Range of mass measurement of filled tanks is approximately 100 grams to 32,000 grams depending on tank volume. For mass measurements more then 6200 grams, the minimum sensitivity of the balance must be 0.1 grams. For mass measurement between 1000 and 6200 grams, the minimum sensitivity of the balance must be 0.01 grams. For mass measurements less than 1000 grams, the minimum sensitivity of the balance must be 0.001 grams.

6. EQUIPMENT

6.1 A hand held Teflon coated aluminum hot plate thermostatically controlled to approximately 218° C (hand held fusion welder) and 1/4" thick high-density polyethylene (HDPE) coupons. Both the hand held fusion welder and HDPE coupons must be of sufficient diameter to completely cover the opening(s) of the tank.

6.2 A top loading balance that meets the requirements of section 4 above. 245

6.3 A vented enclosure with a temperature conditioning system capable of controlling the internal enclosure air temperature with an instantaneous tolerance of ± 1.7° C of the nominal temperature versus time profile throughout the test, and an average tolerance of ± 1.1° C over the duration of the test.

6.4 A barometric pressure transducer capable of measuring atmospheric pressure to within 0.1 millimeters of mercury.

6.5 A temperature instrument capable of measuring ambient temperature to within +/- 0.5° C.

7. CALIBRATION PROCEDURE

The high capacity top loading balance shall be calibrated prior to use per the manufacturer's specifications.

8. DURABILITY DEMONSTRATION

A durability demonstration is required prior to any testing to determine the performance of a fuel tank. These durability tests are designed to ensure that the fuel tank assembly remains effective throughout the useful life of the equipment. A durability demonstration consists of the following tests:

Pressure/Vacuum Test

The Pressure/Vacuum test is performed prior to any preconditioning of the fuel tank. Pressurize the empty tank, sealed with the OEM fuel cap, or a modified OEM fuel cap as required, to 4.0 pounds per square inch gauge (PSIG) using room air heated to 49 °C and then evacuate to negative 1.0 PSIG through the fuel outlet. If the OEM fuel cap is designed to eliminate negative pressure conditions within the fuel tank, the lower pressure threshold for the test may be raised to 0.0 PSIG. Repeat the pressure/vacuum process until the tank has been subjected to not less than 1000 cycles in 8 hours ± 1 hour.

Slosh Test

The Slosh test can be performed during the preconditioning period. Perform a slosh test by filling the tank to 50 percent capacity with CERT fuel. Seal the tank using the OEM fuel cap or modified fuel cap and metal plugs for the fuel tank outlet(s). Use a laboratory sample orbital shaker table or similar device to subject the tank to a centripetal acceleration of at least 2.4 meter/second^2 at a frequency of 2 cycles per second for one million cycles. As an alternative, slosh testing may be performed using the method specified in 40 CFR Part 1051 §1051.515 (c).

Following these durability tests, each tank must be preconditioned to ensure a stable permeation rate. The period of slosh testing may be considered part of the preconditioning period provided each tank tested remains at least half filled with fuel and is never empty for more than one hour minutes over the entire preconditioning period.

9. PRECONDITIONING PROCEDURE

After performing the durability tests, ensure that the fuel tank and any vent outlets are sealed- 241 and leak tight. This can be accomplished by fusion welding a HDPE coupon over the fuel outlet(s) or by inserting and clamping metal plugs into each outlet. Once sealed, fill the tank to its nominal capacity with CERT fuel and attach the OEM fuel cap. Place the tank in a suitable vented enclosure. Record the preconditioning start date on the field data sheet. Soak the tank at 30° C ± 10° C for not less than 140 days. Accelerated preconditioning of the tank can be accomplished by soaking the tank at an elevated temperature. Data documenting that the tank has reached equilibrium must be provided for tanks soaked less than 140 days.

10. SEALING PROCEDURE

10.1 After preconditioning, remove the tank from the enclosure to a well-ventilated area. Record the preconditioning end date on the field data sheet. Remove the cap and empty the tank. The tank must not remain empty for more than fifteen minutes. Immediately refill the tank to its nominal capacity with CERT fuel. Place the unsealed tank in a heated enclosure and allow it to equilibrate to 40° C ± 2° C for a minimum of two hours. After the fuel temperature has equilibrated to 40° C ± 2° C, seal the tank by fusion welding a HDPE coupon over the fuel fill neck opening to make a seal. Perform a leak check by submerging each tank in a water bath large enough to completely cover the tank plus six inches. Observe the tank for any leaks. Leak points will be visible as a bubble or stream of bubbles while immersed in the water bath. If leaks are observed, remove and dry the tank and repair all leaks. Continue this process until no leaks are observed.

10.2 For materials that cannot be sealed using fusion welding, good engineering practices should be used to seal the tank. As an alternative, the technique used to seal tanks described in SAE 920164 "Permeation of Gasoline-Alcohol Fuel Blends Through High-Density Polyethylene Fuel Tanks with Different Barrier Technologies" may be used.

11. TEST PROCEDURE WITH BUOYANT FORCE CORRECTION

11.1 Ensure that the exterior surface of the sealed tank is clean, dry, and free of dirt and debris. Carefully place the sealed tank on the high capacity balance. Record the initial weight (W_{si}), barometric pressure (P_i), temperature (T_i), date, and start time on the field data sheet (Figure 1).

11.2 Immediately place the sealed tank in the enclosure. Begin the 24-hour soak at 40° C ± 2° C. If more than thirty minutes elapses between the time the sealed tank was weighed and the initiation of the 24-hour soak, the sealed tank must be re-weighed.

11.3 At the conclusion of the 24-hour soak period, immediately remove the sealed tank from the enclosure and ensure that the exterior surface is clean, dry, and free of dirt and debris. Carefully place the sealed tank on the high capacity balance. Record the final weight (W_{sf}), barometric pressure (P_f), temperature (T_f), date, and end time on the field data sheet. If more than thirty minutes elapses between the conclusion of the 24-hour soak period and the final weighing of the sealed tank, the final weight is invalid and should not be used in future calculations. If this occurs, the test procedure must be reinitiated.

11.4 Calculate the difference between the initial weight (Wi) and the final weight (Wf). This is the weight loss (Wl) due to permeation. Record the weight loss (Wl) on the field data sheet. Refer to Section 14 for calculation.

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11.5 Repeat this process until the correlation coefficient (R^2), from a plot of the cumulative daily weight loss versus time for three consecutive 24-hour cycles, is 95% or greater.

12. TEST PROCEDURE WITH TRIP BLANK CORRECTION

12.1 As an alternative to the buoyant force correction method, two identical sealed tanks, one containing fuel and one remaining empty, are weighed concurrently. The mass changes documented by the empty tank are used to correct the tank containing fuel. Ensure that the exterior surface of each tank is clean, dry, and free of dirt and debris. Carefully place the full tank on the high capacity balance. Record the initial weight (W_{if}), date, and start time on the field data sheet (Figure 2). Next, carefully place the empty tank on the high capacity balance. Record the initial weight (W_{ie}), date, and start time on the field data sheet.

12.2 Immediately place the two sealed tanks in the enclosure. Begin the 24-soak at 40° C ± 2° C. If more than thirty minutes elapses between the time the sealed tank was weighed and the initiation of the 24-hour soak, then both tanks must be re-weighed.

12.3 At the conclusion of the 24-hour soak period, immediately remove the tanks from the enclosure and ensure that the exterior surface is clean, dry, and free of dirt and debris. Carefully weigh each tank on the high capacity balance. Record the final weights (W_{ff}), (W_{fe}), date, and end time on the field data sheet. If more than thirty minutes elapses between the conclusion of the 24-hour soak period and the final weighing of the sealed tank, the final weight is invalid and should not be used in future calculations. If this occurs, the test procedure must be reinitiated.

12.4 Calculate the difference between the initial weight (*Wi*) and the final weight (*Wf*) for each tank. Record the difference on the field data sheet. Refer to Section 15 for calculation.

12.5 Repeat this process until the correlation coefficient (R^2), from a plot of the cumulative daily weight loss versus time for ten consecutive 24-hour cycles, is 95% or greater.

13. QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

This section is reserved for future specification.

14. RECORDING DATA

Record data on field data sheets shown in figure 1 and figure 2.

15. CALCULATING PERMEATION RATE USING BUOYANT FORCE CORRECTION

The daily weight loss in grams is calculated for each 24-hour cycle as follows:

$$Wl = W_i - W_f$$

Where:

Wl	=	The weight loss in grams
W_i	=	The initial weight of the tank in grams
W_f	=	The final weight of the tank in grams
W_i	=	$W_{si} - W_{bi}$
W_f	=	$W_{sf} - W_{bf}$
W_{bi}	=	The initial bouyant force = $\frac{P_i * Vol_{tank} * 28.96}{R * T_i}$
W_{bf}	=	The final bouyant force = $\frac{P_f * Vol_{tank} * 28.96}{R * T_f}$
P_i	=	The initial barometric pressure in Pascals during weighing
P_f	=	The final barometric pressure in Pascals during weighing
T_i	=	The initial temperature in Kelvin during weighing
T_f	=	The final temperature in Kelvin during weighing
Vol_{tank}	=	The volume of air the tank displaces in cubic meters
R	=	Molar gas constant 8.314 Joules/mol*Kelvin
W_{si}	=	The initial balance response in grams
W_{sf}	=	The final Balance response in grams

Plot the cumulative daily weight loss (in grams) against the sampling time (days). Perform a linear regression on three consecutive data points.

If the correlation coefficient is at least 95%, the permeation rate in grams per square meter per day is calculated by dividing the slope of the regression line (grams/day) by the tanks internal surface area (obtained from the tank manufacturer).

$$P_{rate} = Slope / A_{tank}$$

Where:

P_{rate}	=	The permeation rate in grams/meter^2/day
$Slope$	=	The slope of the regression line in grams/day
A_{tank}	=	The tank's internal surface area in meter^2

16. CALCULATING PERMEATION RATE USING TRIP BLANK CORRECTION

The daily weight loss in grams is calculated for each 24-hour cycle as follows:

$$Wl = W_{if} - D_f$$

Where:

Wl	=	The weight loss in grams
W_{if}	=	The initial weight of the full tank in grams

W_{ff} = The final weight of the full tank in grams
D_f = $W_{ff} + D_e$
D_e = $W_{ie} - W_{fe}$
W_{ie} = The initial weight of the empty tank in grams
W_{fe} = The final weight of the empty tank in grams

Plot the cumulative daily weight loss (in grams) against the sampling time (days). Perform a linear regression on three consecutive data points.

If the correlation coefficient is at least 95%, the permeation rate in grams per square meter per day is calculated by dividing the slope of the regression line (grams/day) by the tanks internal surface area (obtained from the tank manufacturer).

$$P_{rate} = Slope / A_{tank}$$

Where:

P_{rate} = The permeation rate in grams/meter^2/day
$Slope$ = The slope of the regression line in grams/day
A_{tank} = The tank's internal surface area in meter^2

17. EMISSION FACTOR

The emissions factor (grams/day) for the fuel tank is obtained from the slope of the regression line.

18. ALTERNATIVE TEST PROCEDURES

Test procedures, other than specified above, shall only be used if prior written approval is obtained from the ARB Executive Officer. In order to secure the ARB Executive Officer's approval of an alternative test procedure, the applicant is responsible for demonstrating to the ARB Executive Officer's satisfaction that the alternative test procedure is equivalent to this test procedure.

(1) Such approval shall be granted on a case-by-case basis only.

(2) Documentation of any such approvals, demonstrations, and approvals shall be maintained by the ARB Executive Officer and shall be made available upon request.

19. REFERENCES

Permeation of Gasoline-Alcohol Fuel Blends Through High-Density Polyethylene Fuel Tanks with Different Barrier Technologies, SAE Technical Paper Series 920124, International Congress & Exposition, Detroit Michigan, February 1992

20. FIGURES

Figure 1. Field Data Sheet (Buoyant Force Correction)
Figure 2. Field Data Sheet (Trip Blank Correction)

Figure 1
Field Data Sheet
(Buoyant Force Correction)

Tank Manufacturer:____

Volume of Air Displaced by Tank (meter^3):__________________________

Tank I.D:____

Tested By:____

Water Bath Test (pass/fail):__________________________________

Tank Internal Surface Area (meter^2):____________________________

Date/Time Start		Date/Time End		Initial Weight W_{si} (grams)	Final Weight W_{sf} (grams)	Weight Loss Wl (grams)

Date/Time Start		Date/Time End		Initial Pressure P_i *(Pascals)*	Final Pressure P_f (Pascals)	Initial Temperature T_i *(Celsius)*	Final Temperature T_f *(Celsius)*

$$Wl=(W_{si}-(28.96*P_i*Vol_{tank}\ /(8.314*(T_i+273.15)))-((W_{sf}-(28.96*P_f*Vol_{tank}\ /(8.314*(T_f+273.15)))$$

Figure 2
Field Data Sheet
(Trip Blank Correction)

Tank Manufacturer:________________________________

Tank I.D:________________________________

Tested By:________________________________

Water Bath Test (pass/fail):________________________________

Tank Internal Surface Area (meter^2):________________________________

Full Tank Data

Date/Time Start		Date/Time End		Initial Weight W_{if} (grams)	Final Weight W_{ff} (grams)	Difference D_f (grams)	Weight Loss Wl (grams)

$Wl = (W_{if} - D_f)$, $D_f = (W_{ff} + D_e)$, $D_e = (W_{ie} - W_{fe})$

Empty Tank Data

Date/Time Start		Date/Time End		Initial Weight W_{ie} (grams)	Final Weight W_{fe} (grams)	Difference D_e (grams)

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California Environmental Protection Agency

Air Resources Board

Small Off-Road Engine Evaporative Emissions Test Procedure

TP - 902

Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines

Proposed: August 8, 2003

TP-902
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Small Off-Road Engine Evaporative Emissions Test Procedure

TP-902

Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines

A set of definitions common to all Certification and Test Procedures are in Title 13, California Code of Regulations (CCR), Section 2752 et seq.

For the purpose of this procedure, the term "CARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the CARB Executive Officer or his or her authorized representative or designate.

1. APPLICABILITY

This Test Procedure, TP-902, is used by the Air Resources Board to determine the diurnal and resting loss evaporative emissions from small off-road engines below 25 horsepower. Small off-road engines are defined in Title 13, California Code of Regulations (CCR), section 2401 et seq. This Test Procedure is proposed pursuant to Section 43824 of the California Health and Safety Code (CH&SC) and is applicable in all cases where small off-road engines are sold, supplied, offered for sale, or manufactured for use in the State of California.

1.1 Requirement to Comply with All Other Applicable Codes and Regulations

Certification or approval of any engine or evaporative emission control system by the Executive Officer does not exempt the engine or evaporative emission control system from compliance with other applicable codes and regulations such as state and federal safety codes and regulations.

1.2 Safety

This test procedure involves the use of flammable materials and operations and should only be used by or under the supervision of those familiar and experienced in the use of such materials and operations. Appropriate safety precautions should be observed at all times while performing this test procedure.

2. PERFORMANCE STANDARDS

The minimum performance standards for certification of evaporative emission control systems on small off-road engines or equipment that use small off-road engines is defined in CCR Title 13, Chapter 15, Article 1, Section 2754.

3. DURABILITY DEMONSTRATION

A demonstration of durability of the applicants evaporative emission control system is required prior to performing an evaporative emissions test.

Prior to the commencement of a durability demonstration, the applicant is required to submit and obtain approval of an evaporative emission durability test procedure. Once approved, a manufacturer is not required to obtain a new approval for an evaporative emission durability test procedure(s) unless there are changes to the evaporative family and/or components. The Executive Officer shall review the method based on the following requirements:

- The durability test procedure(s) should include a method to cycle and/or test the complete evaporative emission control system to demonstrate that the system remains effective for the duration of the engines useful life.

- The durability test procedure(s) should duplicate the effects of the flow of liquid and gaseous fuel through the evaporative emission control system, and the exposure (both peak and cyclic) to heat, vibration, and fuel slosh based upon the duration of the engines useful life.

- The durability test procedure(s) must actuate control valves, cables, and linkages, where applicable, for a minimum of 5000 cycles.

- The durability test procedure(s) must include specifications for acceptable system performance, including maximum allowable leakage and/or canister efficiency at the end of the engines useful life based on typical consumer use.

- The durability test procedure(s) must include a pressure/vacuum test of the engines fuel tank. The pressure/vacuum test must be performed prior to any preconditioning of the engines fuel tank. The pressure/vacuum test must pressurize the empty fuel tank, sealed with the OEM fuel cap, or a modified OEM fuel cap as required, to 4.0 pounds per square inch gauge (PSIG), or the manufacturer's upper design limit using room air heated to 120 °F, and then evacuate to negative 1.0 PSIG through the fuel outlet. The procedure must repeat the pressure/vacuum process until the tank has been subjected to not less than 1000 cycles in 8 hours ± 1 hour.

- The durability test procedure(s) must include a slosh test of the engines fuel tank. The slosh test can be performed during the preconditioning period. A slosh test must be performed on a fuel tank filled to 50 percent capacity with CERT fuel. The fuel tank must be sealed with the OEM fuel cap. A laboratory orbital shaker table or similar device is then used to subject the tank to a centripetal acceleration of at least 2.4 meter/second^2 at a frequency of 2 cycles per second for one million cycles. As an alternative, slosh testing may be performed using the method specified in 40 CFR Part 1051 §1051.515 (c).

- For evaporative emission control systems that only use a carbon canister and do not pressurize the fuel tank, the durability test procedure(s) must include a method to ensure that the carbon canister has a minimum working capacity of 2 grams of vapor storage capacity per liter of nominal fuel tank volume. Working capacity is determined following the procedure in 40 CFR 86.132-96, Section (h)(iv). In addition, the 256 durability test procedure(s) must demonstrate that the engine actively purges the canister and documents that the carbon canister system is effective throughout the useful life of the engine. At a minimum, the durability test procedure(s) shall include thermal cycling and vibration exposure. For thermal cycling, the procedure must subject the canister to 100 cycles of the following temperature profile:

- Heat and hold at 60°C ± 2°C for 30 minutes. (Up to 5 minutes is allowed for the temperature to rise and stabilize.)
- Cool and hold at 0°C ± 2°C for 30 minutes. (Up to 8 minutes is allowed for the temperature to reach 0°C during the cooling period.)

For vibration exposure, at a minimum, the canister must be placed in a suitable test fixture while maintaining its specified orientation (as designed). Subject the fixture to a horizontal vibration force of 4.5G x 60Hz x 10^7 times directed perpendicular to the base of the test fixture. Following the thermal cycling and vibration exposure tests, the carbon canister must be preconditioned with fuel vapor to develop a stable working capacity prior to determining the diurnal evaporative emissions.

4. GENERAL SUMMARY OF TEST PROCEDURE

A Sealed Housing for Evaporative Determination (SHED) is used to measure diurnal emissions. This method subjects test engines to a preprogrammed temperature profile while maintaining a constant pressure and continuously sampling for hydrocarbons with a Flame Ionization Detector (FID). The volume of a SHED enclosure can be accurately determined. The mass of total hydrocarbons that emanates from a test engine over the test period is calculated using the ideal gas equation.

This test procedure measures diurnal emissions from engines by subjecting them to a hot soak and diurnal test sequence. The basic process is as follows:

- Fill the engine fuel tank with fuel and operate at rated speed for 5-minutes
- Precondition the engines evaporative emission control and fuel delivery system
- Drain and fill engine fuel tank to 50% capacity with California certification fuel
- Purge carbon canister (if so equipped)
- Operate engine at rated speed for fifteen minutes
- Subject engine to a one-hour constant 95°F hot soak profile
- Soak engine for two hours at 65°F
- Subject engine to a 24-hour variable (65°F - 105°F - 65°F) temperature diurnal profile

The mass of total hydrocarbons measured by the SHED over the 24-hour diurnal profile is compared with the performance standards in CCR Title 13, Chapter 15, Article 1, Section 2754. Engines or equipment that meet the appropriate performance standard shall be considered compliant.

5. INSTRUMENTATION

The instrumentation necessary to perform evaporative emission testing for small off-road engines is the same instrumentation used for passenger cars and light duty vehicles, and is described in 40 CFR 86.107-96.

5.1 Diurnal Evaporative Emission Measurement Enclosure

The *diurnal evaporative emissions measurement enclosure shall* be equipped with an internal blower or blowers coupled with an air temperature management system (typically air to water heat exchangers and associated programmable temperature controls) to provide for air mixing and temperature control. The blower(s) shall provide a nominal total flow rate of 0.8 ± 0.2 ft^3/min per ft^3 of the nominal enclosure volume, V_n. The inlets and outlets of the air circulation blower(s) shall be configured to provide a well-dispersed air circulation pattern that produces effective internal mixing and avoids significant temperature or hydrocarbon and alcohol stratification. The discharge and intake air diffusers in the enclosure shall be configured and adjusted to eliminate localized high air velocities which could produce non-representative heat transfer rates between the engine fuel tank(s) and the air in the enclosure. The air circulation blower(s), plus any additional blowers if required, shall also maintain a minimum air speed of 5 mph near the fuel tank of the test engine. The Executive Officer may adjust air speed and location to ensure sufficient air circulation around the fuel tank. The air speed requirement may be satisfied by consistently using a blower configuration that has been demonstrated to meet a broad 5-mph airflow near the engine's fuel tank, subject to verification by the Executive Officer.

The enclosure temperature shall be taken with thermocouples located 3 feet above the floor at the approximate mid-length of each side wall of the enclosure and within 3 to 12 inches of each side wall. The temperature conditioning system shall be capable of controlling the internal enclosure air temperature to follow the prescribed temperature versus time cycle as specified in 40 CFR §86.133-90 as modified by paragraph III.D.10 (diurnal breathing loss test) of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" within an instantaneous tolerance of ± 3.0°F and an average tolerance of ± 2.0°F as measured by side wall thermocouples. The instantaneous tolerance must also be within of ± 5.0°F. The control *system shall be tuned to provide a smooth temperature pattern, which has a minimum of* overshoot, hunting, and instability about the desired long-term temperature profile.

The enclosure shall be of sufficient size to contain the test equipment with personnel access space. It shall use materials on its interior surfaces, which do not adsorb or desorb hydrocarbons, or alcohols (if the enclosure is used for alcohol-fueled vehicles). The enclosure shall be insulated to enable the test temperature profile to be achieved with a heating/cooling system, which has minimum surface temperatures in the enclosure no less than 25.0°F below the minimum diurnal temperature specification. The enclosure shall be equipped with a pressure transducer with an accuracy and precision of ± 0.1 inches H_2O. The enclosure shall be constructed with a minimum number of seams and *joints, which provide potential leakage paths. Particular attention shall be given to* sealing and gasketing of such seams and joints to prevent leakage.

The enclosure shall be equipped with features, which provide for the effective enclosure volume to expand and contract in response to both the temperature changes of the air mass in the enclosure, and any fluctuations in the ambient barometric pressure during the duration of the test. Either a variable volume enclosure or a fixed volume enclosure may be used for diurnal emission testing.

A variable volume enclosure shall have the capability of latching or otherwise 258 constraining the enclosed volume to a known, fixed value, V_n. The V_n shall be determined by measuring all pertinent dimensions of the enclosure in its latched configuration, including internal fixtures, based on a temperature of 84°F, to an accuracy of ± 1/8 inch (0.5 cm) and calculating the net V_n to the nearest 1 ft^3. In addition, V_n shall be measured based on a temperature of 65°F and 105°F. The latching system shall provide a fixed volume with an accuracy and repeatability of $0.005xV_n$. Two potential means of providing the volume accommodation capabilities are; a moveable ceiling which is joined to the enclosure walls with a flexure, or a flexible bag or bags of Tedlar or other suitable materials, which are installed in the enclosure and provided with flowpaths which communicate with the ambient air outside the enclosure. By moving air into and out of the bag(s), the contained volume can be adjusted dynamically. The total enclosure volume accommodation shall be sufficient to balance the volume changes produced by the difference between the extreme enclosure temperatures and the ambient laboratory temperature with the addition of a superimposed barometric pressure change of 0.8 in. Hg. A minimum total volume accommodation range of $\pm 0.07xV_n$ shall be used. The action of the enclosure volume accommodation system shall limit the differential between the enclosure internal pressure and the external ambient barometric pressure to a maximum value of ± 2.0 inches H_2O.

The fixed volume enclosure shall be constructed with rigid panels that maintain a fixed enclosure volume, which shall be referred to as V_n. V_n shall be determined by measuring all pertinent dimensions of the enclosure including internal fixtures to an accuracy of ± 1/8 inch (0.5 cm) and calculating the net V_n to the nearest 1 ft^3. The enclosure shall be equipped with an outlet flow stream that withdraws air at a low, constant rate and provides makeup air as needed, or by reversing the flow of air into and out of the enclosure in response to rising or falling temperatures. If inlet air is added continuously throughout the test, it must be filtered with activated carbon to provide a relatively constant hydrocarbon and alcohol level. Any method of volume accommodation shall maintain the differential between the enclosure internal pressure and the barometric pressure to a maximum value of ±2.0 inches of water. The equipment shall be capable of measuring the mass of hydrocarbon, and alcohol (if the enclosure is used for alcohol-fueled equipment) in the inlet and outlet flow streams with a resolution of 0.01 gram. A bag sampling system may be used to collect a proportional sample of the air withdrawn from and admitted to the enclosure. Alternatively, the inlet and outlet flow streams may be continuously analyzed using an on-line Flame Ionization Detector (FID) analyzer and integrated with the flow measurements to provide a continuous record of the mass hydrocarbon and alcohol removal.

An online computer system or strip chart recorder shall be used to record the following parameters during the diurnal evaporative emissions test sequence:

- Enclosure internal air temperature
- Diurnal ambient air temperature specified profile as defined in 40 CFR §86.133-90 as modified in paragraph III.D.10 of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" (diurnal breathing loss test).
- Enclosure internal pressure
- Enclosure temperature control system surface temperature(s)
- FID output voltage recording the following parameters for each sample analysis:

- zero gas and span gas adjustments
- zero gas reading
- enclosure sample reading
- zero gas and span gas readings

The data recording system shall have a time resolution of 30 seconds and shall provide a permanent record in magnetic, electronic or paper media of the above parameters for the duration of the test.

Other equipment configurations may be used if approved in advance by the Executive Officer. The Executive Officer shall approve alternative equipment configurations if the manufacturer demonstrates that the equipment will yield test results equivalent to those resulting from use of the specified equipment.

5.2 Calibrations

Evaporative emission enclosure calibrations are specified in 40 CFR §86.117-90. Methanol measurements may be omitted when methanol-fueled engines will not be tested in the evaporative enclosure. Amend 40 CFR §86.117-90 to include an additional subsection 1.1, to read:

The diurnal evaporative emission measurement enclosure calibration consists of the following parts: initial and periodic determination of enclosure background emissions, initial determination of enclosure volume, and periodic hydrocarbon (HC) and methanol retention check and calibration. Calibration for HC and methanol may be conducted in the same test run or in sequential test runs.

5.2.1 The initial and periodic determination of enclosure background emissions shall be conducted according to the procedures specified in §86.117-90(a)(1) through (a)(6). The enclosure shall be maintained at a nominal temperature of 105.0°F throughout the four-hour period. Variable volume enclosures may be operated either in the latched volume configuration, or with the variable volume feature active. Fixed volume enclosures shall be operated with inlet and outlet flow streams closed. The allowable enclosure background emissions of HC and/or methanol as calculated according to 40 CFR §86.117-90(a)(7) shall not be greater than 0.05 grams in 4 hours. The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the initial HC concentration reading (C_{HCi}) and the initial methanol concentration reading (C_{CH3OHi}) is taken and the four-hour background measurement period begins.

5.2.2 The initial determination of enclosure internal volume shall be performed according to the procedures specified in paragraph I.A.1.3 of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles". If the enclosure will be used for hot soak determination, the determination of enclosure internal volume shall also be performed based on 105°F.

5.2.3 The HC and methanol measurement and retention checks shall evaluate the accuracy of enclosure HC and methanol mass measurements and the ability of the enclosure to retain trapped HC and methanol. The check shall be conducted over a 24-hour period with all of the normally functioning subsystems of the

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enclosure active. A known mass of propane and/or methanol shall be injected into the enclosure and an initial enclosure mass measurement(s) shall be made. The enclosure shall be subjected to the temperature cycling specified in paragraph III.D.10.1.7 of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" (revising 40 CFR §86.133-90(l)) for a 24-hour period. The temperature cycle shall begin at 105°F (hour 11) and continue according to the schedule until a full 24-hour cycle is completed. A final enclosure mass measurement(s) shall be made. The following procedure shall be performed prior to the introduction of the enclosure into service and following any modifications or repairs to the enclosure that may impact the integrity of this enclosure; otherwise, the following procedure shall be performed on a monthly basis. (If six consecutive monthly retention checks are successfully completed without corrective action, the following procedure may be determined quarterly thereafter as long as no corrective action is required.)

(A) Zero and span the HC analyzer.

(B) Purge the enclosure with atmospheric air until a stable enclosure HC level is attained.

(C) Turn on the enclosure air mixing and temperature control system and adjust it for an initial temperature of 105.0°F and a programmed temperature profile covering one diurnal cycle over a 24 hour period according to the profile specified in paragraph III.D.10.1.7. Of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" (revising 40 CFR §86.133-90). Close the enclosure door. On variable volume enclosures, latch the enclosure to the enclosure volume measured at 105°F. On fixed volume enclosures, close the outlet and inlet flow streams.

(D) When the enclosure temperature stabilizes at 105.0°F ± 3.0°F seal the enclosure; measure the enclosure background HC concentration (C_{HCe1}) and/or background methanol concentration (C_{CH3OH1}) and the temperature (T_1), and pressure (P_1) in the enclosure.

(E) Inject into the enclosure a known quantity of propane between 2 to 6 grams and a known quantity of methanol in gaseous form between 2 to 6 grams. For evaporative emission enclosures that will be used for testing equipment subject to the standards shown in Table 2-1, use a known amount of propane or gaseous methanol between 0.5 to 1.0 grams. The injection method shall use a critical flow orifice to meter the propane and/or methanol at a measured temperature and pressure for a measured time period. Techniques that provide an accuracy and precision of ± 0.5 percent of the injected mass are also acceptable. Allow the enclosure internal HC and/or methanol concentration to mix and stabilize for up to 300 seconds. Measure the enclosure HC concentration (C_{HCe2}) and/or the enclosure methanol concentration (C_{CH3OH2}). For fixed volume enclosures, measure the temperature (T_2) and pressure in the enclosure (P_2). On variable volume enclosures, unlatch the enclosure. On fixed volume enclosures, open the outlet and inlet flow streams. Start the temperature cycling function of the enclosure air mixing and temperature control system. These steps shall be completed within 900 seconds of sealing the enclosure.

(F) For fixed volume enclosures, calculate the initial recovered HC mass (M_{HCe1}) according to the following formula:

$$M_{HCe1} = (3.05 \times V \times 10^{-4} \times [P_2 (C_{HCe2} - rC_{CH3OH2})/T_2 - P_1 (C_{HCe1} - rC_{CH3OH1})/T_1])$$

Where:

V is the enclosure volume at 105°F (ft^3)
P_1 is the enclosure initial pressure (inches Hg absolute)
P_2 is the enclosure final pressure (inches Hg absolute)
C_{HCen} is the enclosure HC concentration at event n (ppm C)

C_{CH3OHn} is the enclosure methanol concentration calculated according to 40 CFR §86.117-90 (d)(2)(iii) at event n (ppm C)
r is the FID response factor to methanol
T_1 is the enclosure initial temperature (°R)
T_2 is the enclosure final temperature (°R)

For variable volume enclosures, calculate the initial recovered HC mass and initial recovered methanol mass according to the equations used above except that P_2 and T_2 shall equal P_1 and T_1.

Calculate the initial recovered methanol mass (M_{CH3OH1}) according to 40 CFR §86.117-96(d)(1), as amended March 24, 1993.

If the recovered HC mass agrees with the injected mass within 2.0 percent and/or the recovered methanol mass agrees with the injected mass within 6.0 percent, continue the test for the 24 hour temperature cycling period. If the recovered mass differs from the injected mass by greater than the acceptable percentage(s) for HC and/or methanol, repeat the enclosure concentration measurement in step (E) and recalculate the initial recovered HC mass (M_{HCe1}) and/or methanol mass (M_{CH3OH1}). If the recovered mass based on the latest concentration measurement agrees within the acceptable percentage(s) of the injected mass, continue the test for the 24-hour temperature cycling period and substitute this second enclosure concentration measurement for C_{HCe2} and/or C_{CH3OH2} in all subsequent calculations. In order to be a valid calibration, the final measurement of C_{HCe2} and C_{CH3OH2} shall be completed within the 900-second time limit outlined above. If the discrepancy persists, the test shall be terminated and the cause of the difference determined, followed by the correction of the problems(s) and the restart of the test.

(G) At the completion of the 24-hour temperature cycling period, measure the final enclosure HC concentration (C_{HCe3}) and/or the final enclosure methanol concentration (C_{CH3OH3}). For fixed-volume enclosures, measure the final pressure (P_3) and final temperature (T_3) in the enclosure.

For fixed volume enclosures, calculate the final recovered HC mass

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(M_{HCe2}) as follows:

$$M_{HCe2} = [3.05 \times V \times 10^{-4} \times (P_3 (C_{HCe3} - rC_{CH3OH3})/T_3 - P_1 (C_{HCe1} - rC_{CH3OH1})/T_1)] + M_{HC,out} - M_{HC,in}$$

Where:

V is the enclosure volume at 105°F (ft^3)
P_1 is the enclosure initial pressure (inches Hg absolute)
P_3 is the enclosure final pressure (inches Hg absolute)
C_{HCe3} is the enclosure HC concentration at the end of the 24-hour temperature cycling period (ppm C)
C_{CH3OH3} is the enclosure methanol concentration at the end of the 24-hour temperature cycling period, calculated according to 40 CFR §86.117-90 (d)(2)(iii) (ppm C)
r is the FID response factor to methanol
T_1 is the enclosure initial temperature (°R)
T_3 is the enclosure final temperature (°R)
$M_{HC,out}$ is mass of HC exiting the enclosure, (grams)
$M_{HC,in}$ is mass of HC entering the enclosure, (grams)

For variable volume enclosures, calculate the final recovered HC mass and final recovered methanol mass according to the equations used above except that P_3 and T_3 shall equal P_1 and T_1, and $M_{HC,out}$ and $M_{HC,in}$ shall equal zero.

Calculate the final recovered methanol mass (M_{CH3OH2}) according to 40 CFR §86.117-96(d)(1), as amended March 24, 1993.

(H) If the calculated final recovered HC mass for the enclosures is not within 3 percent of the initial enclosure mass, or if the calculated final recovered methanol mass for the enclosures is not within 6 percent of the initial enclosure mass, then action shall be required to correct the error to the acceptable level.

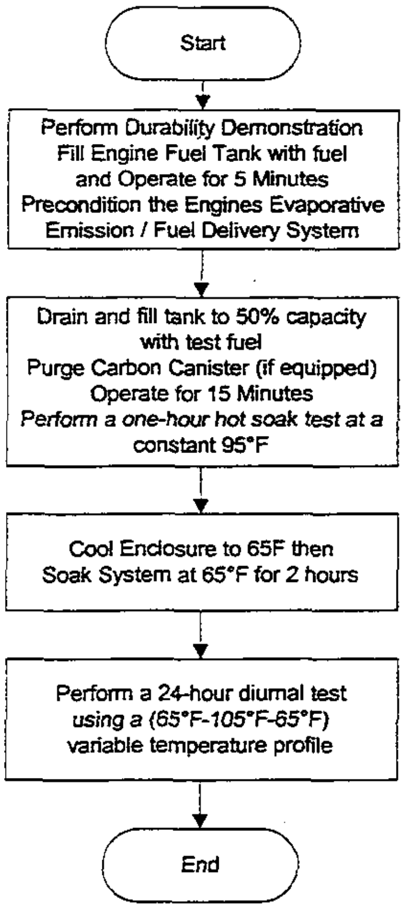
6. TEST PROCEDURE

The test sequence is shown graphically in Figure 1. Methanol measurements may be omitted when methanol-fueled equipment will not be tested in the evaporative enclosure. The temperatures monitored during testing shall be representative of those experienced by the equipment. The equipment shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution. The temperature tolerance of a soak period may be waived for up to 10 minutes to allow purging of the enclosure or transporting the equipment into the enclosure.

Testing a representative piece of equipment for each evaporative family and comparing the results to the appropriate performance standard determines compliance with requirements of CCR Title 13, Chapter 15, Article 1, Section 2754.

The 24-hour diurnal test sequence is shown in Figure 1.

Figure 1.



6.1 Fuel Tank / Fuel System Preconditioning

The purpose of the preconditioning period is to introduce gasoline into the fuel system and precondition all fuel system components. Precondition the tank and other fuel delivery system components by filling the tank to its nominal capacity with fresh test fuel as specified in Section 7 of these procedures. After filling the tank start the engine and allow it to run at rated speed (unloaded or blade load) for approximately five minutes. Soak the tank and other components at 30° C $\pm$ 10° C for not less than 140 days. The period of slosh testing may be considered part of the preconditioning period provided each tank and all fuel system components tested remain filled with fuel and are never empty for more than fifteen minutes over the entire preconditioning period.

As an alternative, accelerated preconditioning of the tank and components can be accomplished by soaking both at an elevated temperature. Precondition the tank and other fuel delivery system components by filling the tank to its nominal capacity with fresh test fuel as specified in Section 7 of these procedures. After filling the tank start the engine and allow it to run at rated speed (unloaded or blade load) for approximately five minutes. Begin soaking the tank and other components at 40° C $\pm$ 2° C. For engines with fuel tanks that have a nominal wall thickness of not greater than 0.15", soak the tank and all fuel system components for not less than 30 days. For engines with fuel tanks that have a nominal wall thickness of greater than 0.15" but less than or equal to 0.2", soak the tank and all fuel system components for not less than 60 days. For engines with fuel tanks that have a nominal wall thickness of greater than 0.2" data documenting that the tank and components have reached equilibrium must be provided for tanks soaked less than 140 days.

6.2 Refueling and Hot Soak Test

Following the preconditioning period, drain the fuel tank and refill to 50 percent of its nominal capacity with test fuel. For evaporative emission control systems that use a carbon canister, the canister must be purged following the preconditioning period but prior to initiating the hot soak test. Operate the engine at its rated speed for fifteen minutes. Immediately place the engine in the SHED enclosure preheated to 95°F. Perform a one-hour hot soak test at a constant 95°F.

6.3 Forced Cooling

After the hot soak test, purge the enclosure to reduce the hydrocarbon concentration to background levels. Cool the enclosure to attain a wall temperature of 65°F. After cooling the enclosure to 65°F, soak the engine in the enclosure for two hours at 65°F.

6.4 24-Hour Diurnal Test

Immediately after soaking for two hours at 65°F, perform a 24-hour diurnal test using the temperature profile shown in Table 6-1.

Table 6-1.
Diurnal Temperature Profile

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12
(°F)	65.0	66.6	72.6	80.3	86.1	90.6	94.6	98.1	101.2	103.4	104.9	105.0	104.2
Hour	13	14	15	16	17	18	19	20	21	22	23	24	--
(°F)	101.1	95.3	88.8	84.4	80.8	77.8	75.3	72.0	70.0	68.2	66.5	65.0	--

6.5 Calculation of Mass of Diurnal Evaporative Emissions

The calculation of the mass of the diurnal evaporative emissions is as specified in Part III of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles".

7. TEST FUEL

Evaporative emission test fuel is specified in Part II Section 100.3 of the "California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles".

8. ALTERNATIVE TEST PROCEDURES

Test procedures, other than specified above, shall only be used if prior written approval is obtained from the ARB Executive Officer. In order to secure the ARB Executive Officer's approval of an alternative test procedure, the applicant is responsible for demonstrating to the ARB Executive Officer's satisfaction that the alternative test procedure is equivalent to this test procedure.

(1) Such approval shall be granted on a case-by-case basis only.

(2) Documentation of any such approvals, demonstrations, and approvals shall be maintained by the ARB Executive Officer and shall be made available upon request.

9. REFERENCES

1. California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, California Environmental Protection Agency, Air Resources Board, El Monte, CA, 2000.

3. California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles, California Environmental Protection Agency, Air Resources Board, El Monte, CA, 2002.

4. 40 CFR Part 86

APPENDIX E: PROPOSED SMALL OFF-ROAD ENGINE EVAPORATIVE EMISSION CONTROL SYSTEM CERTIFICATION PROCEDURES

California Environmental Protection Agency

Air Resources Board

Small Off-Road Engine Evaporative Emission Control System Certification Procedures

CP - 901

Certification And Approval Procedures for Small Off-Road Engine Fuel Tanks

Proposed: August 8, 2003

CP-901
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California Environmental Protection Agency
Air Resources Board

Small Off-Road Engine Evaporative Emission Control System Certification Procedures

CP-901

Certification and Approval Procedures for Small Off-Road Engine Fuel Tanks

A set of definitions common to all Certification and Test Procedures are in Title 13, California Code of Regulations (CCR), Section 2752 et seq.

For the purpose of this procedure, the term "ARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the ARB Executive Officer, or his or her authorized representative or designate.

1. GENERAL INFORMATION AND APPLICABILITY

This document contains the procedures for evaluating and certifying fuel tanks used on equipment that use small off-road engines with displacements less than or equal to 80 cc. This Certification Procedure, CP-901, is proposed pursuant to Section 43824 of the California Health and Safety Code (CH&SC). Small off-road engines are defined in Title 13, California Code of Regulations (CCR), Section 2401 et seq.

1.1 Requirement to Comply with Applicable Codes and Regulations

Certification of any equipment fuel tank by the Executive Officer does not exempt the fuel tank from compliance with other applicable codes and regulations such as state and federal safety codes and regulations.

2. PERFORMANCE STANDARDS AND SPECIFICATIONS

2.1 Performance Standards

A performance standard defines the minimum performance requirements for an equipment fuel tank. Compliance with the maximum allowable permeation performance standard must be demonstrated in order to obtain certification under these Certification Procedures. Title 13, CCR, Section 2755 identifies the performance standard and the affected model year.

3. OPTIONAL PERFORMANCE STANDARDS

Optional performance standards are emission targets that are more stringent than the normal performance standards. Manufacturers that certify equipment fuel tanks to these optional standards are allowed to affix a unique label to their equipment, which identifies it as low polluting. Title 13, CCR, Section 2757 identifies the optional performance standards.

4. CERTIFICATION OVERVIEW

Fuel tanks of equipment that use spark ignited (SI) small off-road engines with displacements of less than or equal to 80 cc must be certified by the California Air Resources Board (ARB) to be legal for sale and use in California. Executive Orders certifying equipment fuel tanks to the maximum allowable permeation emissions performance standard are valid for only one model year of production. New Executive Orders in each subsequent model year must be obtained from ARB to be legal for sale and use in California. Selling equipment in California before receiving an ARB certification will subject the manufacturer and the selling dealers to ARB enforcement actions as authorized by state laws.

Manufacturers' that certify equipment fuel tanks under these procedures are required to submit test data that documents compliance with the maximum allowable permeation emissions performance standard. A manufacturer must test a minimum of one fuel tank for every engine family for which certification is requested. The fuel tank selected for testing must be of a configuration and material composition such that it is expected to yield the highest permeation emissions within an engine family. The test procedures used to determine compliance with maximum allowable permeation emissions performance standard are described in TP-901, "Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks".

5. CERTIFICATION

5.1 Certification Process

5.1.1 Emission-Compliant Fuel Tanks: For each engine family, the equipment manufacturer must select and test an equipment fuel tank to show compliance with the maximum allowable permeation emissions performance standard. The equipment fuel tank selected must use the same method of permeation control and be constructed of the same material as specified in the certification application. In addition, the equipment fuel tank shall be selected such that the fuel tank is expected to exhibit worst-case emissions, (e.g., highest permeation emissions) of all the fuel tanks within the applicable engine family. The ARB may direct the manufacturer to conduct a retest if the original test results indicate marginal (within 5% of the standard) compliance.

5.1.2 Application for Certification: As part of the exhaust emission certification application set forth in "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1999, and last amended _______, the manufacturer must submit to ARB information and permeation test data in the ARB-specified format. To expedite the certification approval, requests for ARB approval of anti-tampering devices, labels, the emission warranty statement, and any modification to the test procedure should be submitted in advance of the application.

5.2 Certification Responsibilities

Under these procedures, equipment manufacturers are required to obtain ARB certification for small off-road engine equipment fuel tanks that are required to adhere to the maximum allowable permeation emissions performance standard and are held liable for complying with all of ARB's certification and emission warranty requirements.

5.3 Certification Testing

Prior to the time of production, the fuel tank selected for testing is durability tested and preconditioned as specified in TP-901 to stabilize the permeation emissions. An emission test is then conducted using TP-901 and the results submitted to ARB as part of the certification application. If, after review of the application for certification including all test data submitted by the manufacturer and any other pertinent data or information the Executive Officer determines is necessary, the Executive Officer determines that the application has satisfied the conditions set forth in these procedures, the Executive Officer may approve the application and issue an Executive Order.

5.4 Data Carryover and Carryacross

Subject to ARB approval, the certification permeation emissions data may be carried over, in lieu of new tests, to similar fuel tanks in other engine families in following model years, provided there have been no changes to the equipment fuel tank that could affect the overall permeation emissions. Similar fuel tanks must be manufactured using the same manufacturing process, be of a volume no greater than the certified tank, and use identical materials and additives. Also, subject to ARB approval, the permeation emissions data may be carried across, in lieu of new tests, to a different engine family in the same model year if similar tanks as defined above are used.

6. GENERAL INSTRUCTIONS – FUEL TANK CERTIFICATION

These instructions provide guidance regarding the preparation, submission, and revision of small off-road engine fuel tank certification applications. Only information essential for certification is required in this format. Other information required by the test procedures (e.g., test equipment build records, test and maintenance records, etc.) must be maintained by the manufacturer and made available to the ARB within **30 days** upon request. An application submitted in accordance with these instructions will enable an expedited review by the ARB. Manufacturers must submit all revisions to the application to the ARB for approval. This section covers the following subject matter:

- Where To Submit Applications for Certification
- Letter of Intent (LOI)
- Cover Letter
- Equipment Labeling
- Test Procedure
- Modified Test Procedures
- Certification Test Fuels
- Amendments to the Application
- Running Changes and Field Fixes
- Confidentiality

6.1 Where to Submit Applications For Certification

All certification-related applications and correspondence should be forwarded to:

Mobile Source Operations Division
Air Resources Board
9480 Telstar Avenue, Suite 4
El Monte, California 91731-2988
Attn: Division Chief

6.2 Letter of Intent (LOI)

As part of the exhaust emission certification application set forth in "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1999, and last amended _________, a manufacturer shall include information regarding the application for certification for the model-year. This additional information should list planned engine families and the projected dates when the applications will be submitted. The manufacturer's phase-in compliance plan for the Model Year should also be included. Any certification or testing issues that could delay the certification process of any fuel tank may be included in the exhaust emission certification application. Any updates to the manufacturer's certification plan should be submitted in a timely manner.

6.3 Cover Letter

As part of the exhaust emission certification application set forth in "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1999, and last amended _________, a cover letter, signed by the manufacturer's authorized representative, must accompany each application. The cover letter should recap highlights about the equipment fuel tank and the engine family, such as its new or carry-over test data status, the use of a new emission control technology, the use of a modified test procedure, or the anticipated start date of production.

6.4 Equipment Labeling

The permeation emissions certification label is an important ARB requirement for identifying certified and legal equipment from those uncertified. The labels are used to assist enforcement activities. The permeation emissions certification label may be integrated with the exhaust emission label and must include an unconditional statement of conformance with the maximum allowable permeation standard and uniquely identify the manufacturer and the engine displacement.

Manufacturers are required to submit samples of the permeation emissions certification labels (or copies) for each evaporative family to ARB for review and approval of the format, content and placement location. Labels must be readily legible and visible on the engine per Title13 CCR Article 1, Section 2404. The proposed location(s) must be shown by either a drawing or photograph. Detailed written explanations of the label locations are also acceptable. Label samples and proposed label locations may be submitted to ARB for approval in advance of the actual certification application to prevent any certification delay.

6.5 Test Procedure

The test procedures used to determine compliance with the Performance Standards, including equipment provisions and emission test procedures, are specified in TP-901, Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment

Fuel Tanks, adopted _____.

6.6 Modified Test Procedure

Any modifications to the prescribed test equipment and/or test procedure due to unique equipment fuel tank designs, laboratory equipment arrangements, facility limitations, etc. must be approved in advance by the Executive Officer and described in the certification application. The use of unapproved test equipment or procedures may result in rejection of generated test data by the Executive Officer.

6.7 Certification Test Fuel

The fuel for emission testing must meet the specifications in the test procedure to reduce emission variations. Testing with unauthorized fuel will result in rejection of the test results. The allowable test fuel specified in TP-901 is Phase II California Reformulated Certification (CERT). The specifications of this certification gasoline are provided in "California Exhaust Emission Standards and Test Procedures For 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles", (Reference #3, Part II, Section 100.3.1).

6.8 Amendments to the Application

Any revisions to an application due to typographical errors, corrections, running changes or field fixes, new test data, or additional information must be submitted to ARB. If the changes affect the Certification Summary, the entire application shall be resubmitted to ARB. For the other parts of the application, only the revised information on the affected application pages must be submitted, together with the following for identification purposes:

- Manufacturer Name
- Model Year
- Engine Family
- Process Code (e.g., correction, running change)
- Engine Displacement
- Comments Field (describing the update or change)
- The fields that have been changed or corrected.

6.9 Running Changes and Field-Fixes

Any factory change to an equipment fuel tank during the model-year production that could potentially affect the permeation emissions must be approved by ARB via a manufacturer's submitted running change request. In addition, any post assembly line change to an equipment fuel tank (e.g., at factory warehouses, distribution centers, dealers) must be approved by ARB via a manufacturer's submitted field fix request. A field fix request typically occurs after the model-year production has ended. Running changes and field fixes not approved by ARB will render any affected engine family uncertified and subject the manufacturer to ARB enforcement actions. If the change affects the permeation emissions or results in a new worst-case emissions equipment fuel tank, new test data will be required to demonstrate that the engine family will remain in compliance and a new certification application must be submitted. If the change does not affect the permeation emissions or result in a new worst-case engine family fuel tank, only the affected pages and information fields of the certification application need to be submitted.

6.10 Confidentiality

Any information that is designated by the manufacturer as confidential may not receive automatic treatment for confidentiality unless the manufacturer can justify that the information is truly privileged, confidential business information. California guidelines (Sections 91000-91002, Title 17, California Code of Regulations, and Health and Safety Code Section 39660(e)) will be followed in the handling of confidential information.

6.11 Summary of Certification Process

The applicant shall prepare a summary of the certification process for each certified engine family fuel tank. It shall contain documentation of the successful completion of all applicable portions of the requirements contained in this Certification Procedure including but not limited to the following:

- All problems encountered throughout the certification process,
- The types of testing performed, and
- The frequency and/or duration of any testing, as appropriate.

Any other pertinent information about the evaluation process shall be contained in the summary.

7. APPLICATION FORMAT INSTRUCTIONS

For information regarding the format of the certification application please see the exhaust emission certification application set forth in "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines," adopted March 20, 1999, and last amended _______.

8. DOCUMENTATION OF CERTIFICATION

Documentation of certification shall be in the form of an Executive Order.

The certification Executive Order shall include, at a minimum, the following items.

- A list of approved engines/model(s) under the engine family.
- Applicable Performance Standard and Test Procedures.
- Applicable Operating Parameters and Limitations.
- Tank Volume and Internal Surface Area
- Tank Material (Resin and Additives)
- Tank Treatment Type
- Unique Properties
- Warranty period(s).
- Factory testing requirements, if applicable.

9. CONDITIONS OF CERTIFICATION

Equipment fuel tank certifications shall specify the duration and conditions by which the certification is issued and include a list of all engine models covered by the certification.

9.1 Duration of System Certification

Equipment fuel tanks shall be certified for a period of one model-year.

9.2 Performance Monitoring

During the certification period, any deficiencies identified through complaint investigations, certification or compliance tests, etc., shall be noted in the performance section of the certification file and brought to the attention of the equipment manufacturer. If the deficiencies result in emissions in excess of the applicable standard, the manufacturer may be subject to remedial actions that are accepted and approved by ARB.

10. APPROVAL OF APPLICATION FOR CERTIFICATION

The Executive Officer shall certify only those equipment fuel tanks that can be expected to comply with the performance standard.

After a review of the complete application for certification and any other information that the Executive Officer requires, the Executive Officer will approve the application for certification if all the foregoing conditions are satisfied.

REFERENCES

1. Title 13, California Code of Regulations, (13 CCR) Sections 2400,2401, and 2752.

2. California Exhaust Emission Standards and Test Procedures For 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, California Environmental Protection Agency, Air Resources Board, El Monte CA, 2000.

3. California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines, California Environmental Protection Agency, Air Resources Board, El Monte CA, 1999.

4. Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks, TP-901, California Environmental Protection Agency, Air Resources Board, Sacramento, CA, 2002.

California Environmental Protection Agency

Air Resources Board

Small Off-Road Engine Evaporative Emission Control System Certification Procedures

CP - 902

Certification And Approval Procedures for Evaporative Emission Control Systems

Proposed: August 8, 2003

CP-902
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California Environmental Protection Agency
Air Resources Board

Small Off-Road Engine Evaporative Emission Control System Certification Procedures

CP-902

Certification and Approval Procedures for Evaporative Emission Control Systems

A set of definitions common to all Certification and Test Procedures are in Title 13, California Code of Regulations (CCR), Section 2752 et seq.

For the purpose of this procedure, the term "ARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the ARB Executive Officer, or his or her authorized representative or designate.

1. GENERAL INFORMATION AND APPLICABILITY

This document describes the procedures for evaluating and certifying evaporative emission control systems on small off-road engines or equipment that use small off-road engines. By definition, evaporative emission control systems are fuel system components that are designed to reduce evaporative and permeation emissions. Fuel system components may include fuel tanks, fuel lines and any or all associated fittings, mechanisms to control fuel tank venting, tethered fuel caps, and any other equipment, components, or technology necessary for the control of evaporative and permeation emissions.

These Certification Procedures, CP-902, are proposed pursuant to Section 43824 of the California Health and Safety Code (CH&SC) and describe the process required to certify evaporative emission control systems on small off-road engines (SORE) or equipment that use small off-road engines to evaporative emission performance standards. Small off-road engines are defined in Title 13, California Code of Regulations (CCR), Section 2401 et seq.

1.1 Requirement to Comply with Applicable Codes and Regulations

Certification of any evaporative emission control system by the Executive Officer does not exempt the same from compliance with other applicable codes and regulations such as state and federal safety codes and regulations.

2. PERFORMANCE STANDARDS AND SPECIFICATIONS

2.1 Performance Standards

A performance standard defines the minimum performance requirements for certification of an evaporative emission control system, including any or all associated components. Compliance with all applicable performance standards must be demonstrated in order to obtain certification as described in these procedures. Title 13, CCR, Section 2754 identifies the performance standards and the affected model years.

2.2 Performance Specifications

A performance specification is an engineering requirement that relates to the proper operation of a specific system or component used in a small off-road engine evaporative emission control system. Performance specifications shall be identified in the application for certification. Compliance with the minimum level of performance specifications identified herein must be demonstrated in the application for certification and specified in the certification Executive Orders. The performance specification to which a system or component is certified shall be the minimum allowable level of performance the evaporative emission control system is required to meet throughout its useful life.

3. OPTIONAL PERFORMANCE STANDARDS

Optional performance standards are emission targets that are more stringent than the normal performance standards. Manufacturers that certify to these optional standards are allowed to affix a unique label to their engines or equipment that identifies them as low polluting. Title 13, CCR, Section2757 identifies the optional performance standards.

4. CERTIFICATION OVERVIEW

For certification purposes, small off-road engines (SORE) are grouped into three categories. The first category includes all walk-behind mowers with displacements greater than 80 cc to less than 225 cc, which must be certified beginning with model year (MY) 2007 onward. The second includes all other SI engines with displacements greater than 80 cc to less than 225 cc, which must be certified by beginning with model year (MY) 2007 onward. The third and final category includes SI engines with displacements greater than or equal to 225 cc, which must be certified beginning with model year (MY) 2008 onward. Executive Orders certifying the evaporative emission control system on engines or equipment are valid for only one model-year of production. New Executive Orders in each subsequent model year must be obtained from ARB for any small off-road engine or equipment subject to any of the performance standards prescribed herein. Manufacturing for sale, selling, offering for sale, introducing or delivering or importing into California any engine or equipment subject to any of the performance standards before receiving an ARB certification will subject the manufacturer and the selling dealers to ARB enforcement actions as authorized by state laws.

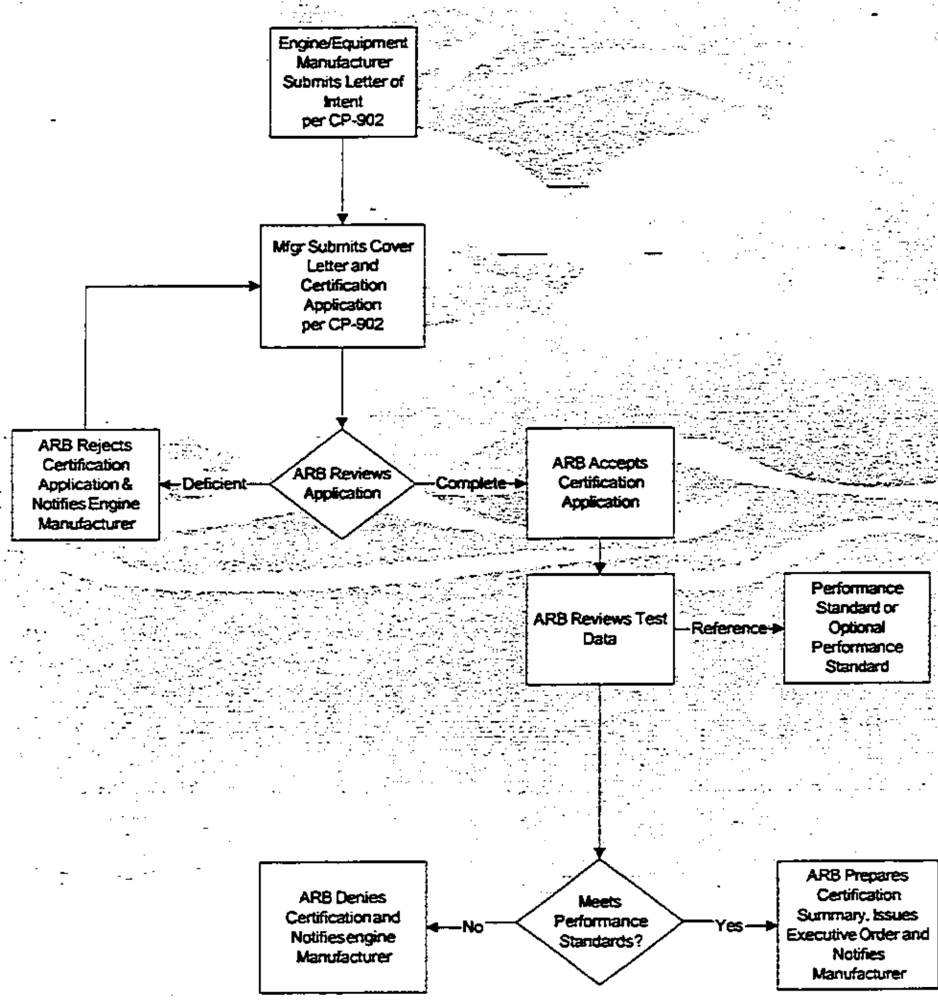
Evaporative emission control systems may be grouped into evaporative families for certification and other implementation purposes (e.g., testing, recall). An evaporative family includes engine or equipment models that share similar fuel systems, engine designs, and emission control features such that the equipment can be expected to exhibit similar evaporative emission characteristics. Attachment 1 of these procedures defines the classification criteria and codes for determining evaporative families.

Manufacturers that certify evaporative emission control systems under these procedures are required to submit test data that documents compliance with the applicable diurnal evaporative emission standard. A manufacturer must test a minimum of one engine model or equipment for every evaporative family for which certification is requested. The engine or equipment selected for testing must be of a configuration that is expected to yield the highest evaporative emissions within an evaporative family. The test procedures used to determine compliance with applicable diurnal evaporative emission standards are described in TP-902, "Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines".

Figure I provides a graphic overview of the certification process.

Figure I

Evaporative Emission Control System Certification Process



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5. CERTIFICATION OF ENGINES AND EQUIPMENT

5.1 Certification Process

5.1.1 Emission-Compliant Engines: For each evaporative family, the manufacturer must select and test a certification engine or equipment. The certification engine or equipment must contain a complete and functional evaporative emission control system. The system shall include all emission control systems and components that are specified in the certification application. The official certification engine or equipment that is one that has been selected and stabilized as to show compliance with the appropriate diurnal evaporative emission performance standard. In addition, the evaporative family test engine or equipment shall be selected such that the evaporative emission control system is expected to exhibit worst-case emissions, (e.g., highest diurnal evaporative emissions) of all engines or equipment within the evaporative family. The ARB may direct the manufacturer to conduct a retest if the original test results indicate marginal (within 5% of the standard) compliance. Any anti-tampering devices that will be installed on production engines for protection against unauthorized adjustments of emission-related adjustable parameters must be approved by ARB. The manufacturer's format for the certification label and the location where the label is affixed to the production engine must be approved by the ARB. The manufacturer's emission warranty statement provided with each production engine must also be approved by ARB.

5.1.2 Application for Certification: For each evaporative family, the manufacturer must submit to ARB an application for certification containing all the required information and/or test data in the ARB-specified format. The ARB is required to approve or disapprove an application within **90 days** after receipt of the complete application. The normal processing time is about 4-6 weeks. To expedite the certification approval, requests for ARB approval of anti-tampering devices, labels, the emission warranty statement, and any modification to the test procedure should be submitted in advance of the application.

5.2 Certification Responsibilities

Under these procedures, manufacturers are required to obtain ARB certification for evaporative emission control systems on small off-road engines or equipment that use small off-road engines. Manufacturers applying for certification are held liable for complying with all of ARB's certification and emission warranty requirements.

5.3 Certification Testing

Prior to the time of production, an evaporative family test engine or equipment is durability tested and preconditioned as specified in TP-902 to stabilize the evaporative and permeation emissions. An emission test is then conducted using TP-902 and the results submitted to ARB as part of the certification application. If, after review of the application for certification including all test data submitted by the manufacturer, and any other pertinent data or information the Executive Officer determines is necessary, the Executive Officer determines that the application has satisfied the conditions set forth in these procedures, the Executive Officer may approve the application and issue an Executive Order.

5.4 Data Carryover and Carryacross

Subject to approval by the Executive Officer, certification test data of an evaporative family test engine or equipment may be carried over, in lieu of new tests, to subsequent evaporative families in following model years, provided there have been no changes to the evaporative emission control system or to any evaporative emission control system component(s). Also, subject to ARB approval, the certification test data of an evaporative family certification engine or equipment may be carried across, in lieu of new tests, to a different evaporative family in the same model year if the manufacturer adequately demonstrates to the satisfaction of the ARB that the emission data is representative of the new evaporative family.

6. CERTIFICATION OF EVAPORATIVE EMISSION CONTROL SYSTEMS

6.1 Certification Options

There are two options for certifying evaporative emission control systems. They are:

- Option one allows an engine manufacturer to certify a complete evaporative emission control system installed on a small off-road engine.
- Option two allows an equipment manufacturer to certify a complete evaporative emission control system installed on equipment that uses a small off-road engine.

Option one is intended for engine manufacturers that sell engines with complete evaporative emission control systems.

Option two is intended for equipment manufacturers that purchase engines without evaporative emission control systems. In this case, equipment manufacturers independently install and certify complete evaporative emission control systems on equipment they intend to sell.

6.2 Evaporative Emission Control System Modifications

The evaporative emission control system components used to certify the system are defined as nominal components. Modification to the evaporative emission control system's fuel tank and/or fuel line is allowed without affecting the original certification of the engine or equipment only in cases where the fuel tank and/or fuel line are equivalent to the nominal fuel tank and/or fuel line.

7. GENERAL INSTRUCTIONS – EVAPORATIVE EMISSION CERTIFICATION

These instructions provide guidance regarding the preparation, submission and revision of small off-road engine evaporative emission certification applications for 2007 and subsequent model year small off-road engines. Only information essential for certification is required in this format. Other information required by the test procedures (e.g., test equipment build records, test and maintenance records, etc.) must be maintained by the manufacturer and made available to the ARB within **30 days** upon request. An application submitted in accordance with these instructions would enable an expedited review and approval by the ARB. Manufacturers must submit all revisions to the application to the ARB for approval. This Section covers the following subject matter:

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- Where To Submit Applications for Certification
- Letter of Intent (LOI)
- Cover Letter
- Engine Labeling
- Certification Summary Sheet
- Certification Database Form (Paper and/or electronic copies)
- Emission Warranty
- Test Procedures
- Modified Test Procedures
- Nominal Fuel Tank and/or Fuel Line (if applicable)
- Adjustable Parameters and Anti-Tampering Devices
- Certification Test Fuels
- Amendments to the Application
- Running Changes and Field Fixes
- Confidentiality

7.1 Where To Submit Applications For Certification

All certification-related applications and correspondence should be forwarded to:

Mobile Source Operations Division
Air Resources Board
9480 Telstar Avenue, Suite 4
El Monte, California 91731-2988
Attn: Division Chief

7.2 Letter of Intent (LOI)

ARB staff uses the information provided in the LOI to plan ahead for the certification year and to resolve issues in advance so that manufacturers' anticipated certification schedules can be met. A LOI should be submitted to the ARB at least 90 days prior to the first application for certification for the model-year. The LOI should list planned evaporative families and the projected dates when the applications will be submitted. The manufacturer's phase-in compliance plan for the Model Year should also be included in the LOI. Any certification or testing issues that could delay the certification process of any evaporative family may be included in the LOI. Any updates to the manufacturer's certification plan should be submitted in a timely manner.

7.3 Cover Letter

A cover letter, signed by the manufacturer's authorized representative, must accompany each evaporative family application. The cover letter should recap highlights about the evaporative family, such as its new or carry-over test data status, the use of a new emission control technology, the use of a modified test procedure, or the anticipated start date of production. The following statements of compliance must be provided in the letter:

- Conformance with the general standards regarding an increase in emissions and unsafe conditions as required by Section 5 of the "California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines", adopted March 20, 1992, and amended March 26, 1998.

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- Conformance with the specifications for the emission control label per 13 CCR, Article 8, Section 2759.

7.4 Equipment Labeling

The evaporative emission certification label is an important ARB requirement for identifying certified and legal equipment from those uncertified. The labels are used to assist enforcement activities. The evaporative emission certification label may be integrated with the exhaust emission label and must include an unconditional statement of conformance with applicable standards. Labeling requirements are specified in 13 CCR, Article 8, Section 2759.

Manufacturers are required to submit samples of the evaporative emission certification labels (or copies) for each evaporative family to ARB for review and approval of the format, content and placement location. The proposed location(s) must be shown by either a drawing or photograph. Detailed written explanations of the label locations are also acceptable. Label samples and proposed label locations may be submitted to ARB for approval in advance of the actual certification application to prevent any certification delay.

7.5 Certification Summary Sheet (A sample is provided as Attachment 2)

7.6 Certification Database Form (A sample is provided as Attachment 3)

7.7 Emission Warranty

A copy of the manufacturer's emission warranty statement for the small off-road engine evaporative emission control system and/or components must be submitted for ARB review and approval. The warranty requirements are specified in 13 CCR, Article 8, Section 2760.

7.8 Test Procedures

The test procedures used to determine compliance with the Performance Standards, including equipment provisions and emission test procedures, are specified in TP-902, Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines, adopted _____.

7.9 Modified Test Procedures

Any modifications to the prescribed test equipment and/or test procedures due to unique engine designs, laboratory equipment arrangements, facility limitations, etc. must be approved in advance by the Executive Officer and described in the certification application. The use of unapproved test equipment or procedures may result in rejection of generated test data by the Executive Officer.

7.10 Adjustable Parameters and Anti-Tampering Devices

A manufacturer shall utilize good engineering practice to prevent unauthorized or in-use adjustments of any adjustable parameter of an evaporative emission control system. These may include the use of anti-tampering devices. Samples of a manufacturer's proposed anti-tampering measure to prevent unauthorized or in-use adjustments or other such devices, should be submitted in advance of the application to ARB for approval. In-use adjustments of adjustable parameters of an evaporative emission control system are allowed if the adjustments do not invalidate a system's compliance. All adjustable parameters and the corresponding ARB approval number must be reported in the application. If the parameter or method of tamper-resistance is subsequently modified, a new ARB approval will be required.

7.11 Certification Test Fuels

The fuel for emission testing must meet the specifications in the test procedures to reduce emission variations. Testing with unauthorized fuel will result in rejection of the test results. The allowable test fuels are the same as the allowable test fuels for on-road cars and light-duty vehicles (Reference 3). The test fuel specifications are listed here for manufacturer's convenience.

Gasoline. Two test fuels are allowed:

(i) Indolene Clear. This certification gasoline is specified in the Code of Federal Regulations, Title 40, Part 86, Section 113-94(a)(1). [40 CFR 86.113-94(a)(1)].

(ii) California Phase 2 Gasoline (Cleaner Burning Gasoline). The specifications of this certification gasoline are provided in "California Exhaust Emission Standards and Test Procedures For 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles", (Reference #3, Part II, Section 100.3.1). This gasoline may be used as an option to Indolene Clear.

7.12 Amendments to the Application

Any revisions to an application due to typographical errors, corrections, running changes or field fixes, new test data, or additional information must be submitted to ARB. If the changes affect the Certification Summary, the entire application shall be resubmitted to ARB. For the other parts of the application, only the revised information on the affected application pages must be submitted, together with the following for identification purposes:

- Manufacturer Name
- Model Year
- Evaporative Family
- Engine Family
- Process Code (e.g., correction, running change)
- Engine Displacement
- Comments Field (describing the update or change)
- The fields that have been changed or corrected.

7.13 Running Changes and Field-Fixes

Any factory change to an evaporative family during the model-year production that could potentially affect the evaporative emissions must be approved by ARB via a manufacturer's submitted running change request. In addition, any post assembly line change to the evaporative family (e.g., at factory warehouses, distribution centers, dealers) must be approved by ARB via a manufacturer's submitted field fix request; a field fix request typically occurs after the model-year production has ended. Running changes and field fixes not approved by ARB will render an affected evaporative family uncertified and subject the manufacturer to ARB enforcement actions. If the change affects an emission-related part or results in a new evaporative family test engine, new test data and engineering evaluations will be required to demonstrate that the evaporative family will remain in compliance and a new certification application must be submitted. If the change does not result in a new evaporative family test engine, only the affected pages and information fields of the certification application need to be submitted.

7.14 Confidentiality

Any other information that is designated by the manufacturer as confidential may not receive automatic treatment for confidentiality unless the manufacturer can justify that the information is truly privileged, confidential business information. California guidelines (Sections 91000-91002, Title 17, California Code of Regulations, and Health and Safety Code Section 39660(e)) will be followed in the handling of confidential information.

7.15 Summary of Certification Process

The applicant shall prepare a summary of the certification process for each certified evaporative family. It shall contain documentation of the successful completion of all applicable portions of the requirements contained in this Certification Procedure including but not limited to the following:

- All problems encountered throughout the certification process,
- The types of testing performed, and
- The frequency and/or duration of any testing, as appropriate.

Any other pertinent information about the evaluation process shall be contained in the summary.

8. APPLICATION FORMAT INSTRUCTIONS

For information regarding the format of the certification application please see Attachment 2.

9. DOCUMENTATION OF CERTIFICATION

Documentation of certification shall be in the form of an Executive Order.

The certification Executive Order shall include, at a minimum, the following items.

- A list of approved engines/model(s) under the evaporative family.
- A list of components certified for use with the evaporative family including component specifications.
- Applicable Performance Standards, Performance Specifications and Test Procedures.
- Applicable Operating Parameters and Limitations.
- Warranty period(s).
- Factory testing requirements, if applicable.

10. CONDITIONS OF CERTIFICATION

Evaporative family certifications shall specify the duration and conditions by which the certification is issued and include a list of all engine models covered by the certification.

10.1 Duration of System Certification

Evaporative families shall be certified for a period of one model-year.

10.2 Performance Monitoring

During the certification period; any deficiencies identified through complaint investigations, certification or compliance tests, etc., shall be noted in the performance section of the certification file and brought to the attention of the engine manufacturer. If the deficiencies result in emissions in excess of the applicable standard, the manufacturer may be subject to remedial actions that are accepted and approved by ARB.

11. APPROVAL OF APPLICATION FOR CERTIFICATION

The Executive Officer shall certify only those evaporative families that can be expected to comply with the performance standards.

After a review of the complete application for certification and any other information that the Executive Officer requires, the Executive Officer will approve the application for certification if all the foregoing conditions are satisfied.

REFERENCES

1. Title 13, California Code of Regulations, (13 CCR) Section 2400.

2. 13 CCR, Sections 2401 and 2467.1.

3. California Exhaust Emission Standards and Test Procedures For 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, California Environmental Protection Agency, Air Resources Board, El Monte CA, 2000.

4. California Exhaust Emission Standards and Test Procedures for 1995 and Later Small Off-Road Engines, California Environmental Protection Agency, Air Resources Board, El Monte CA, 1998.

5. Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Equipment Fuel Tanks, TP-901, California Environmental Protection Agency, Air Resources Board, Sacramento, CA, 2003.

6. Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines, TP-902, California Environmental Protection Agency, Air Resources Board, Sacramento, CA, 2003.

7. Test Procedure for Determining Fuel Line, Fitting, Component, and Assembly Emissions, TP-903, California Environmental Protection Agency, Air Resources Board, Sacramento, CA, 2003.

8. Title 40, Code of Federal Regulations, Part 86

Attachment 1
SORE Evaporative Family Classification Criteria

Engine Displacement		*Venting Control*		*Fuel Line Length*	
Displacement	Code	Type	Code	Length	Code
≤ 80 cc	1	Canister	C	≤ 12 inches	1
> 80 cc ≤ 225 cc	2	Sealed Tank	S	> 12 inches	2
> 225 cc	3				

Tank Material		*Tank Volume*	
Type	Code	Nominal Vol.	Code
Metal	M	≤ 1.0 gal	1
HDPE or PE	P	> 1.0 gal ≤ 5.0 gal	2
Nylon	N	> 5.0 gal	3
Acetal	A		

Manufacturers must group the their equipment into evaporative families based on the above criteria and coding.

For example:

A 2006 model year mower with the following characteristics:

- engine with 168 cc displacement
- sealed tank venting control system
- 10 inch fuel line
- 0.38 gallon HDPE fuel tank

The evaporative family code would be "2S1P1".

An equipment manufacturer must list all the models of equipment they produce into distinct evaporative families. Equipment models falling under a particular evaporative family code may be certified or approved with one application.

Attachment 2
SMALL OFF-ROAD EQUIPMENT CERTIFICATION
Certification Summary Sheet

Model Year:
Manufacturer:
Evaporative Family Name:

Application Type:
Executive Order:

Engine families within the evaporative family above:

Certification for Diurnal Emissions:
a) New Testing?: _____ if carry over/carry across, from evaporative family:______________
b) Test Equipment Model: ____________ Test Equipment ID:___________
c) Test Fuel: _____________
d) Test Procedure: _____________
Special Test Equipment

Test No. And Type, Fuel	Official Test Results, g/day	
	WBM <225cc Or Sore Equipment >80cc to <225cc	Sore Equipment ≥225cc

WBM <225cc Or Sore Equipment >80cc to <225cc		Sore Equipment ≥225cc	
Certification (g/test)	Standard (g/test)	Certification (g/test)	Standard (g/test)

Remarks:

Equipment Models:

Processed By: ______ Date Processed ______ Reviewed By: ______ Date Reviewed: ______

Attachment 3
Certification Database Form
(Supplementary Information)

S1. MODEL SUMMARY (Use an asterisk (*) to identify "worst-case" equipment model used for certification testing.)

S2. Equipment Model	S3. Sales Codes (Check all appropriate)			S4. Engine Disp. (cc)	S5. Fuel System	S6. Fuel Tank Vol. (cc)	S7. Fuel Tank Internal Surf. Area (m^2)	S8. Fuel Line SAE Type	S9. Fuel Line Length (mm)	S10. Fuel Line Inside Dia. (mm)
	Calif. Only	49-State	50-State							

S11. LABELING:
Evaporative emission label format approved? No____ Yes ___ If yes, reference approval:___________
Sample label attached? No____ Yes (put label in #S13)____

S12. WARRANTY: Evaporative emission warranty approved? No___ (Provide full warranty statement in #S15)
Yes ___ (Reference approval: _______________)
Have any changes been made since the last approval? No____ Yes ____ If yes, provide an explanation of the changes:

S13. EVAPORATIVE EMISSION LABEL INFORMATION

S14. ADJUSTABLE PARAMETERS AND ANTI-TAMPERING MEASURES

Parameter	Adjustable Range (or N/A)	Tamper Resistance Method (or N/A)	Approval Reference

S15. EVAPORATIVE EMISSION WARRANTY STATEMENT

S16. ADDITIONAL INFORMATION AND COMMENTS

APPENDIX F: CONSTRUCTION AND FARM EQUIPMENT PREEMPTION

Previously Classified Off-Road Equipment

(a) Equipment types with engines less than 25 horsepower are presumed not to be construction or farm equipment, with the exception of the following equipment types, which have been determined to be construction or farm equipment:

Aerial devices: vehicle mounted
Asphalt recycler/reclaimer, sealer
Augers: earth
Back-hoe
Backpack Compressors
Baler
Boring machines: portable line
Breakers: pavement and/or rock
Brush cutters/Clearing saws 40 cc and above (blade capable only)
Burners: bituminous equipment
Cable layers
Chainsaws 45 cc and above
Chippers
Cleaners: high pressure, steam, sewer, barn
Compactor: roller/plate
Compressors
Concrete buggy, corer, screed, mixer, finishing equipment
Continuous Digger
Conveyors: portable
Crawler excavators
Crushers: stone
Cultivators: powered
Cutting machine
Debarker
Detassler
Drills
Dumper: small on-site
Dusters
Elevating work platforms
Farm loaders: front end
Feed conveyors
Fertilizer spreader
Forage box/Haulage and loading machine
Forklifts: diesel and/or rough terrain
Harvesters, crop
Jackhammer
Light towers
Mixers: mortar, plaster, grout
Mowing equipment: agricultural
Mud jack
Pavers: asphalt, curb and gutter

Pipe layer
Plows: vibratory
Post hole diggers
Power pack: hydraulic
Pruner: orchard
Pumps 40 cc and above
Rollers: trench
Sawmill: portable
Saws: concrete, masonry, cutoff
Screeners
Shredder/grinder
Signal boards: highway
Silo unloaders
Skidders
Skid-steer loaders
Specialized fruit/nut harvester
Sprayers: bituminous, concrete curing, crop, field
Stump cutters, grinders
Stumpbeater
Surfacing equipment
Swathers
Tampers and rammers
Tractor: compact utility
Trenchers
Troweling machines: concrete
Vibrators: concrete, finisher, roller
Welders
Well driller: portable
Wheel loaders

(b) Equipment types with engines 25 horsepower or greater are presumed to be construction or farm equipment, with the exception of the equipment types listed below, which have been determined not to be construction or farm equipment.

Aircraft Ground Power
Baggage Handling
Forklifts that are neither rough terrain nor powered by diesel engines
Generator Sets
Mining Equipment not otherwise primarily used in the construction industry
Off-Highway Recreational Vehicles
Other Industrial Equipment
Refrigeration Units less than 50 horsepower
Scrubbers/Sweepers
Tow/Push
Turf Care Equipment

APPENDIX G: DURABILITY OF LOW-EMISSIONS SMALL OFF-ROAD ENGINES (INTERIM REPORT)

SwRI 08.05734

DURABILITY OF LOW-EMISSIONS SMALL OFF-ROAD ENGINES

Prepared by

Chad C. Lela
Jeff J. White

INTERIM REPORT

Prepared for

CALIFORNIA AIR RESOURCES BOARD
Mobile Sources Operations Division
9528 Telstar Ave.
El Monte, CA 91731

May 30, 2003

SOUTHWEST RESEARCH INSTITUTE
6220 Culebra Road P.O. Drawer 28510
San Antonio, Texas 78228-0510

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May 30, 2003

Prepared by:

Chad C. Lela, Project Leader

Approved by:
— Bruce Bykowski —

Bruce B. Bykowski, Director

Reviewed by:

Jeff J. White, Manager

DEPARTMENT OF EMISSIONS RESEARCH
AUTOMOTIVE PRODUCTS AND EMISSIONS RESEARCH DIVISION

DISCLAIMER

"The statements and conclusions in this report are those of the Contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products."

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MECA-member catalyst companies supplying samples for the engines.

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LIST OF ABBREVIATIONS

Appl	Application
BS	Brake-Specific
BSLN	Baseline
CARB	California Air Resources Board
CO	Carbon monoxide
CO_2	Carbon dioxide
CPSI	Cells per square inch
CVS	Constant Volume Sampling
DER	Department of Emissions Research at Southwest Research Institute
EGO	Exhaust Gas Oxygen sensor
FID	Flame Ionization Detector
GEN	Generator
G	Grams
HC	Hydrocarbons
Hr	Hour
hp	Horsepower
MECA	Manufacturers of Emission Controls Association
Mfg	Manufacturer
mm	Millimeter
NDIR	Non-Dispersive Infrared
NH_3	Ammonia
NO_x	Oxides of nitrogen
OPEI	Outdoor Power Equipment Institute
O_2	Oxygen
PII	California Phase II gasoline
RPM	Revolutions per minute
SAI	Secondary air injection or secondary air induction
SORE	Small Off-Road Engine
TWC	Three-Way Catalyst
WBM	Walk-Behind Mower

I. INTRODUCTION

The California Air Resources Board (CARB) contracted with Southwest Research Institute (SwRI®) to demonstrate useful-life durability of six low-emission developed small off-road engines (SORE). SOREs are a relatively high source of hydrocarbon pollutants in California producing approximately 85 tons per day[1].

The objective of this program was to develop six non-handheld SOREs in low-emission configurations, and then age the engines through their useful life. Four of the engines are used in walk-behind mower (WBM) applications, one is used in a riding mower, and one is used in constant-speed/generator applications. The goal was to reduce the tailpipe-out hydrocarbon (HC) plus oxides of nitrogen (NO_x) emissions to 50% or less of the current useful life standard of 12 $^{g}/_{hp\text{-}hr}$ for Class I engines, or 10 $^{g}/_{hp\text{-}hr}$ for Class II engines. Low-emission engines were developed using three-way catalytic converters, passive secondary-air induction (SAI) systems, and enleanment, when needed. Catalysts were provided by members of the Manufacturers of Emission Controls Association (MECA).

Evaporative emission reduction technologies were also evaluated on two SOREs. The goal was to reduce evaporative emissions by incorporating low-permeation fuel delivery components and pressure relief systems.

[1] Salardino, D., "Small Engine Workshop" Presentation, California Air Resources Board, Nov. 13, 2002.

II. DESCRIPTION OF PROGRAM

A. Project Engines

Six engines meeting current Tier II standards were selected by CARB, based on application and market share information. Table 1 lists the engines tested in the program. All engines are naturally aspirated, air-cooled, four-stroke, carbureted engines with an overhead valve train. All engines, with the exception of the Kawasaki, are single cylinder.

Originally, two identical Briggs and Stratton Intek engines were selected so that a comparison could be made between a high-loaded and a low-loaded catalyst for the same engine calibration. The needed catalysts, however, were not available in time to perform this experiment. Therefore, the second Briggs and Stratton engine was developed separately from the first engine, with an alternative catalyst and a more refined passive SAI system. Engines tested are shown in Figures 1-4.

TABLE 1. PROJECT ENGINES

Engine No.	Class	Mfg.	Appl.	Family/Model	Displacement, cc	Rated Power, hp
1	I	Briggs	WBM	YBSXS.1901VE Intek	190	6.5
2	I	Briggs	WBM	YBSXS.1901VE Intek	190	6.5
3	I	Tecumseh	WBM	YTPXS.1951AA OVRM 120	195	6.5
4	I	Honda	WBM	2HNXS.1611AK GCV160	160	5.5
5	II	Kawasaki	Rider	YKAX6752QA FH601V	675	19
6	II	Honda	GEN	2HNXS.3892AK GX-340QA2	340	11

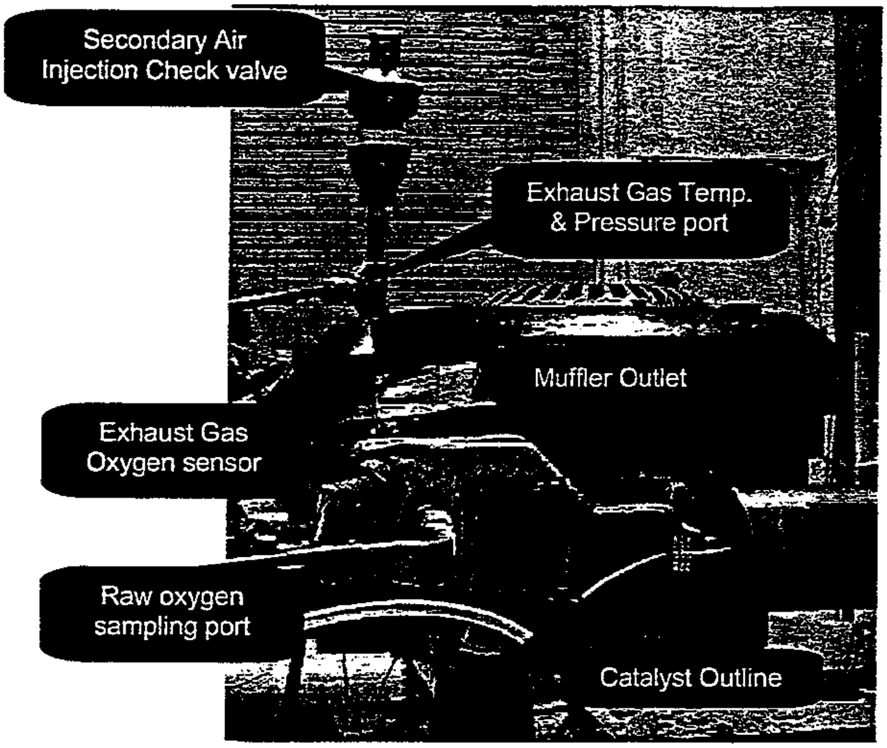

FIGURE 1. BRIGGS AND STRATTON ENGINE NO.1 WITH CATALYST C INTEGRATED IN MUFFLER

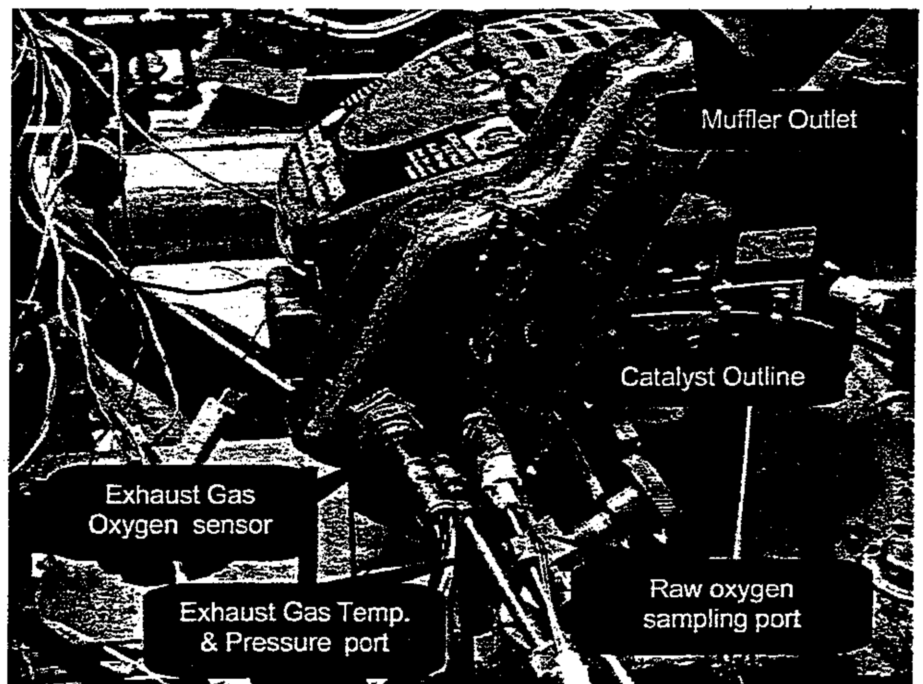

FIGURE 2. TECUMSEH OVRM120 ENGINE WITH CATALYST C INTEGRATED IN MUFFLER

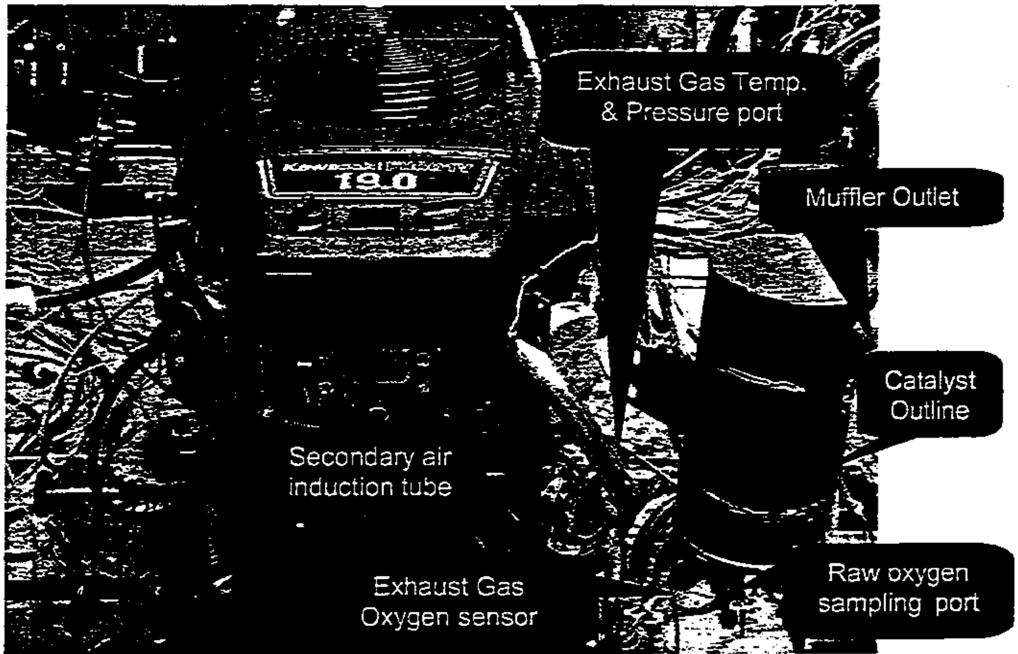

FIGURE 3. KAWASAKI FH601V ENGINE WITH CATALYST E INTEGRATED IN MUFFLER

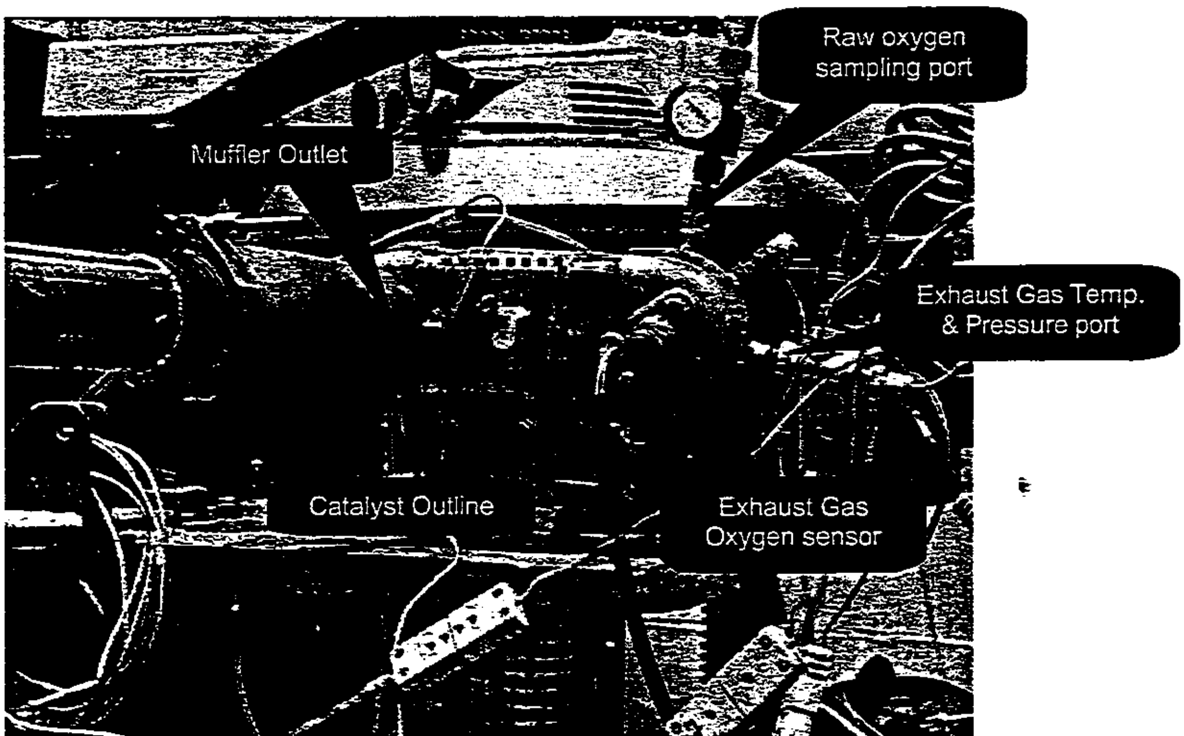

FIGURE 4. HONDA GCV160 ENGINE WITH CATALYST J INTEGRATED IN MUFFLER

Table 2 outlines the test cycle for the Class I walk-behind mower engines, which use an intermediate speed of 3060 RPM for testing. Table 3 outlines the duty cycle for generator engines, which run at a rated speed of 3600 RPM with no idle mode. For this program, the Briggs and Stratton engines used a 5-mode cycle with an intermediate speed of 3060 RPM consistent with manufacturers' certification procedures, as shown in Table 4.

TABLE 2. CARB 6-MODE SORE TEST CYCLE (TECUMSEH OVRM120, HONDA GCV160, AND KAWASAKI FH601V)

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Speed (% rated)	85	85	85	85	85	Idle
Load (%)	100	75	50	25	10	0
Weight Factor (%)	9	20	29	30	7	5

TABLE 3. CARB 5-MODE GENERATOR TEST CYCLE (HONDA GX340)

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
Speed (% rated)	100	100	100	100	100
Load (%)	100	75	50	25	10
Weight Factor (%)	9	21	31	32	7

TABLE 4. TEST CYCLE USED FOR BRIGGS AND STRATTON ENGINES

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
Speed (% rated)	85	85	85	85	85
Load (%)	100	75	50	25	10
Weight Factor (%)	9	21	31	32	7

Engines were operated repetitively using the above test cycles to age the engines through their useful life. Durability modes were run based on the modal weight percentage over one-hour. The Briggs and Stratton, Tecumseh, and Honda GCV160 engines were aged 250 hours with emissions testing performed at 0, 125, and 250 hours. The Kawasaki and Honda GX340 engines were aged 500 hours with emissions testing at 0, 125, 250, and 500 hours.

B. Project Catalysts

At the beginning of the program, participating MECA members were each assigned an engine for which they were to provide a three-way catalyst (TWC). Catalysts were chosen by manufacturers based on prior small off-road engine experience, program objectives, and data specific to each engine. Actual test data, including exhaust temperatures, baseline air-fuel ratios, and mass emission rates were not available at the time of catalyst selection. Table 5 outlines the catalysts that were used in final, developed configurations. All catalysts are of three-way formulation with metallic substrates. An attempt has been made to integrate all of the catalysts in modified stock mufflers for their respective engines. Figures 5-10 show the selected catalysts.

TABLE 5. CATALYSTS USED IN FINAL DEVELOPMENT CONFIGURATIONS FOR SMALL OFF-ROAD ENGINES

Engine	Catalyst ID	Diameter, mm	Length, mm	Cell Density, cpsi
Briggs and Stratton No. 1	C	60.0	50.8	200
Tecumseh OVRM120	C	60.0	50.8	200
Kawasaki FH601V	E	118	115	400
Honda GCV160	J	60.0	50.8	400

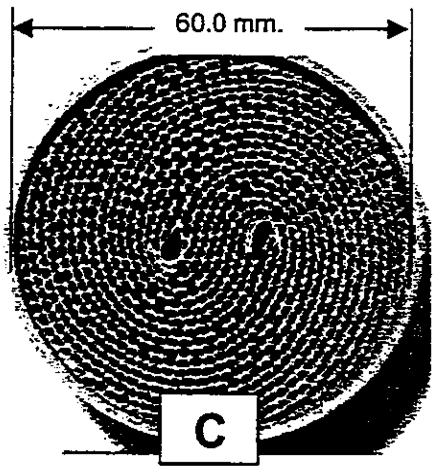

FIGURE 5. CATALYST C (CROSS-SECTIONAL VIEW)

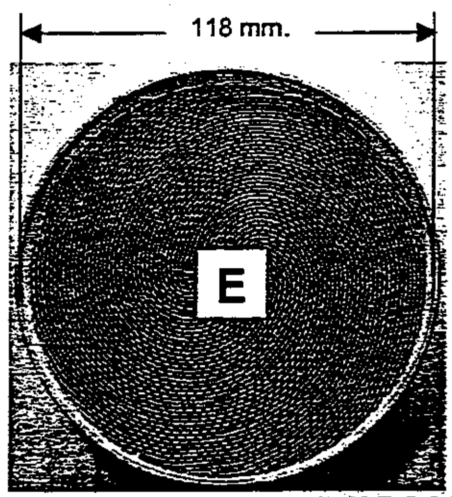

FIGURE 6. CATALYST E (CROSS-SECTIONAL VIEW)

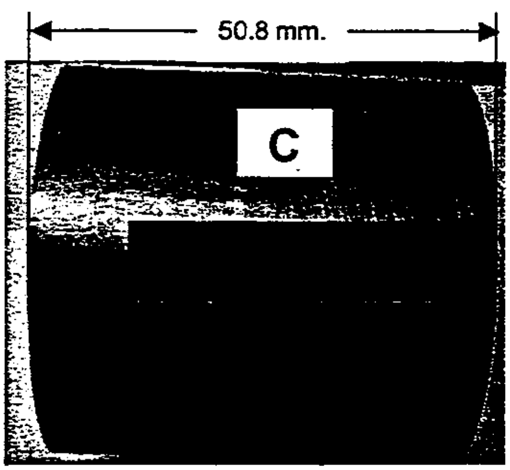

FIGURE 7. CATALYST C (AXIAL VIEW)

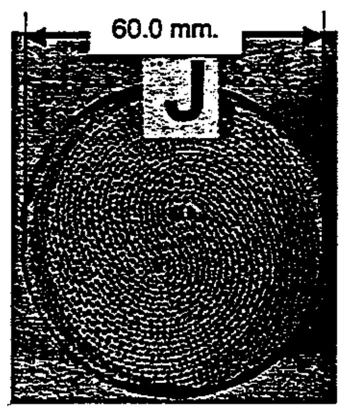

FIGURE 8. CATALYST J (CROSS-SECTIONAL VIEW)

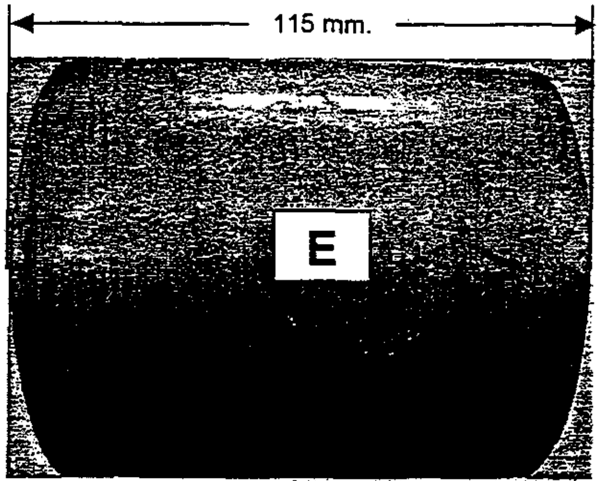

FIGURE 9. CATALYST E (AXIAL VIEW)

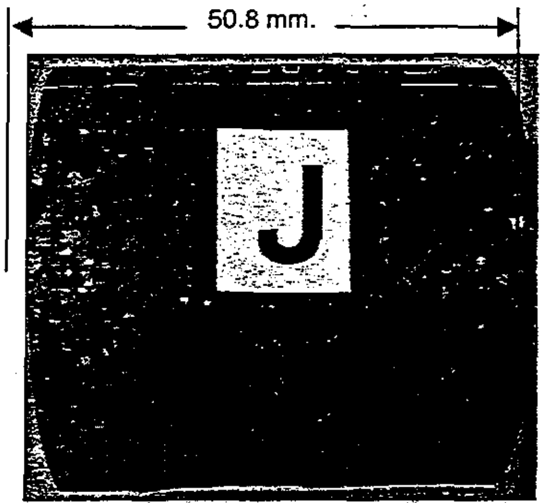

FIGURE 10. CATALYST J (AXIAL VIEW)

C. Exhaust Emissions Development

Emissions development was performed in several steps. After an engine was run-in for two-hours and baseline emission tested, a suitable catalyst was coupled to the engine to observe the performance of the system with "bolt-on" aftertreatment. Next, a controlled amount of air was injected into the exhaust system upstream of the catalyst. Since these engines all employ rich, base calibrations, additional air is needed to achieve the target HC reduction level. If the catalyst was able to meet the emission reduction target, a passive secondary-air induction system was developed.

The passive SAI system used the venturi principle to add supplemental air upstream of the catalyst, without connection to an external air supply. A schematic of the passive SAI system is shown in Figure 11. Similar SAI systems were incorporated on the Tecumseh, Kawasaki, and Honda GCV160 engines. The SAI system is designed to capture air circulated above the engine from the flywheel impeller, and direct it into the exhaust pipe through the use of a transfer tube and dampening chamber. The dampening chamber traps exhaust that escapes the SAI orifices, and allows it to be mixed with fresh air from the flywheel impeller, thereby redirecting it into the exhaust. To reduce exhaust scavenging through the orifices, a venturi is designed into the pipe to create a low-pressure region. Figure 12 shows the SAI system on the Tecumseh engine.

For the Kawasaki and first Briggs and Stratton engines, sufficient emission reductions were not achievable with baseline engine calibrations because the engines were running too rich. These engines were conservatively enleaned to achieve higher catalyst performance, adhering to manufacturer recommended guidelines for safe operation. Figure 13 shows the zero-hour air-fuel ratio profiles of the five engines tested to date in baseline and low-emission developed configurations. No enleanment was performed on the Tecumseh or Honda GCV160 engines.

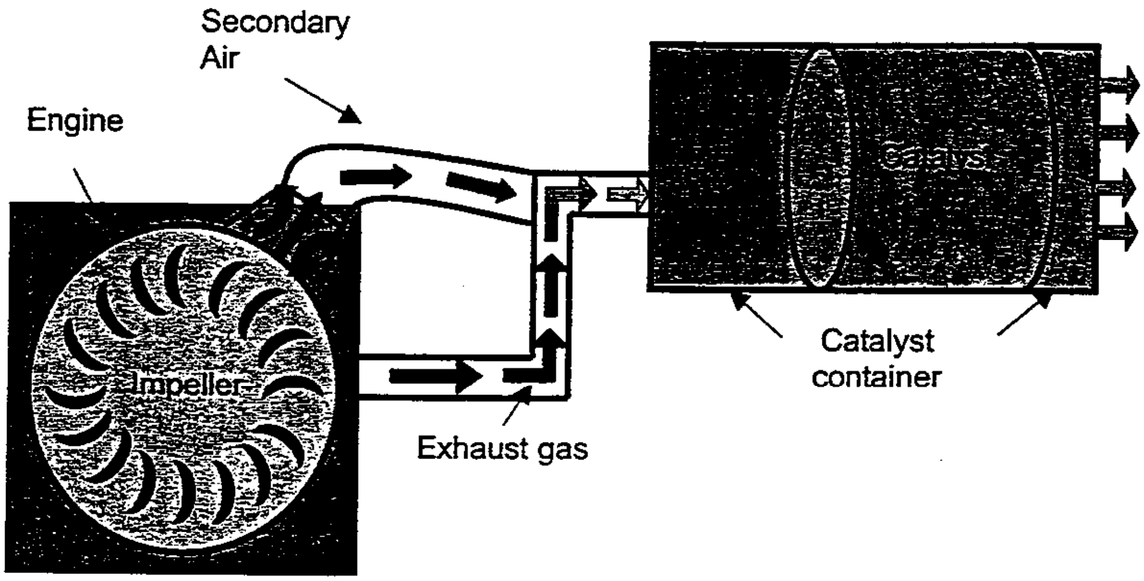

FIGURE 11. SCHEMATIC OF DEVELOPED PASSIVE SAI

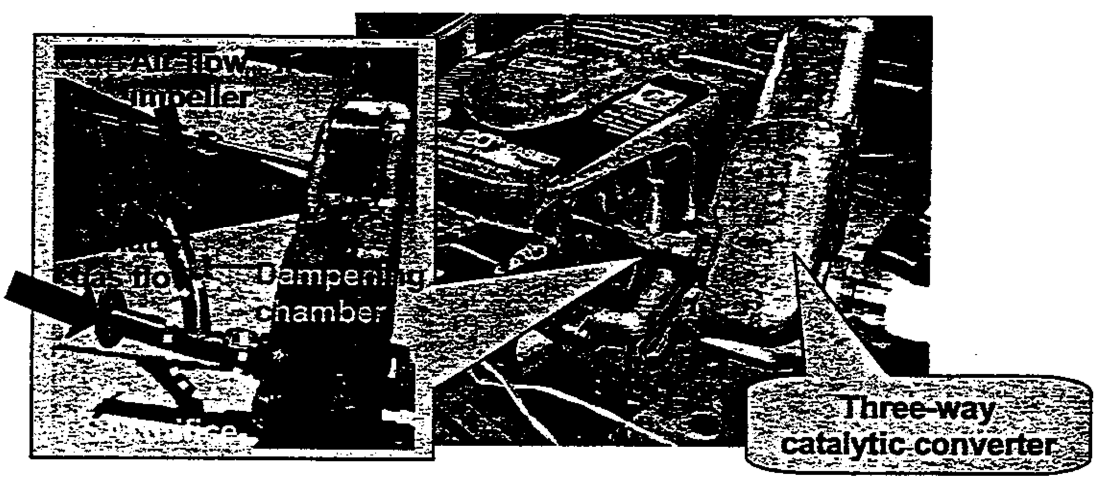

FIGURE 12. PASSIVE SAI SYSTEM ON TECUMSEH OVRM120 ENGINE

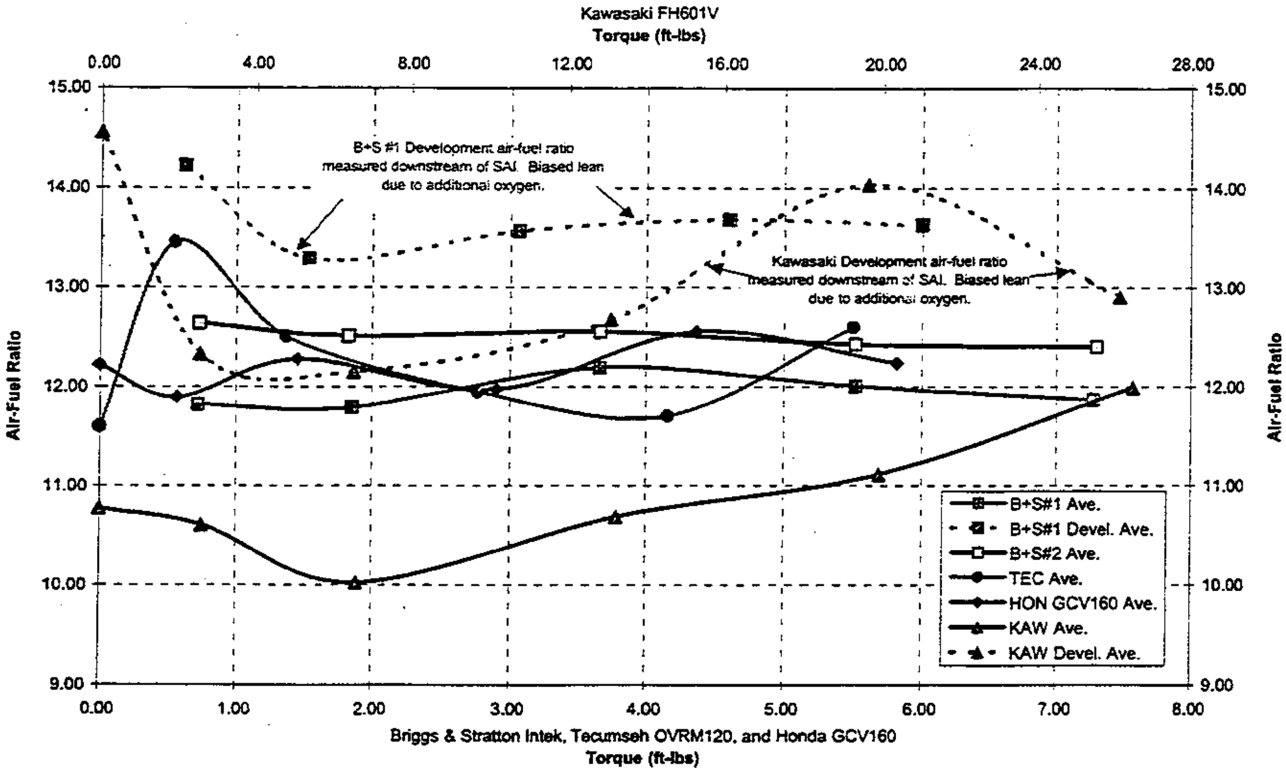

FIGURE 13. AVERAGE BASELINE AIR-FUEL RATIOS OF SMALL OFF-ROAD ENGINES

D. Emissions Testing

Emissions testing was performed on the Department of Emissions Research (DER) small off-road engine test stand. It includes a 20-hp eddy-current dynamometer on a movable stand that can accommodate both horizontal and vertical-shaft engines. Emissions measurement was performed using a Horiba MEXA 7200D emissions bench. Hydrocarbon emissions were measured using a multi-range heated flame ionization detector (HFID), oxides of nitrogen (NO_x) were measured using a chemiluminescent analyzer, and carbon monoxide (CO) and carbon dioxide (CO_2) emissions were measured using non-dispersive infrared analyzers (NDIR). Exhaust was collected using an 8-inch dilution tunnel with bag sampling of diluted exhaust. Bags were sampled after each mode.

All emissions testing was performed with the same batch of California Phase II gasoline. Table 6 presents the properties of the fuel used.

TABLE 6. CALIFORNIA PHASE II GASOLINE FUEL PROPERTIES (EM-4749-F)

Fuel Property	Method	Phase II RFG
Specific Gravity	ASTM D4052	0.7383
Aromatics, vol.%	ASTM D1319	23.9
Olefins		4.8
Saturates		60.4
Carbon, wt.%	ASTM D5291	84.29
Hydrogen, wt.%		13.31
Nitrogen Content (ppm)	ASTM D4629	4.9
RON	ASTM D2699	96.6
MON	ASTM D2700	87.5
Oxygenates	ASTM D4815	
tBa-vol%		0.06
tBa-wt%		0.06
MTBE-vol%		10.82
MTBE-wt%		10.95
Distillation, °F	ASTM D86	
IBP		101
10%		136
20%		155
30%		171
40%		187
50%		205
60%		223
70%		241
80%		263
90%		298
FBP		377
Recovery, %		96.5
Residue, %		1.0
Loss, %		2.5

The Briggs and Stratton, Tecumseh, and Kawasaki user manuals recommend 30W engine oil for operation in the temperature range observed in the laboratory. For consistency, Briggs and Stratton 30W engine oil was used in these engines. The Honda engines were lubricated using a multi-grade oil, as specified in the user manuals. Table 7 shows the properties of the Briggs and Stratton and multi-grade oils.

TABLE 7. ENGINE OIL PROPERTIES

Oil Property	Method	Briggs and Stratton 30W engine oil	Castrol GTX 10W30 engine oil*
Specific Gravity	ASTM D4052	0.88	
Viscosity @ 25 °C, cSt	ASTM D455	202.16	
Viscosity @ 40 °C, cSt	ASTM D455	85.78	
Viscosity @ 100 °C, cSt	ASTM D455	11.00	
Flash Point, °C (open cup)	ASTM D92	230	
Total Base Number	ASTM D4739	6.53	
Total Acid Number	ASTM D664	1.39	
Carbon, mass % Hydrogen, mass %	ASTM D5291	85.09 13.42	
Ba, ppm Ca, ppm Mg, ppm Mn, ppm Na, ppm P, ppm Zn, ppm	ASTM D5185	<1 1231 419 <1 516 986 1038	
Distillation by GC, °C IBP 10% 20% 30% 40% 50% 60% 70% 80% 90% FBP	ASTM D6352	 284.9 394.6 417.4 432.8 446.9 460.2 474.8 494.4 545.7 619.9 760.6	
* Data are not yet available			

At zero-hours, the first Briggs and Stratton and Tecumseh engines were evaporative emissions tested in a vehicle SHED. Testing included a one-hour hot soak following a 15 minute warm-up, and a 24-hr. diurnal test. CARB discontinued testing of these prototype evaporative emissions control devices due to vapor leaks in the fuel tank cap.

E. Durability Testing

Engine service accumulation was performed at SwRI's Engine and Vehicle Research Division. The durability site included two 30-hp eddy current dynamometers. Each dynamometer was fully automated including safety system monitoring. Safeties were defined for certain engine parameters with automated engine shutdown. These parameters are listed in Table 8. Engines were fueled with California Phase II gasoline. With the exception of the first Briggs and Stratton and Tecumseh engines through 125 hours, maintenance was performed during the service accumulation periods according to manufacturer recommended procedures, including oil changes, air filter cleaning and replacement, and spark plug cleaning and replacement.

TABLE 8. PARAMETERS MONITORED FOR AUTOMATED SAFETY SHUTDOWN DURING DURABILITY

Engine Speed (RPM)
Cylinder Head Temperature (°F)
Oil Temperature (°F)
Exhaust Gas Temperature (°F)
Catalyst Mid-Bed Temperature (°F)

III. RESULTS AND DISCUSSIONS

A. Briggs and Stratton Intek Engine No. 1

Briggs and Stratton Engine No. 1 was baseline tested and then developed to a low-emissions configuration. During development, the engine showed signs of power loss and emissions deterioration. After inspection of the engine with Briggs and Stratton personnel, it was decided to continue to use the engine for the program. Baseline, engine-out, and fully developed emissions results are presented in Table 9. Individual test data sheets are presented in Appendix A.

The final low-emissions configuration incorporated catalyst C with a lean fixed carburetor jet (Jet #2-0.027 in.), and a passive secondary air induction system utilizing a 4-hole venturi and a check valve. The throat of the venturi was shrouded so a portion of the flywheel impeller cooling air was directed into the venturi throat. This augmented the supplemental air at the catalyst inlet, improving HC and CO conversion.

Figure 14 shows the exhaust pipe with the SAI system. The engine calibration change was conservative, remaining within the not-to-exceed engine operating limits defined by Briggs and Stratton. On average at zero-hours, the developed configuration generated 3.67 $^g/_{hp\text{-}hr}$ HC, 0.47 $^g/_{hp\text{-}hr}$ NO_x, and 91 $^g/_{hp\text{-}hr}$ CO.

TABLE 9. BRIGGS AND STRATTON ENGINE NO. 1 EMISSION RESULTS

Test No.	Mode 1 Power, hp	Catalyst	Carburetor Jetting	g/hp-hr				
				THC	NMHC	NO_x	THC+NO_x	CO
Baseline Emissions								
B+S#1 BSLN5	4.24	None	Stock-fixed	7.88	NA	2.06	9.94	304
B+S#1 BSLN6	4.32	None	Stock-fixed	8.04	7.25	1.96	10.00	303
BSLN Ave.	**4.28**			**7.96**	**7.25**	**2.01**	**9.97**	**304**
Development Emissions (0-Hour)								
B+S#1 BSLN-JET#2	3.43	None	Fixed Jet #2	10.26	NA	4.46	14.73	224
B+S#1 CAT-C-BSLN3	3.59	Cat. C	Fixed Jet #2	3.48	2.96	0.40	3.88	86
B+S#1 CAT-C-BSLN4	3.48	Cat. C	Fixed Jet #2	3.85	NA	0.55	4.40	96
125-hour Emissions								
B+S#1-125-BSLN	3.18	None	Fixed Jet #2	15.63	NA	4.73	20.35	235
B+S#1-125-STK-BSLN	3.25	None	Stock-fixed	17.46	NA	2.21	19.67	353
B+S#1-125-#1	3.16	Cat. C	Fixed Jet #2	7.27	6.33	0.85	8.12	144
B+S#1-125-#2	3.26	Cat. C	Fixed Jet #2	7.51	6.63	0.94	8.45	146
250-hour Emissions								
No 250-hour testing was performed on Briggs and Stratton engine no. 1								

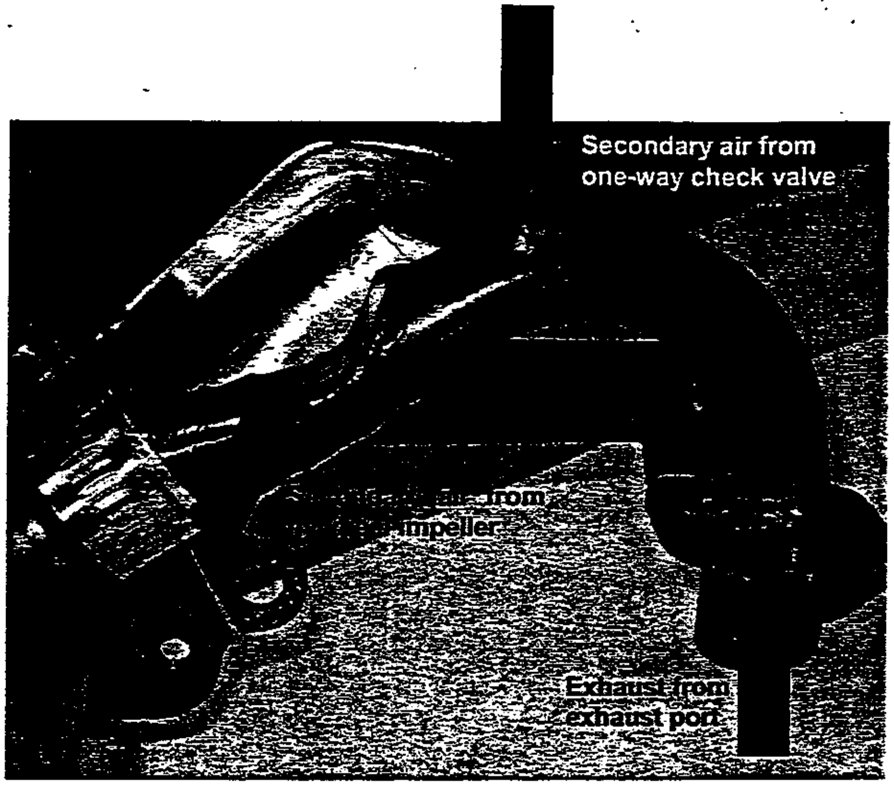

FIGURE 14. SECONDARY AIR INDUCTION SYSTEM ON BRIGGS AND STRATTON ENGINE NO. 1 MUFFLER

Figure 15 shows the zero-hour emissions of four configurations: baseline, stock carburetion with catalyst C and secondary air, engine-out with stock muffler and fixed jet #2, and fully developed configurations. Overall, HC+NO_x emissions were reduced by 58%, HC emissions by 54%, NO_x emissions by 76%, and CO emissions by 70% compared to the baseline configuration.

After completing the 125-hour service accumulation, the engine was emissions tested. During durability, the engine stopped running on ten separate occasions. After service checks were performed, the problem was determined to be caused by misfiring due to a bad spark plug. After a change of spark plug, the problem was no longer experienced. At 125 hours, the engine's stock-baseline emissions increased significantly from those at zero hours. Figure 16 presents a comparison between 0-hour and 125-hour emissions data. Engine-out (no catalyst) emissions have significantly increased at 125-hours while catalyst performance held up reasonably well. On average at 125 hours, compared to zero-hour baseline emissions, the fully developed configuration reduced HC+NO_x emissions by 17%, HC emissions by 7%, NO_x emissions by 56%, and CO emissions by 52%. The catalyst reduced HC+NO_x emissions by 70% at zero-hours and by 58% at 125 hours. The reduction in HC+NO_x conversion may be due to the increase of engine-out HC emissions and a lack of sufficient oxygen to completely oxidize these hydrocarbons. The misfire/engine shutdown episodes during durability may also have caused some loss in catalyst efficiency.

After review of the 125-hour emissions data, CARB decided to remove Briggs and Stratton Engine No. 1 from the program due to engine deterioration. No additional emissions tests or durability was performed on this engine. From results presented in Table 9, a set of multiplicative deterioration factors (DF) were calculated for a useful life of 125 hours based on the standard least squares curve fit method and the equation below. The DFs are presented in Table 10 for the three different engine configurations.

$$DF = \frac{E_{UL}}{E_o}$$

E_{UL} = Useful life emission level calculated from least squares trendline equation

E_o = Baseline emission level of stabalized engine

TABLE 10. CALCULATED DETERIORATION FACTORS FOR BRIGGS AND STRATTON ENGINE NO. 1 THROUGH 125 HOURS

Configuration	0-Hour Test No.	125-Hour Test No.	Deterioration Factors			
			$HC+NO_x$	HC	NO_x	CO
Stock-Baseline	B+S#1 BSLN5 & 6	B+S#1-125-STK-BSLN	1.97	2.19	1.10	1.16
Engine-Out	B+S#1 BSLN-JET#2	B+S#1-125-BSLN	1.38	1.52	1.06	1.05
Developed	B+S#1 CAT-C-BSLN3 & 4	B+S#1-125-#1 & #2	2.00	2.02	1.87	1.59

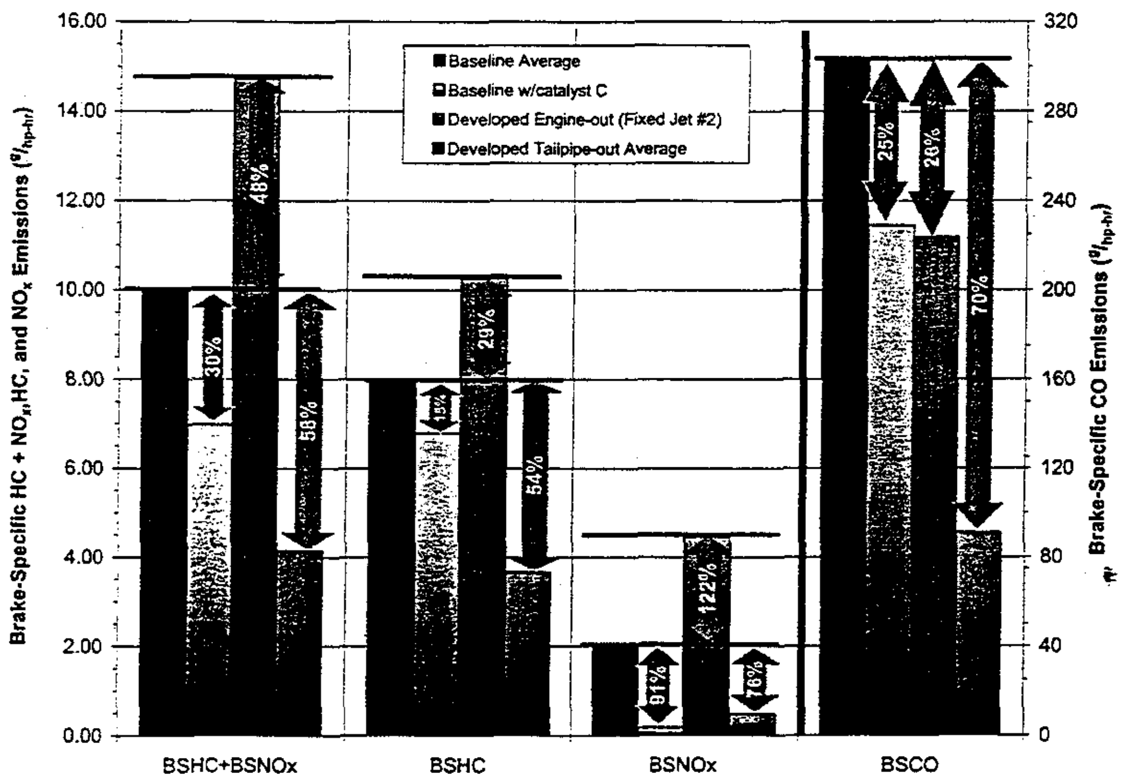

FIGURE 15. BRIGGS AND STRATTON ENGINE NO. 1-- ZERO-HOUR EMISSIONS

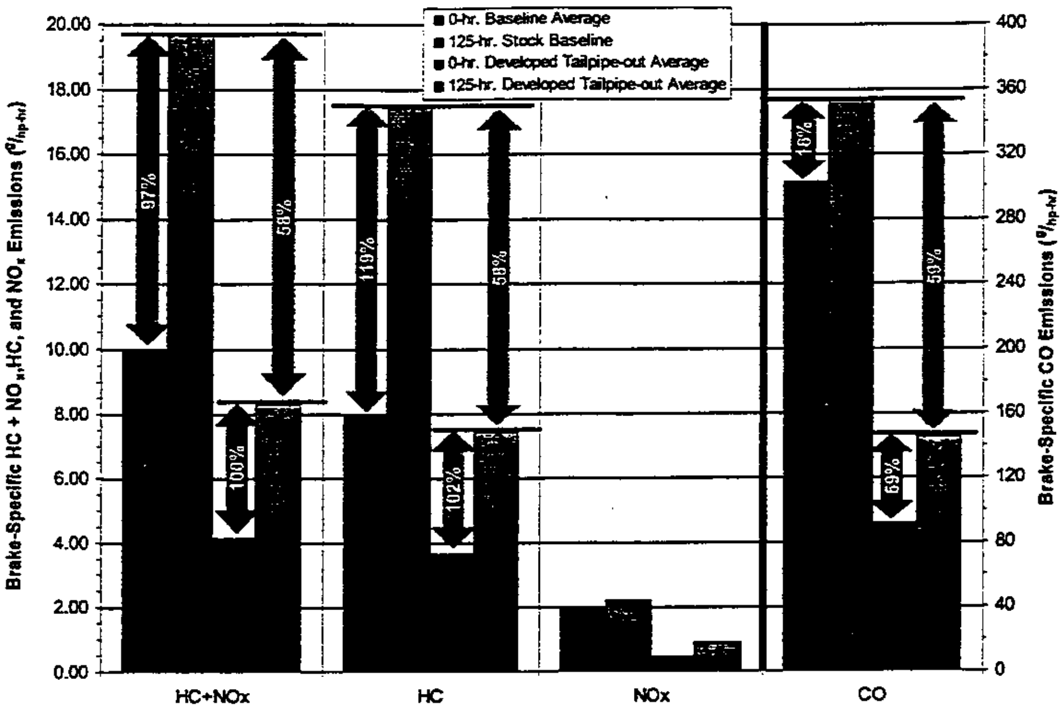

FIGURE 16. BRIGGS AND STRATTON ENGINE NO. 1—ZERO-HOUR AND 125-HOUR EMISSIONS

B. Briggs and Stratton Intek Engine No. 2

Briggs and Stratton Engine No. 2 was baseline tested following baseline testing of the first Briggs and Stratton engine. Table 11 shows emission results for Briggs and Stratton Engine No. 2. Engine No. 2 emits 19% less HC+NO_x than Engine No. 1 in the baseline configuration. Individual test data sheets are presented in Appendix B.

TABLE 11. BRIGGS AND STRATTON ENGINE NO. 2 EMISSION RESULTS

Test No.	Mode 1 Power, hp	Catalyst	Carburetor Jetting	g/hp-hr				
				THC	NMHC	NO_x	THC+NO_x	CO
Baseline Emissions								
B+S#2 BSLN1	4.31	None	Stock-fixed	6.75	NA	1.48	8.23	326
B+S#2 BSLN2	4.29	None	Stock-fixed	6.64	NA	1.62	8.26	322
B+S#2 BSLN3	4.35	None	Stock-fixed	6.08	5.30	1.67	7.75	312
BSLN Ave.	**4.32**			**6.49**	**5.30**	**1.59**	**8.08**	**320**
Development Emissions								
Development has not yet occurred								
125-hour Emissions								
Development has not yet occurred								
250-hour Emissions								
Development has not yet occurred								

C. Tecumseh OVRM120 Engine

Tecumseh OVRM120 engine testing and development followed development of the first Briggs and Stratton engine. Upon review of the initial baseline results, Tecumseh and SwRI felt that the engine was not operating as it should. The engine was running slightly leaner than expected, resulting in higher NO_x emissions and elevated combustion temperatures. Checks were performed to verify proper fuel delivery, carburetor setup, and full throttle operation. Diagnostics were also performed to verify intake and exhaust valve lash, as well as to check for leakage past the piston rings. All checks verified correct setup and normal operation. To determine whether the problem was due to a faulty carburetor, a replacement carburetor was installed and tested. The engine ran leaner with the replacement carburetor, and it was concluded that a problem existed in the engine. It was decided to replace the Tecumseh engine with an identical engine ARB had previously used for evaporative emissions testing.

The replacement engine was baseline emissions tested and then developed in its low-emission configuration. Table 12 presents engine emission results. Individual test data sheets are presented in Appendix C. The developed Tecumseh engine utilized catalyst C integrated inside a muffler, with a passive SAI system. Enleanment was not needed. The layout is shown earlier in Figure 12. On average, the final zero-hour developed configuration reduced $HC+NO_x$ emissions by 63%, HC emissions by 58%, NO_x emissions by 84%, and CO emissions by 53%. The final, average zero-hour emissions for the developed configuration were 2.54 $^{g}/_{hp\text{-}hr}$ HC, 0.26 $^{g}/_{hp\text{-}hr}$ NO_x, and 169 $^{g}/_{hp\text{-}hr}$ CO. Zero-hour emission results are shown in Figure 17.

The engine was emissions tested after completing the 125-hour service accumulation. No problems were experienced during the durability period. At 125 hours, the engine was tested in the stock-baseline and fully developed configurations, before and after scheduled maintenance. Maintenance included an oil change, air filter replacement, and spark plug replacement. Emissions after maintenance were higher than emissions prior to maintenance. The reason for this is unknown. At 125 hours, the engine's stock-baseline $HC+NO_x$ emissions increased by 42% compared to zero-hour data. Compared to zero-hour baseline levels, at 125 hours the fully developed configuration reduced $HC+NO_x$ emissions by 33%, HC emissions by 22%, NO_x emissions by 76%, and CO emissions by 30%. Catalyst reduction performance at 125 hours was on the order of 50% for $HC+NO_x$, 46% for HC, 73% for NO_x, and 36% for CO. After maintenance during the 125-hour emissions test, an oil leak was noticed near the head of the cylinder past the 'flange' gasket, as well as a leak around the o-ring at the bottom of the oil fill tube. Tecumseh mentioned that oil leakage past the 'flange' gasket has been observed on OVRM120s in the past. The leak past the oil fill tube may have been due to slightly higher crankcase pressures resulting from excess oil in the sump.

After completing the second and final durability interval, the engine was tested at 250 hours. No problems were experienced during the durability period. As at 125 hours, the engine was tested before and after scheduled maintenance in both the fully developed and stock-baseline configurations. As observed at 125 hours, tests after maintenance generated higher emissions than tests prior to maintenance, mostly from increased HC emissions. As shown in Figure 18, testing of the Tecumseh engine at 250 hours demonstrated an average reduction of 50% for HC+NO_x emissions, 42% for HC emissions, 78% for NO_x emissions, and 30% for CO emissions, compared to zero-hour baseline results. Catalyst performance at 250 hours was 64% for HC+NO_x, 61% for HC, 78% for NO_x, and 40% for CO. Figures 19 and 20 show emissions results in baseline and developed configurations, respectively, at each test interval. From these figures, it is noted that the durability data do not fall on a straight line, due to variability in engine operation. Using the least squares method, a set of deterioration factors was calculated for the Tecumseh engine at 125 and 250 hours. Deterioration factors are presented in Table 13.

TABLE 12. REPLACEMENT TECUMSEH OVRM120 ENGINE EMISSION RESULTS

Test No.	Mode 1 Power, hp	Catalyst	Carburetor Jetting	g/hp-hr				
				THC	NMHC	NO_x	THC+NO_x	CO
Baseline Emissions								
TEC2 BSLN#1	3.26	None	Stock (174)	5.45	4.74	1.58	7.03	337
TEC2 BSLN#2	3.33	None	Stock (174)	6.05	NA	1.65	7.70	342
TEC2 BSLN#3	3.00	None	Stock (174)	6.48	NA	1.54	8.02	405
BSLN Ave.	**3.20**			**5.99**	**4.74**	**1.59**	**7.58**	**361**
Development Emissions (0-Hour)								
TEC2-C-BSLN1m	3.58	Cat. C	Stock (174)	2.77	2.22	0.21	2.98	184
TEC2-C-BSLN2m	3.59	Cat. C	Stock (174)	2.31	NA	0.30	2.61	153
125-hour Emissions								
TEC2-125-STK-#1*	3.15	None	Stock (174)	8.07	7.08	1.33	9.40	375
TEC2-125-STK-#2	2.96	None	Stock (174)	9.27	8.20	1.49	10.76	411
TEC2-125-#1*	3.36	Cat. C	Stock (174)	4.47	3.69	0.27	4.74	256
TEC2-125-#2	3.21	Cat. C	Stock (174)	4.80	NA	0.47	5.27	247
TEC2-125-#3	3.18	Cat. C	Stock (174)	4.84	4.03	0.41	5.25	256
250-hour Emissions								
TEC2-250-STK-#1*	3.01	None	Stock (174)	8.43	7.34	1.49	9.93	397
TEC2-250-STK-#2	2.89	None	Stock (174)	9.58	8.38	1.70	11.28	457
TEC2-250-#1*	3.32	Cat. C	Stock (174)	3.32	2.64	0.33	3.65	230
TEC2-250-#2*	3.30	Cat. C	Stock (174)	3.55	2.76	0.31	3.86	250
TEC2-250-#3	3.19	Cat. C	Stock (174)	3.79	2.91	0.36	4.15	286
TEC2-250-#4	3.15	Cat. C	Stock (174)	3.24	2.43	0.40	3.64	252
* Testing prior to maintenance								

TABLE 13. CALCULATED DETERIORATION FACTORS FOR TECUMSEH OVRM120 ENGINE THROUGH 250 HOURS

Time (hrs.)	Configuration	0-Hour Test No.	Interval Test No.	Deterioration Factors			
				HC+NO_x	HC	NO_x	CO
125	Stock-Baseline	TEC2 BSLN#1, #2, & #3	TEC2-125-STK-#1 & #2	1.24	1.32	0.96	1.09
125	Developed	TEC2-C-BSLN1m & 2m	TEC2-125-#1, #2, & #3	1.40	1.41	1.29	1.33
250	Stock-Baseline	TEC2 BSLN#1, #2, & #3	TEC2-250-STK-#1 & #2	1.44	1.57	0.97	1.18
250	Developed	TEC2-C-BSLN1m & 2m	TEC2-250-#1, #2, #3, #4	1.58	1.59	1.48	1.59

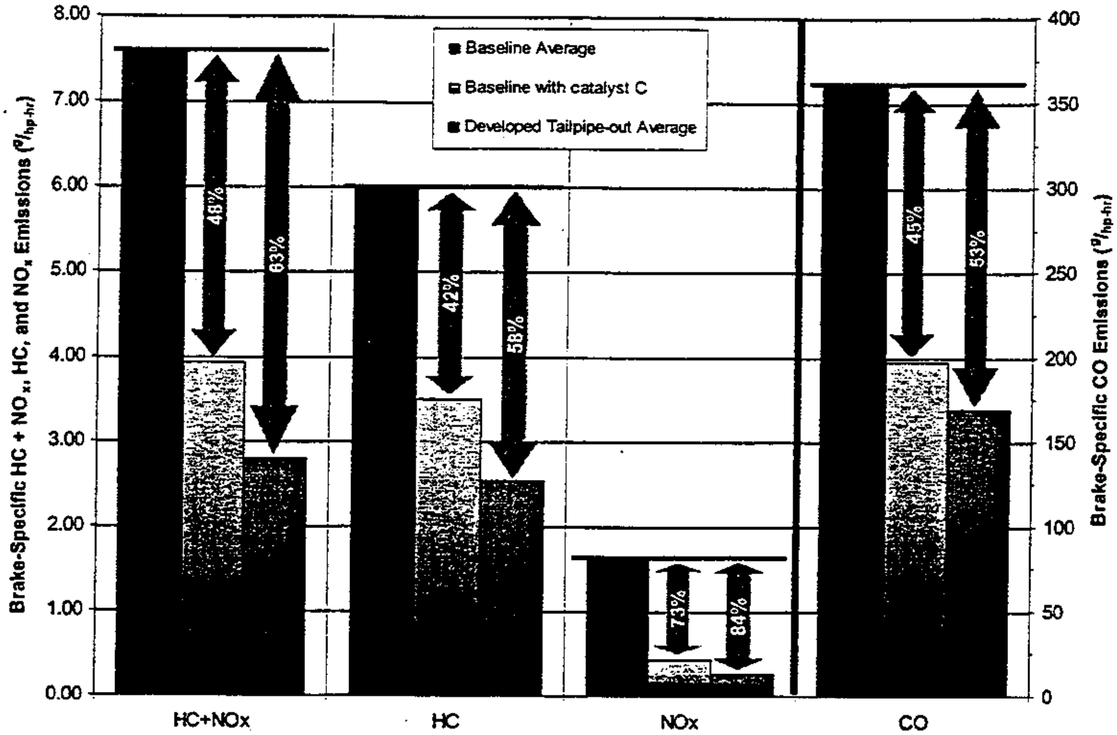

FIGURE 17. TECUMSEH OVRM120 ENGINE-- ZERO-HOUR EMISSIONS

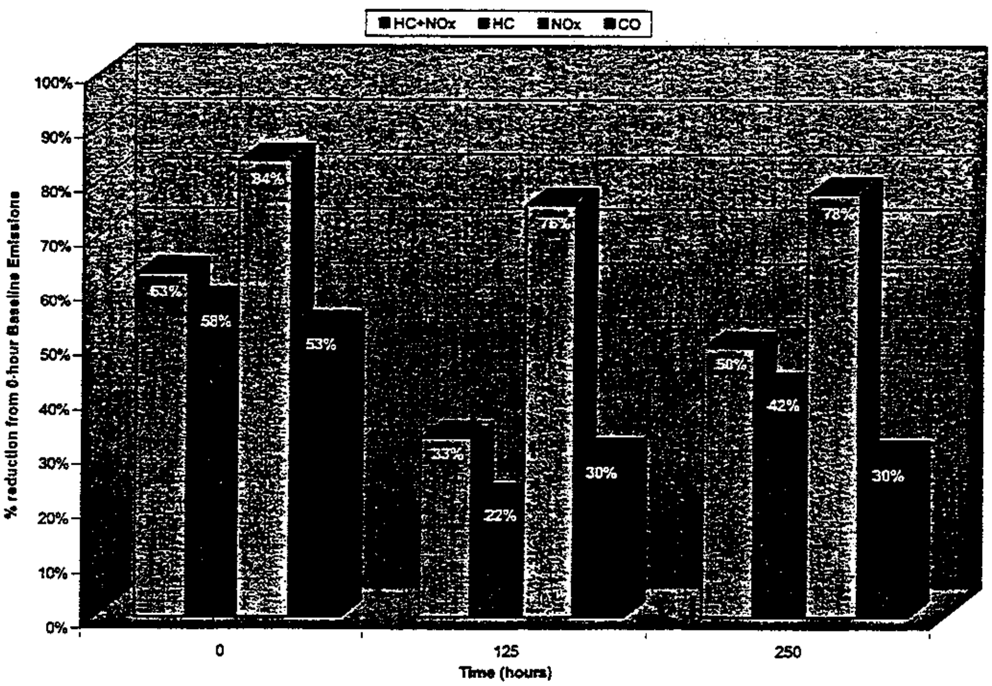

FIGURE 18. TECUMSEH OVRM120 ENGINE EMISSIONS—DEVELOPED CONFIGURATION PERCENT REDUCTION THROUGH 250 HOURS (COMPARED TO 0-HOUR BASELINE EMISSIONS)

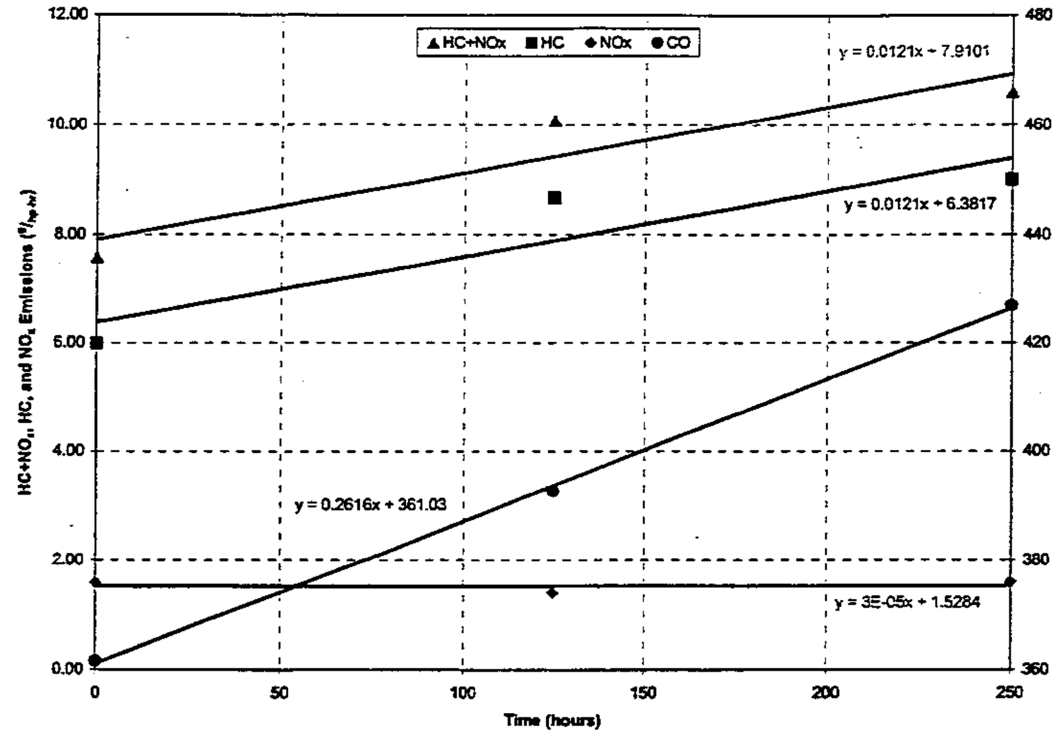

FIGURE 19. TECUMSEH OVRM120 EMISSIONS FOR STOCK CONFIGURATION

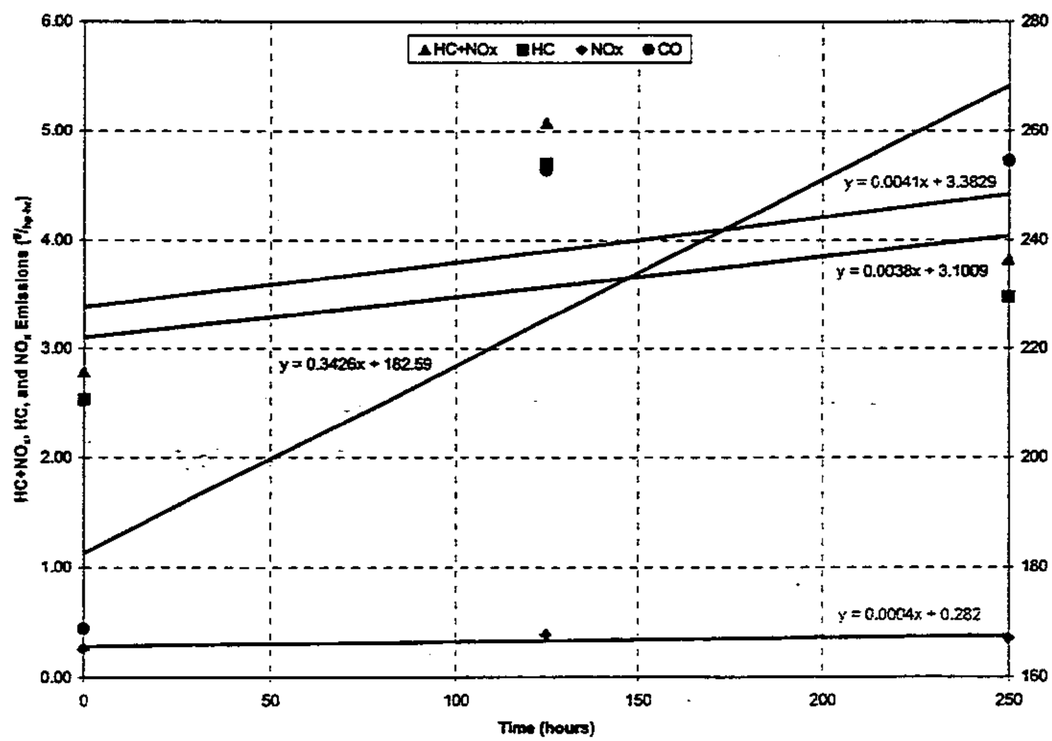

FIGURE 20. TECUMSEH OVRM120 EMISSIONS FOR DEVELOPED CONFIGURATION

D. Honda GCV160 Engine

It was originally planned to develop a small displacement horizontal-shaft generator engine. CARB decided, however, to replace the horizontal-shaft Honda GX160 engine with a similar displacement GCV160 vertical-shaft engine that is used in walk-behind lawnmowers. The Honda GCV160 engine was baseline emissions tested in its stock configuration, then developed and durability tested. Results are summarized in Table 14. Individual test data sheets are presented in Appendix D.

TABLE 14. HONDA GCV160 ENGINE EMISSION RESULTS

Test No.	Mode 1 Power, hp	Catalyst	Carburetor Jetting	g/hp-hr				
				THC	NMHC	NO_x	THC+NO_x	CO
Baseline Emissions								
HON-160-BSLN#1	3.41	None	Stock-fixed	6.45	5.81	2.26	8.71	296
HON-160-BSLN#2	3.37	None	Stock-fixed	6.80	NA	2.17	8.97	303
HON-160-BSLN#3	3.54	None	Stock-fixed	6.20	NA	2.48	8.69	280
BSLN Ave.	**3.44**			**6.48**	**5.81**	**2.30**	**8.79**	**293**
Development Emissions (0-Hour)								
HON-160-J-BSLN#1	3.73	Cat. J	Stock-fixed	2.23	1.83	0.25	2.48	105
HON-160-J-BSLN#2	3.58	Cat. J	Stock-fixed	2.19	1.82	0.34	2.53	110
125-hour Emissions								
HON-160-STK-125-#1	3.18	None	Stock-fixed	5.16	4.78	5.46	10.62	157
HON-160-STK-125-#2	3.13	None	Stock-fixed	5.43	5.04	5.40	10.83	161
HON-160-J-125-#1	3.40	Cat. J	Stock-fixed	1.52	1.29	0.47	1.99	66
HON-160-J-125-#2	3.35	Cat. J	Stock-fixed	1.52	1.27	0.58	2.10	64
250-hour Emissions								
HON-160-STK-250-#1	3.28	None	Stock-fixed	5.57	5.14	6.14	11.71	150
HON-160-STK-250-#1	3.40	None	Stock-fixed	4.95	4.57	6.01	10.96	141
HON-160-J-250-#1	3.55	Cat. J	Stock-fixed	2.54	2.27	0.36	2.90	72
HON-160-J-250-#2	3.47	Cat. J	Stock-fixed	1.97	NA	0.44	2.41	78

The developed GCV160 engine utilized catalyst J integrated inside a modified GCV160 muffler, with a passive SAI system. The low-emission developed engine is shown in Figure 4. Catalysts K and L were also evaluated during development, however, catalyst J was chosen due to its enhanced performance. The engine was not enleaned due to engine manufacturer concerns with startability in certain applications. On average, the zero-hour developed configuration reduced HC+NO_x emissions by 71%, HC emissions by 66%, NO_x emissions by 87%, and CO emissions by 63%. The final, average zero-hour emissions for the developed configuration were 2.21 $^{g}/_{hp\text{-}hr}$ HC, 0.30 $^{g}/_{hp\text{-}hr}$ NO_x, and 108 $^{g}/_{hp\text{-}hr}$ CO. Figure 21 presents zero-hour emissions in the stock-baseline, baseline with catalyst J, and fully developed configurations (catalyst J with SAI).

The Honda GCV160 engine was emissions tested after completing the first 125-hour service accumulation. No problems were experienced during the durability period. At 125 hours, the engine was tested in the stock-baseline and fully developed configurations. Scheduled maintenance was performed every 50 hours during durability, including oil changes, air filter cleaning and replacement, and spark plug cleaning and regapping. On average at 125 hours, the developed configuration produced 2.04 g/hp-hr of $HC+NO_x$, 1.52 g/hp-hr of HC, 0.52 g/hp-hr of NO_x, and 64 g/hp-hr of CO, thus reducing $HC+NO_x$ emissions by 77%, HC emissions by 77%, NO_x emissions by 77%, and CO emissions by 78%, compared to zero-hour baseline results. At 125 hours, catalyst percent conversions were 81% $HC+NO_x$, 71% HC, 90% NO_x, and 60% CO. The engine was running leaner at 125 hours than during baseline and development testing, resulting in increased NO_x emissions and reduced HC and CO emissions. It is believed that the increase in stock HC emissions at 125 hours was mostly from higher HC emissions at idle, due to leaner operation with potentially incomplete combustion. Also, the engine was harder to start, requiring the use of the choke, and idle operation was erratic.

The engine was tested at 250 hours after completing the second durability interval. No problems were experienced during durability. Similar starting difficulty and erratic idle operation were observed as at 125 hours. As shown in Figure 22, testing of the Honda GCV160 engine at 250 hours demonstrated an average reduction of 70% for $HC+NO_x$ emissions, 65% for HC emissions, 83% for NO_x emissions, and 74% for CO emissions, compared to zero-hour baseline results. On average at 250 hours, the developed configuration produced 2.66 g/hp-hr of $HC+NO_x$, 2.26 g/hp-hr of HC, 0.40 g/hp-hr of NO_x, and 75 g/hp-hr of CO. Catalyst performance at 250 hour was 77% for $HC+NO_x$, 57% for HC, 93% for NO_x, and 48% for CO. Figures 23 and 24 show emissions results in stock and developed configurations, respectively, at each test interval. Using the least squares method, a set of deterioration factors was calculated for the Honda GCV160 engine at 125 and 250 hours, as shown in Table 15.

After completing 250-hour testing, carburetor maintenance was performed on the Honda GCV160 engine in an attempt to improve idle operation and startability. The carburetor was removed from the engine and cleaned according to Honda specified procedures. Upon removing the carburetor from the engine, a warn gasket was found between the carburetor and the intake port. The carburetor was thoroughly cleaned and reassembled, and a new gasket was fitted between the carburetor and the engine. A repeat set of tests was performed. Overall, composite emissions were only slightly affected by the carburetor maintenance. However, idle operation was less erratic and the engine did not run as lean at idle.

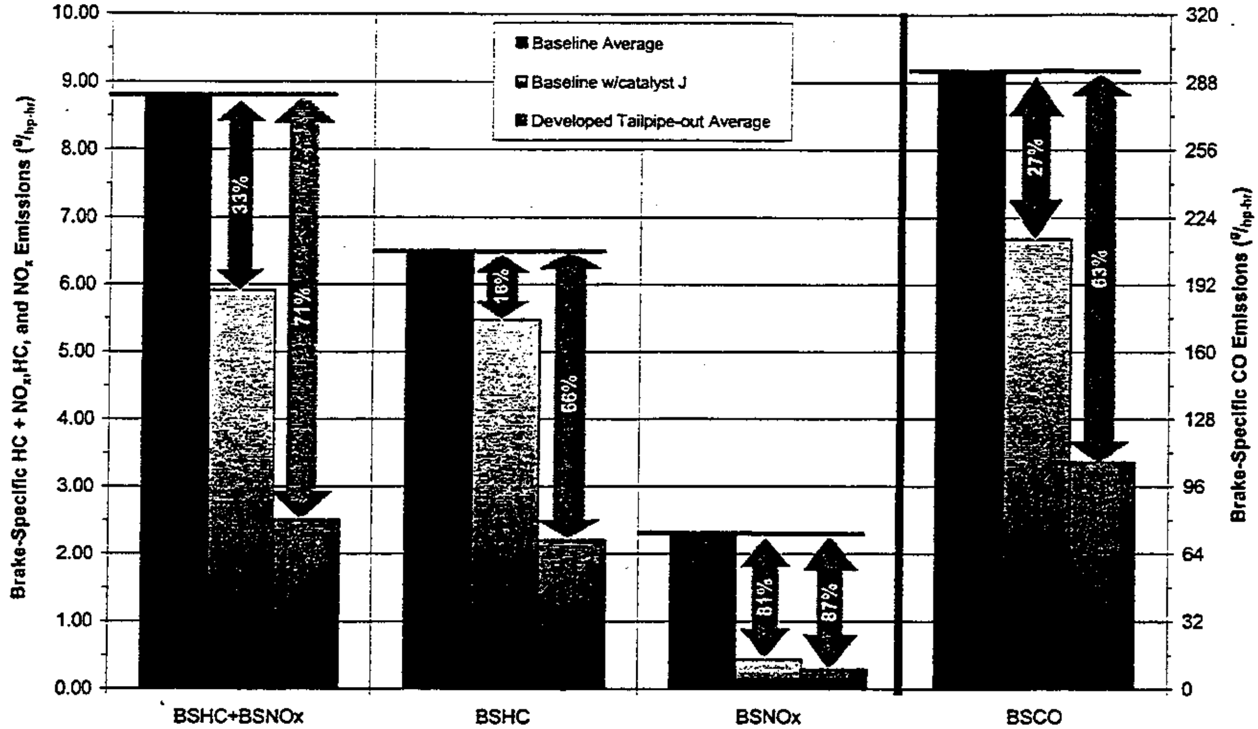

FIGURE 21. HONDA GCV160 ENGINE—ZERO-HOUR EMISSIONS

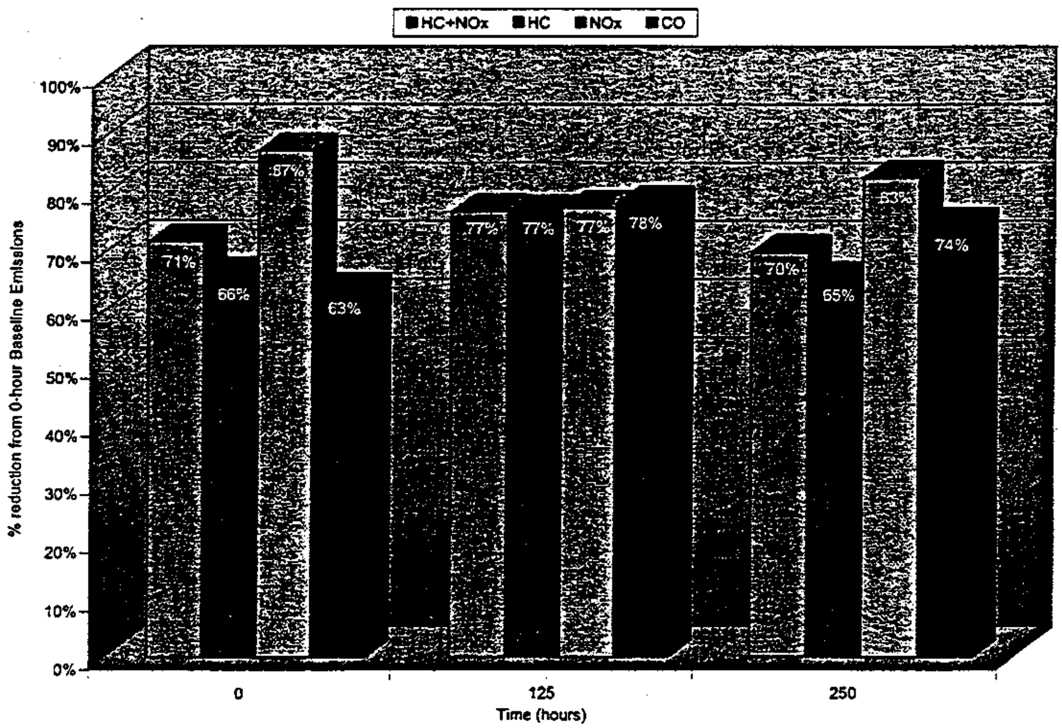

FIGURE 22. HONDA GCV160 ENGINE EMISSIONS—DEVELOPED CONFIGURATION PERCENT REDUCTION THROUGH 250 HOURS (COMPARED TO 0-HOUR BASELINE EMISSIONS)

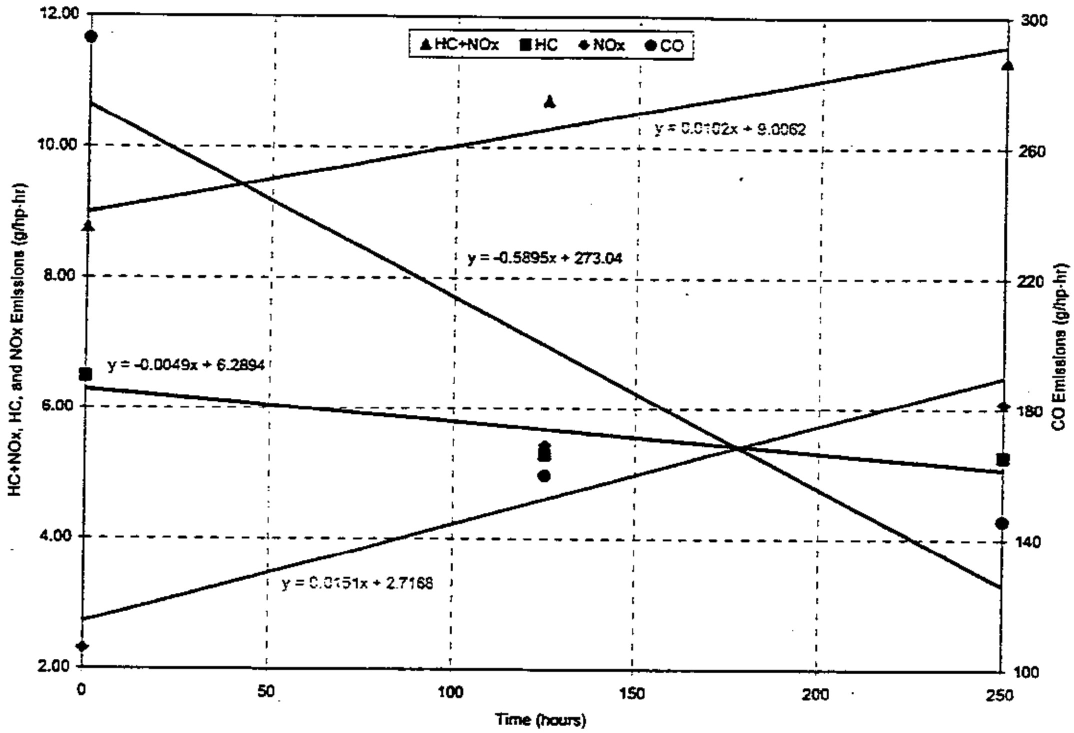

FIGURE 23. HONDA GCV160 EMISSIONS FOR STOCK CONFIGURATION

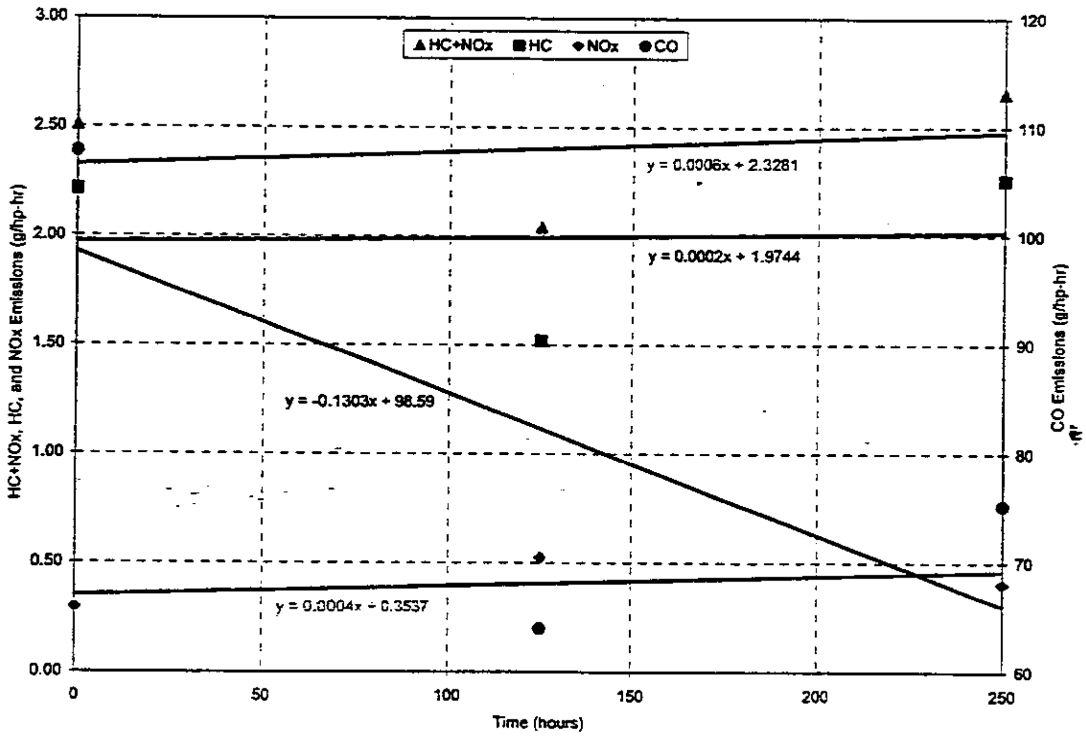

FIGURE 24. HONDA GCV160 EMISSIONS FOR DEVELOPED CONFIGURATION

TABLE 15. CALCULATED DETERIORATION FACTORS FOR HONDA GCV160 ENGINE THROUGH 250 HOURS

Time (hrs.)	Configuration	0-Hour Test No.	Interval Test No.	Deterioration Factors			
				$HC+NO_x$	HC	NO_x	CO
125	Stock-Baseline	HON-160-BSLN-#1, #2, & # 3	HON-160-STK-125-BSLN#1, & #2	1.17	0.88	2.00	0.68
125	Developed	HON-160-J-BSLN#1, & #2	HON-160-J-125-#1, & #2	0.96	0.90	1.38	0.76
250	Stock-Baseline	HON-160-BSLN-#1, #2, & # 3	HON-160-STK-250-#1, & #2	1.32	0.78	2.82	0.43
250	Developed	HON-160-J-BSLN#1, & #2	HON-160-J-250-#1, & #2	0.99	0.91	1.56	0.61

E. Kawasaki FH601V Engine

After completion of a two-hour break-in, the Kawasaki engine was found to be running noticeably leaner at high loads and richer at low loads, as compared to Kawasaki-supplied historical data. This was observed in exhaust gas oxygen sensor readings as well as in engine-out emission data. It was suspected that there was a problem with the fuel system (filter and pump) or the carburetor, resulting in inadequate fueling at wide-open throttle and excess fueling at idle. A replacement carburetor from Kawasaki was installed. It exhibited similar performance, except with more reasonable fuel control at lower loads. From this data, it was suspected that there was an engine fuel delivery malfunction. A replacement engine was procured for testing.

The replacement engine was broken-in for two hours and then baseline tested. A set of four tests was run on this engine in its stock configuration. Consecutive tests were run on one day (*KAW2-BSLN#1* and *KAW2-BSLN#2*), and a second set of tests (*KAW2-BSLN#3* and *KAW2-BSLN#4*) were run the following day. Test #2 was considered invalid because of an emission measurement error during the idle mode, and was not used in the calculation of the baseline average. Emission results are summarized in Table 16. Individual test data sheets are presented in Appendix E.

Baseline results indicated variability in engine operation and emissions. To understand why this was observed, experiments were run at wide-open throttle with varied intake air temperatures. These experiments showed that fuel control and emissions for this engine are very sensitive to changes in intake air conditions (temperature and humidity). Test procedures were subsequently adjusted to more consistently maintain intake air temperature, however, intake air humidity could not be readily controlled.

TABLE 16. KAWASAKI FH601V ENGINE EMISSION RESULTS

Test No.	Mode 1 Power, hp	Catalyst	Carburetor Jetting	g/hp-hr				
				THC	NMHC	NO_x	THC+NO_x	CO
Baseline Emissions								
KAW2-BSLN#1	15.38	None	Stock (136/140)	6.63	5.49	1.27	7.90	418
KAW2-BSLN#3	16.12	None	Stock (136/140)	5.21	NA	2.08	7.29	386
KAW2-BSLN#4	15.60	None	Stock (136/140)	4.69	3.97	2.46	7.15	338
BSLN Ave.	**15.70**			**5.51**	**4.73**	**1.94**	**7.45**	**380**
Development Emissions								
KAW2-EO3-#1	15.23	None	Tier 3 (116/120)	3.55	NA	3.89	7.43	226
KAW2-E-DEV-FNL#1	15.56	Cat. E	Tier 3 (116/120)	1.45	1.06	0.07	1.52	111
KAW2-E-DEV-FNL#2	15.35	Cat. E	Tier 3 (116/120)	1.32	NA	0.05	1.37	101
125-hour Emissions								
KAW2-125-STK-#1	15.22	None	Stock (136/140)	5.70	5.25	0.86	6.55	410
KAW2-125-STK-#2	15.16	None	Stock (136/140)	6.08	5.24	0.76	6.84	435
KAW2-125-EO3-#1	15.16	None	Tier 3 (116/120)	3.77	NA	4.16	7.93	199
KAW2-125-E-#1	15.39	Cat. E	Tier 3 (116/120)	1.67	1.23	0.10	1.77	128
KAW2-125-E-#2	15.34	Cat. E	Tier 3 (116/120)	1.52	1.09	0.07	1.59	119
250-hour Emissions								
KAW2-250-STK-#1	15.00	None	Stock (136/140)	7.54	6.47	0.85	8.39	435
KAW2-250-STK-#2	14.96	None	Stock (136/140)	7.70	NA	0.83	8.53	431
KAW2-250-EO3-#1	14.93	None	Tier 3 (116/120)	4.10	NA	4.55	8.65	187
KAW2-250-EO3-#2	14.91	None	Tier 3 (116/120)	4.28	3.84	4.57	8.85	190
KAW2-250-E-#1	14.97	Cat. E	Tier 3 (116/120)	1.83	1.38	0.11	1.94	126
KAW2-250-E-#2	14.79	Cat. E	Tier 3 (116/120)	1.77	1.32	0.10	1.87	126
KAW2-250-E-#3	14.94	Cat. E	Tier 3 (116/120)	1.78	NA	0.11	1.89	120
500-hour data are not yet available								

The developed configuration included catalyst E integrated inside a Kawasaki muffler, passive secondary air induction (SAI), and enleanment using fixed jets manufactured by Kawasaki for "Tier 3" lean settings. On average, the zero-hour developed configuration produced 1.45 $^{g}/_{hp\text{-}hr}$ HC+NO_x, 1.39 $^{g}/_{hp\text{-}hr}$ HC, 0.06 $^{g}/_{hp\text{-}hr}$ NO_x, and 106 $^{g}/_{hp\text{-}hr}$ CO. Overall, the developed configuration reduced HC+NO_x emissions by 81%, HC by 75%, NO_x by 97%, and CO by 72%, as compared to average baseline results. Figure 25 summarizes emissions in baseline, baseline with catalyst E, developed engine-out, and developed configurations.

The engine was emission tested after 125 hours of service accumulation. No problems were experienced during durability. Scheduled maintenance was performed, including oil changes, air filter cleanings, and spark plug checks. It was noted that the engine was running leaner at idle compared to baseline testing. Following aging, the engine was tested at 125 hours in the fully developed configuration, engine-out configuration ('Tier 3' jets with SAI system), and stock-baseline configuration. On average at 125 hours, the developed configuration produced 1.69 $^{g}/_{hp\text{-}hr}$ of HC+NO_x, 1.60 $^{g}/_{hp\text{-}hr}$ of HC, 0.09 $^{g}/_{hp\text{-}hr}$ of NO_x, and 123 $^{g}/_{hp\text{-}hr}$ of CO, thus reducing HC+NO_x emissions by 77%, HC emissions by 71%, NO_x emissions by 96%, and CO emissions by 68%, compared to zero-hour baseline results.

After completing the second durability interval, the engine was tested at 250 hours. No problems were experienced during durability. Scheduled maintenance was performed, including oil changes, air filter cleanings, and spark plug checks. As shown in Figure 26, testing of the Kawasaki engine at 250-hours demonstrated an average reduction of 74% for $HC+NO_x$ emissions, 67% for HC emissions, 94% for NO_x emissions, and 67% for CO emissions, compared to zero-hour baseline results. On average at 250 hours, the developed configuration produced 1.91 $^g/_{hp\text{-}hr}$ of $HC+NO_x$, 1.80 $^g/_{hp\text{-}hr}$ of HC, 0.11 $^g/_{hp\text{-}hr}$ of NO_x, and 124 $^g/_{hp\text{-}hr}$ of CO. Catalyst percent conversions at 250 hours were 75% for HC+NOx, 73% for HC, 89% for NOx, and 71% for CO. Figures 27 and 28 show emissions results in baseline and developed configurations, respectively, at each test interval. Using the least squares method, a set of deterioration factors was calculated for the Kawasaki FH601V engine at 125 and 250 hours, as shown in Table 17.

As observed with the Honda GCV160 engine, the Kawasaki appeared to be running slightly leaner at idle than during baseline testing and development. A fuel conditioner was run through the engine after 250-hour testing, however, no change in operation was observed. After the 250-hour emissions tests, the ceramic insulators of the original spark plugs appeared to be slightly burned. The spark plugs were replaced prior to beginning the aging through 500 hours.

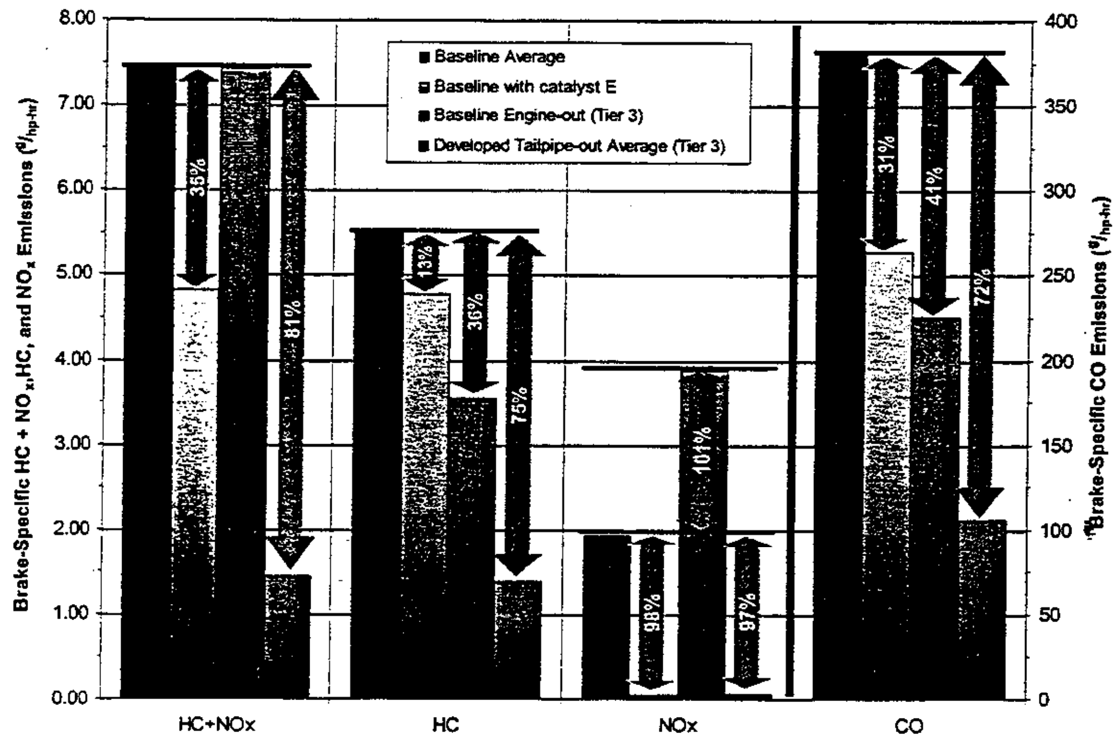

FIGURE 25. KAWASAKI FH601V ENGINE— ZERO-HOUR EMISSIONS

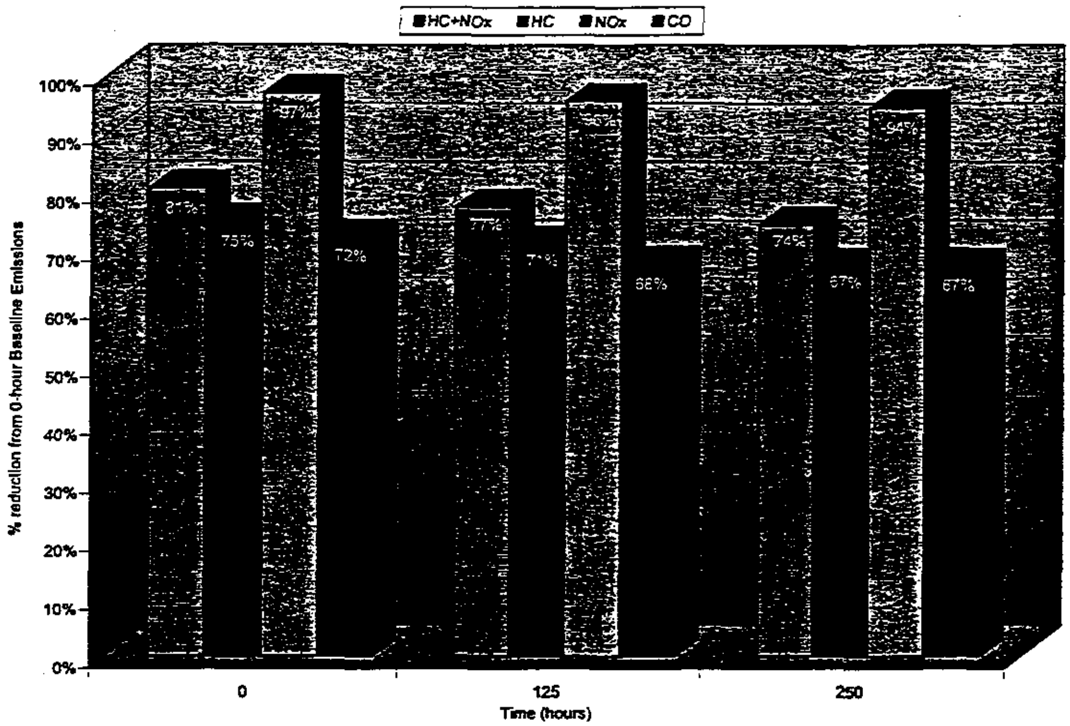

FIGURE 26. KAWASAKI FH601V ENGINE EMISSIONS—DEVELOPED CONFIGURATION PERCENT REDUCTION THROUGH 250-HOURS (COMPARED TO 0-HOUR BASELINE EMISSIONS)

TABLE 17. CALCULATED DETERIORATION FACTORS FOR KAWASAKI FH601V ENGINE THROUGH 250 HOURS

Time (hrs.)	Configuration	0-Hour Test No.	Interval Test No.	Deterioration Factors			
				$HC+NO_x$	HC	NO_x	CO
125	Stock-Baseline	KAW2-BSLN#1, #3, & #4	KAW2-125-STK-#1 & #2	1.01	1.15	0.62	1.08
125	Engine-Out	KAW2-EO3-#1	KAW2-125-EO3-#3	1.08	1.08	1.08	0.91
125	Developed	KAW2-E-DEV-FNL#1, & #2	KAW2-125-E-#1, & #2	1.16	1.15	1.40	1.11
250	Stock-Baseline	KAW2-BSLN#1, #3, & #4	KAW2-250-STK-#1, & #2	1.08	1.34	0.34	1.15
250	Engine-Out	KAW2-EO3-#1	KAW2-250-EO3-#1, & #2	1.17	1.17	1.17	0.82
250	Developed	KAW2-E-DEV-FNL#1, & #2	KAW2-250-E-#1, #2, & #3	1.32	1.30	1.78	1.20

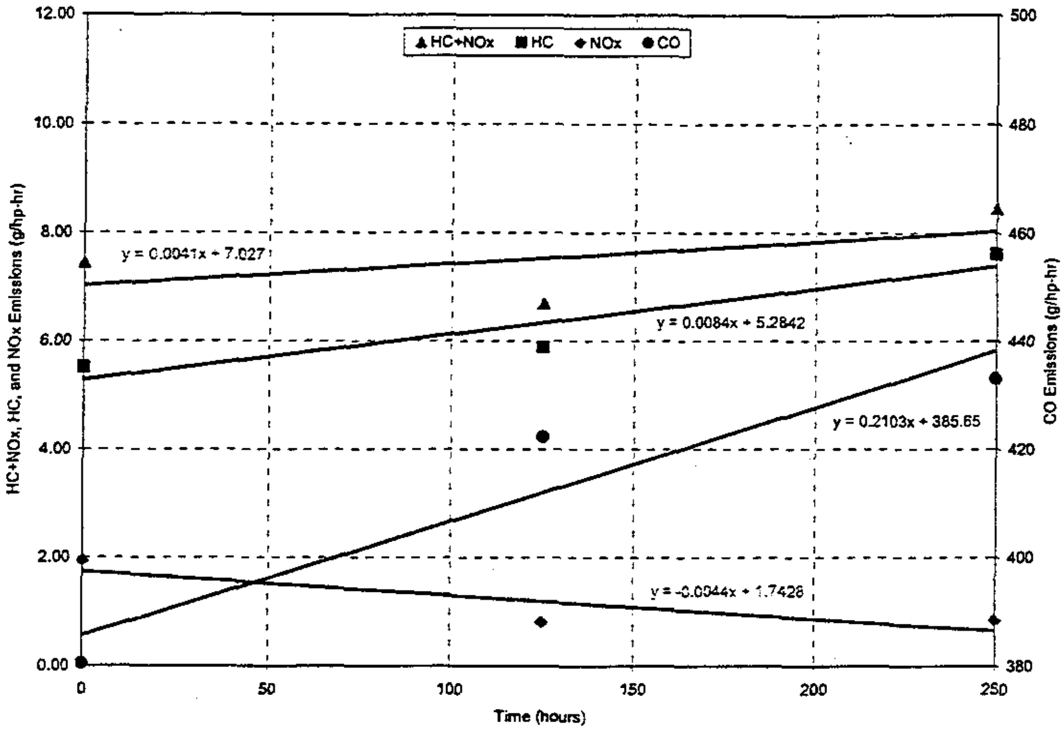

FIGURE 27. KAWASAKI FH601V EMISSIONS FOR STOCK CONFIGURATION

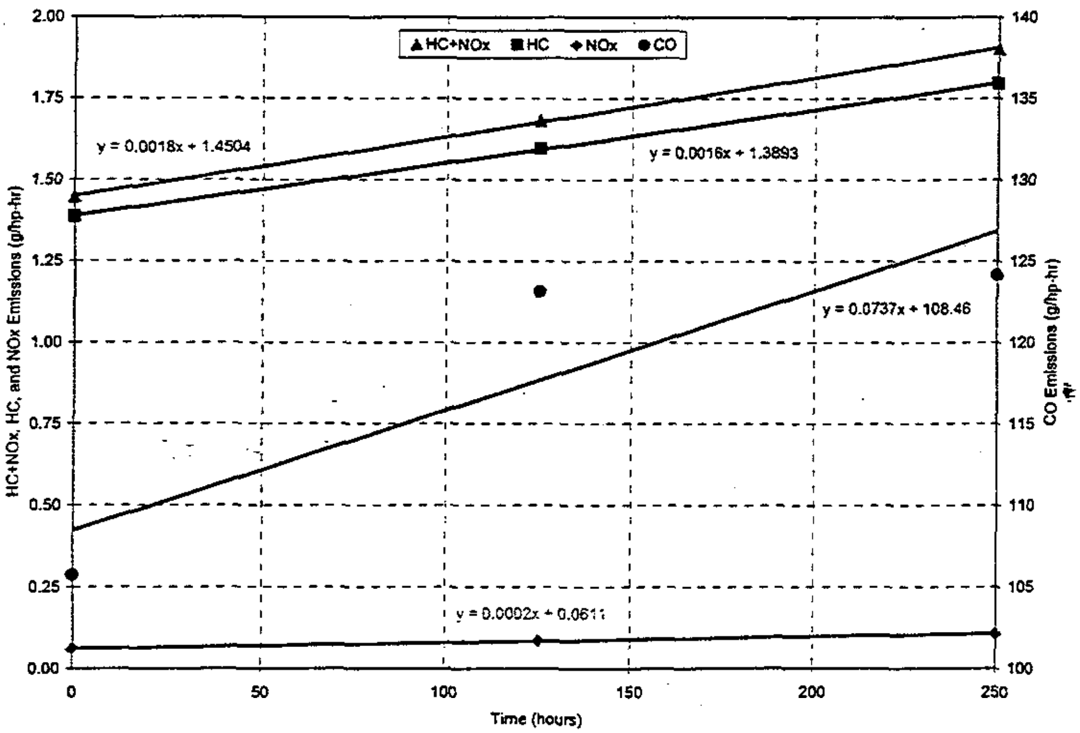

FIGURE 28. KAWASAKI FH601V EMISSIONS FOR DEVELOPED CONFIGURATION

F. Honda GX340 Engine

No testing has taken place on this engine to date.

IV. SUMMARY AND CONCLUSIONS

Six small, off-road engines are being developed in low-emission configurations and aged through their useful lives to demonstrate the effectiveness and durability of catalyst application. Four of the engines are used in walk-behind mower (WBM) applications, one is for a riding mower, and one is used in constant-speed/generator applications. The program goal is to reduce HC+NO_x emissions at the end of the engine's useful life by at least 50% as compared to current CARB standards. Low-emission engines were developed using three-way catalytic converters, passive secondary-air induction (SAI) systems, and enleanment, where needed.

Variability in engine operation and emissions presented additional challenges. One of the developed engines failed and was removed from the program. Two of the the three other engines tested to date were replaced at zero hours due to questions about their operation. Engine fueling characteristics and resulting emissions were observed to shift from one durability interval to the next. Good results were obtained in spite of these difficulties.

Results demonstrate that emissions from these engines can be significantly reduced. The project goal of a 50% minimum HC+NO_x reduction at useful life was successfully demonstrated on three of the four engines tested thus far, as shown in Figure 29.

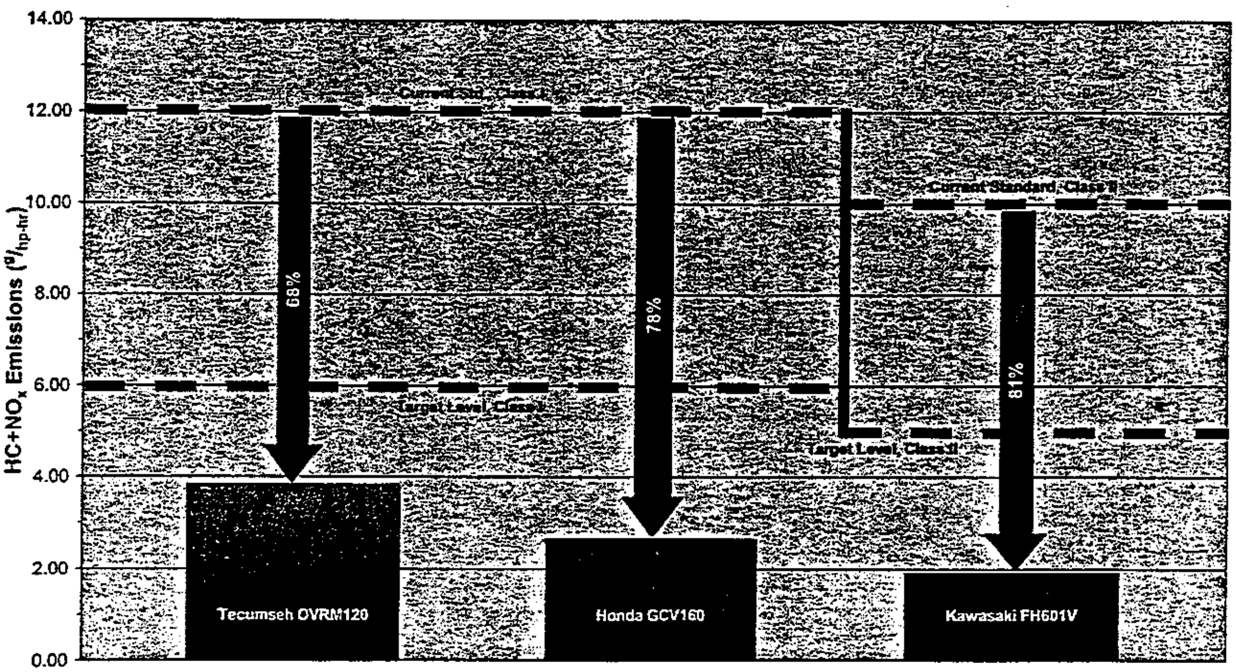

FIGURE 29. DEVELOPED ENGINE EMISSIONS AT 250 HOURS

Emissions were reduced from the first Briggs and Stratton engine using a three-way catalyst, a passive SAI system, and enleanment. The engine was removed from the program after 125 hours due to engine deterioration. Overall emission reductions at 125 hours were poor, primarily due to a large increase in engine-out emissions. In spite of the engine deterioration, the catalyst held up well, reducing engine-out $HC+NO_x$ emissions at 125 hours by 58%, and CO emissions by 59%. While the engine may have been deteriorated by the somewhat leaner calibration employed, there were already indications of engine problems at zero hours, prior to beginning durability. A second Briggs and Stratton engine is being developed with no change to base engine calibration in an attempt to meet the low emissions goal.

The Tecumseh OVRM120 engine successfully completed 250 hours of durability. The developed, low emissions configuration included a three-way catalyst and a passive SAI system. The stock engine air/fuel calibration was not altered. At 250 hours, emissions were reduced by 50% for $HC+NO_x$, 42% for HC, 78% for NO_x, and 30% for CO, as compared to 0-hour baseline emissions. Catalyst performance at 250 hours was 64% for $HC+NO_x$, 61% for HC, 78% for NO_x, and 40% for CO.

The Honda GCV160 engine successfully completed 250 hours of durability. The developed, low emissions configuration included a three-way catalyst and a passive SAI system. As was the case with the Tecumseh engine, the stock engine calibration was not changed. At 250 hours, $HC+NO_x$ emissions were reduced by 70%, HC by 65%, NO_x by 83%, and CO by 74%, as compared to 0-hour baseline emissions. Catalyst performance held up well with 250 hour conversions of 77% for $HC+NO_x$, 57% for HC, 93% for NO_x, and 48% for CO.

To date, the Kawasaki FH601V engine has been tested at 250 hours and is currently being aged to 500 hours. The developed configuration includes a three-way catalyst, passive SAI system, and enleanment. At 250 hours, $HC+NO_x$ emissions were reduced by 74%, HC by 67%, NO_x by 94%, and CO by 67%, as compared to 0-hour baseline emissions. Catalyst percent conversions at 250 hours were 75% for $HC+NO_x$, 73% for HC, 89% for NO_x, and 71% for CO.

Overall reductions in $HC+NO_x$ emissions for the Tecumseh, Honda, and Kawasaki engines, as compared to 0-hour baseline emissions, are shown in Figure 30. Catalyst performance on the three engines is shown in Figure 31, which summarizes percent $HC+NO_x$ conversions at test intervals.

It should be kept in mind that these are prototype systems, developed for the purpose of a demonstration. They are by no means optimized for size or cost. Catalysts were conservatively chosen in order to meet program goals. Solutions employing smaller and less expensive catalysts can likely achieve similar performance with additional development.

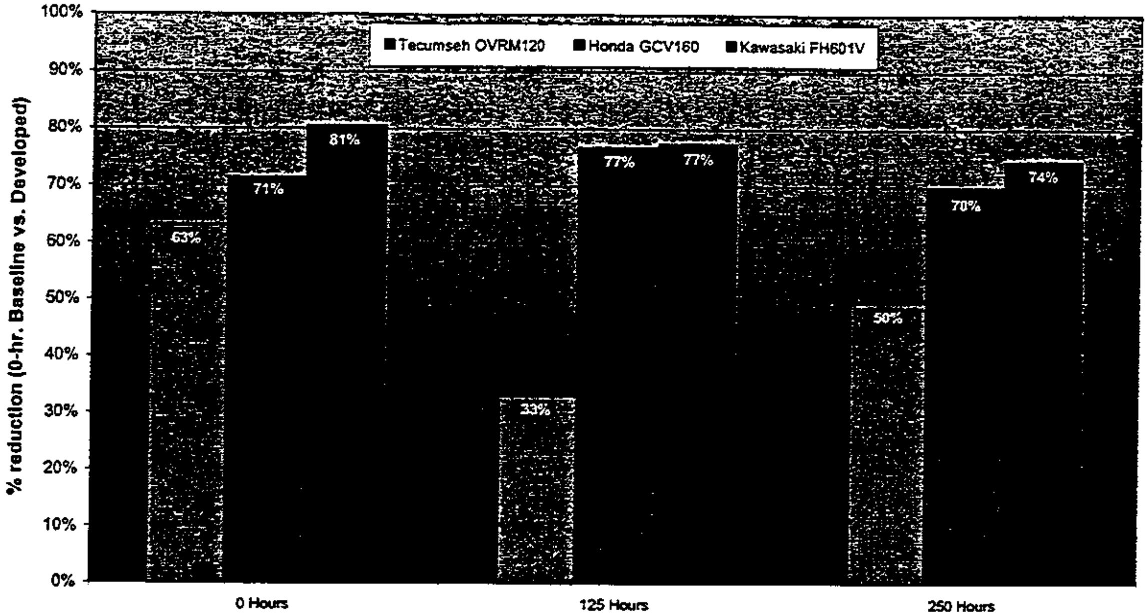

FIGURE 30. EMISSION REDUCTIONS COMPARED TO 0-HOUR BASELINE RESULTS

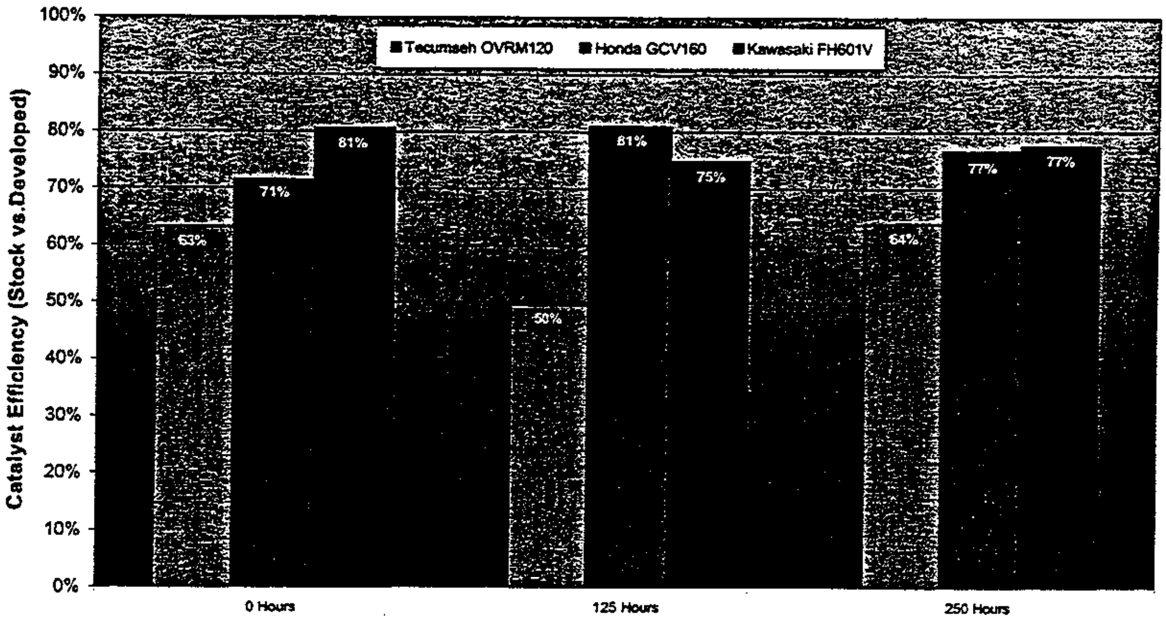

FIGURE 31. CATALYST HC+NO_x PERCENT CONVERSION VS. DURABILITY HOURS

APPENDIX A

BRIGGS AND STRATTON INTEK NO. 1 EMISSION DATA SHEETS

Steady-State SORE Engine Test Information **Engine: B+S #1 6.5HP**

Date: 10/23/02

Test ID: B+S #1 BSLN5

Baseline emissions test with "lighter" governor spring and stock jetting

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
Obs. Speed	rpm		3041	3062	3060	3063	3019	
Obs. Power	hp		4.24	3.27	[illegible]	1.08	0.42	
Obs. Torque	ft-lb		7.23	5.53	3.67	1.82	[illegible]	
Calc. Power (Obs. Torque*Speed)	hp		4.19	3.22	2.14	1.06	0.42	
Work (5 min Interval)	hp-hr		0.354	0.272	0.181	0.090	0.035	
Fuel Flow	lb/hr		2.846	2.428	1.925	1.333	1.080	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		254	268	244	210	190	
Exhaust Gas (muffler-in/manifold)	deg F		1259	1251	1252	1225	1216	
Exhaust Gas (muffler out)	deg F		766	663	546	406	336	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		79	79	78	77	76	
Intake Air DewPoint (EPA)	deg F		61	61	61	61	62	
Cyl Head (Spark Plug)	deg F		449	427	387	330	302	
PRESSURES								
Exhaust BP Before Cat	psig		0.77	0.56	0.35	0.15	0.08	
Barometer	"Hg		29.098	29.096	29.094	29.092	29.095	
F Factor	—		1.027	1.027	1.027	1.025	1.024	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		145.85	131.55	116.55	118.11	120.41	
Dilute CO conc (dry)	%		0.39	0.32	0.24	0.17	0.13	
Dilute CO_2 conc (dry)	%		0.58	0.51	0.42	0.29	0.24	
Dilute NO_x conc (dry)	ppm		18.07	16.72	10.06	3.50	2.16	
Measured A/F	—		11.90	12.05	12.16	11.79	11.83	
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	
NO_x Humidity Correction	—		1.04	1.04	1.04	1.04	1.05	
Raw O_2 conc $(dry)_{measured}$	%		-0.01	0.20	0.18	0.25	0.35	
HC Mass	g/hr		19.38	17.45	15.61	15.97	16.41	
NO_x Mass	g/hr		8.16	7.56	4.60	1.60	1.00	
CO Mass	g/hr		1022.0	843.7	631.7	454.9	363.7	
CO_2 Mass	g/hr		2269	1978	1621	1079	871	
BSHC	g/hp-hr		4.48	5.33	7.19	14.79	37.99	
$BSNO_x$	g/hp-hr		1.89	2.31	2.12	1.48	2.31	
BSCO	g/hp-hr		236.22	257.72	290.95	421.17	842.23	
$BSCO_2$	g/hp-hr		524.55	604.10	746.69	999.53	2017.47	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**7.88**	**2.06**	**9.94**	**303.5**	**729.4**	**0.890**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: B+S #1 6.5HP**

Date: 10/23/02

Test ID: B+S #1 BSLN6

Baseline emissions test with "lighter" governor spring and stock jetting (methane test)

DESCRIPTION	UNIT						
Mode	—		1	2	3	4	5
Weight Factor	—		0.09	0.21	0.31	0.32	0.07
DF Mode Interval (sec)	—		300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85
Load Set	%Rated		100	75	50	25	10
ENGINE DATA							
Obs. Speed	rpm		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Obs. Power	hp		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Obs. Torque	ft-lb		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calc. Power (Obs. Torque*Speed)	hp		4.26	3.21	2.13	1.11	0.41
Work (5 min Interval)	hp-hr		0.360	0.271	0.180	0.094	0.035
Fuel Flow	lb/hr		2.875	2.467	1.856	1.389	1.097
TEMPERATURES							
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA
Oil	deg F		239	259	234	203	192
Exhaust Gas (muffler-in/manifold)	deg F		1264	1250	1258	1237	1223
Exhaust Gas (muffler out)	deg F		767	651	537	412	337
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		76	77	76	75	75
Intake Air DewPoint (EPA)	deg F		62	61	61	61	61
Cyl Head (Spark Plug)	deg F		442	419	380	328	302
PRESSURES							
Exhaust BP Before Cat	psig		0.74	0.53	0.31	0.14	0.06
Barometer	"Hg		29.129	29.124	29.123	29.117	29.109
F Factor	—		1.022	1.023	1.022	1.021	1.021
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**				
Dilute HC conc (wet)	ppm		158.40	148.42	112.35	118.65	121.63
Dilute CO conc (dry)	%		0.40	0.32	0.22	0.17	0.14
Dilute CO_2 conc (dry)	%		0.58	0.51	0.41	0.30	0.24
Dilute NO_x conc (dry)	ppm		17.29	15.23	9.49	3.56	1.79
Measured A/F	—		11.84	11.97	12.22	11.80	11.81
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.05	1.04	1.04	1.04	1.03
Raw O_2 conc $(dry)_{measured}$	%		0.25	0.34	0.27	0.31	0.34
HC Mass	g/hr		20.90	19.73	14.90	15.92	16.42
NO_x Mass	g/hr		7.87	7.04	4.35	1.63	0.81
CO Mass	g/hr		1043.7	862.1	594.9	472.5	376.8
CO_2 Mass	g/hr		2270	1996	1585	1128	874
BSHC	g/hp-hr		4.77	6.07	6.94	14.27	39.11
$BSNO_x$	g/hp-hr		1.80	2.17	2.02	1.46	1.92
BSCO	g/hp-hr		238.42	265.20	276.87	423.51	897.49
$BSCO_2$	g/hp-hr		518.57	613.95	737.82	1011.51	2082.50

Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**8.04**	**1.96**	**10.00**	**303.4**	**732.1**	**0.892**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information **Engine: B&S#1 6.5hp**

Date: 11/22/02

Test ID: B&S #1 BSLN-JET#2

Baseline Test with Fixed Jet #2 (.027 in) and STOCK muffler

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		120	120	120	120	120	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.39	2.58	1.71	0.85	0.34	
Work (5 min Interval)	hp-hr		0.114	0.087	0.058	0.029	0.012	
Fuel Flow	lb/hr		2.417	2.015	1.475	1.146	0.969	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		276	280	247	223	203	
Exhaust Gas (muffler-in/manifold)	deg F		1309	1264	1221	1181	1204	
Exhaust Gas (muffler out)	deg F		844	698	536	430	389	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		88	90	90	89	87	
Intake Air DewPoint (EPA)	deg F		36	36	35	35	35	
Cyl Head (Spark Plug)	deg F		475	435	383	339	319	
PRESSURES								
Exhaust BP Before Cat	psig		0.60	0.39	0.25	0.17	0.14	
Barometer	"Hg		29.370	29.375	29.377	29.377	29.375	
F Factor	—		1.018	1.021	1.020	1.018	1.016	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		138.45	155.84	133.87	107.99	96.10	
Dilute CO conc (dry)	%		0.22	0.18	0.13	0.11	0.09	
Dilute CO_2 conc (dry)	%		0.61	0.51	0.38	0.29	0.25	
Dilute NO_x conc (dry)	ppm		53.83	39.11	17.96	4.81	2.29	
Measured A/F	—		13.08	13.11	13.00	12.71	12.77	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.83	0.83	0.83	0.83	0.83	
Raw O_2 conc $(dry)_{measured}$	%		NA	NA	NA	NA	NA	
HC Mass	g/hr		18.20	20.82	18.04	14.55	13.00	
NO_x Mass	g/hr		19.56	14.41	6.65	1.75	0.81	
CO Mass	g/hr		583.6	473.5	344.2	304.9	258.3	
CO_2 Mass	g/hr		2412	2014	1469	1081	911	
BSHC	g/hp-hr		5.26	8.01	10.37	16.84	37.36	
$BSNO_x$	g/hp-hr		5.66	5.55	3.82	2.03	2.33	
BSCO	g/hp-hr		168.69	182.26	197.81	352.85	742.14	
$BSCO_2$	g/hp-hr		697.30	775.23	844.34	1250.81	2618.58	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**10.26**	**4.46**	**14.73**	**223.8**	**899.7**	**0.916**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: B&S#1**

Date: 11/27/02

Test ID: B+S #1 CAT-C-STCK-JET

Catalyst C integrated in stock muffler, 4-hole Venturi and Check Valve SAI, with STOCK Carburetor Jet

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
Obs. Speed	rpm		3056	3066	3052	3057	3061	
Obs. Power	hp		3.48	2.65	1.76	0.88	0.36	
Obs. Torque	ft-lb		5.90	4.48	2.98	1.48	0.61	
Calc. Power (Obs. Torque*Speed)	hp		3.43	2.61	1.73	0.86	0.36	
Work (5 min Interval)	hp-hr		0.290	0.221	0.146	0.073	0.030	
Fuel Flow	lb/hr		0.000	0.000	0.000	0.000	0.000	
TEMPERATURES								
Catalyst Mid-bed	deg F		1267	1242	1215	1207	1229	
Oil	deg F		307	287	238	210	195	
Exhaust Gas (muffler-in/manifold)	deg F		972	897	797	748	758	
Exhaust Gas (muffler out)	deg F		831	729	615	545	511	
Catalyst/Muffler Surface	deg F		758	710	647	612	599	
Intake Air (EPA)	deg F		93	95	94	91	89	
Intake Air DewPoint (EPA)	deg F		24	25	24	25	25	
Cyl Head (Spark Plug)	deg F		473	435	373	325	309	
PRESSURES								
Exhaust BP Before Cat	psig		1.02	0.67	0.38	0.27	0.23	
Barometer	"Hg		29.445	29.439	29.423	29.436	29.435	
F Factor	—		1.019	1.022	1.020	1.016	1.014	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		126.59	107.84	80.20	74.42	57.11	
Dilute CO conc (dry)	%		0.25	0.19	0.12	0.11	0.07	
Dilute CO_2 conc (dry)	%		0.64	0.52	0.40	0.32	0.29	
Dilute NO_x conc (dry)	ppm		3.24	1.79	0.62	0.17	0.15	
Measured A/F	—		12.57	12.62	12.56	11.88	12.27	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.79	0.80	0.79	0.79	0.80	
Raw O_2 conc $(dry)_{measured}$	%		0.94	1.10	1.38	1.70	1.90	
HC Mass	g/hr		16.75	14.33	10.69	9.99	7.58	
NO_x Mass	g/hr		1.10	0.61	0.20	0.04	0.03	
CO Mass	g/hr		672.1	504.7	341.9	318.2	215.8	
CO_2 Mass	g/hr		2537	2052	1574	1206	1081	
BSHC	g/hp-hr		4.81	5.41	6.09	11.41	20.87	
$BSNO_x$	g/hp-hr		0.32	0.23	0.11	0.05	0.09	
BSCO	g/hp-hr		193.05	190.49	194.76	363.21	593.79	
$BSCO_2$	g/hp-hr		728.63	774.61	896.61	1376.80	2973.92	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.80**	**0.18**	**6.98**	**229.1**	**946.4**	**0.948**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: B+S #1

Date: 11/27/02

Test ID: B+S #1 CAT-C-BSLN3

657

Catalyst C integrated in muffler, Jet #2 (0.027 in.), 4-hole Venturi with Check Valve SAI

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.54	2.71	1.79	0.89	0.36	
Work (5 min interval)	hp-hr		0.299	0.229	0.151	0.075	0.031	
Fuel Flow	lb/hr		2.388	1.934	1.499	1.179	0.893	
TEMPERATURES								
Catalyst Mid-bed	deg F		1308	1299	1300	1316	1314	
Oil	deg F		304	276	238	205	192	
Exhaust Gas (muffler-in/manifold)	deg F		1100	1037	967	888	896	
Exhaust Gas (muffler out)	deg F		857	756	668	597	510	
Catalyst/Muffler Surface	deg F		771	718	672	634	614	
Intake Air (EPA)	deg F		85	82	82	77	77	
Intake Air DewPoint (EPA)	deg F		23	24	23	23	24	
Cyl Head (Spark Plug)	deg F		483	435	379	330	311	
PRESSURES								
Exhaust BP Before Cat	psig		0.87	0.50	0.31	0.20	0.15	
Barometer	"Hg		29.523	29.550	29.548	29.555	29.555	
F Factor	—		1.006	1.000	1.001	0.993	0.994	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		75.08	59.52	42.95	41.93	12.81	
Dilute CO conc (dry)	%		0.11	0.08	0.05	0.04	0.00	
Dilute CO_2 conc (dry)	%		0.71	0.59	0.47	0.37	0.32	
Dilute NO_x conc (dry)	ppm		6.54	3.86	1.42	0.56	1.08	
Measured A/F	—		13.63	13.72	13.59	13.31	14.26	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.79	0.79	0.79	0.79	0.79	
Raw O_2 conc $(dry)_{measured}$	%		0.98	1.26	1.59	2.20	2.65	
HC Mass	g/hr		9.78	7.77	5.56	5.49	1.42	
NO_x Mass	g/hr		2.24	1.33	0.47	0.16	0.35	
CO Mass	g/hr		303.5	206.0	137.4	115.9	5.4	
CO_2 Mass	g/hr		2837	2361	1867	1453	1238	
BSHC	g/hp-hr		2.70	2.84	3.07	6.11	3.81	
$BSNO_x$	g/hp-hr		0.62	0.49	0.26	0.18	0.95	
BSCO	g/hp-hr		83.77	75.30	75.87	128.81	14.47	
$BSCO_2$	g/hp-hr		783.10	862.77	1030.60	1614.86	3329.66	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.48**	**0.40**	**3.88**	**86.1**	**1075.0**	**0.872**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: B&S#1

Date: 11/27/02

Test ID: B+S #1 CAT-C-BSLN4

Catalyst C integrated in muffler, Jet #2 (0.027 in.), 4-hole Venturi with Check Valve SAI

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]					
[redacted]	hp	[redacted]	[redacted]					
[redacted]	ft-lb	[redacted]	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp		3.43	2.67	1.77	0.90	0.36	
Work (5 min Interval)	hp-hr		0.290	0.226	0.150	0.076	0.030	
Fuel Flow	lb/hr		2.393	2.016	1.518	1.159	0.858	
TEMPERATURES								
Catalyst Mid-bed	deg F		1310	1305	1299	1289	1328	
Oil	deg F		307	288	243	204	194	
Exhaust Gas (muffler-in/manifold)	deg F		1099	1038	967	879	897	
Exhaust Gas (muffler out)	deg F		855	764	665	564	502	
Catalyst/Muffler Surface	deg F		770	724	671	624	614	
Intake Air (EPA)	deg F		83	84	80	83	82	
Intake Air DewPoint (EPA)	deg F		24	25	24	23	23	
[redacted]	deg F	[redacted]	[redacted]					
PRESSURES								
Exhaust BP Before Cat	psig		0.87	0.53	0.31	0.19	0.15	
Barometer	"Hg		29.476	29.455	29.458	29.459	29.453	
F Factor	—		1.004	1.006	1.002	1.005	1.004	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
[redacted]	ppm	[redacted]	[redacted]					
[redacted]	%	[redacted]	[redacted]					
[redacted]	%	[redacted]	[redacted]					
[redacted]	ppm	[redacted]	[redacted]					
Measured A/F	—		13.63	13.66	13.56	13.28	14.19	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.79	0.79	0.79	0.79	0.79	
Raw O_2 conc (dry)$_{measured}$	%		1.05	1.27	1.62	2.05	2.43	
HC Mass	g/hr		9.97	9.37	6.63	5.21	1.61	
NO_x Mass	g/hr		2.44	1.93	0.76	0.25	0.33	
CO Mass	g/hr		310.6	235.9	156.3	128.8	0.0	
CO_2 Mass	g/hr		2833	2425	1861	1405	1197	
BSHC	g/hp-hr		2.79	3.46	3.68	5.71	4.48	
$BSNO_x$	g/hp-hr		0.68	0.71	0.42	0.28	0.93	
BSCO	g/hp-hr		86.87	86.99	86.81	141.26	0.00	
$BSCO_2$	g/hp-hr		792.16	894.04	1033.72	1540.23	3322.61	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.85**	**0.55**	**4.40**	**96.0**	**1076.4**	**0.885**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: B+S#1 6.5 hp

Date: 2/6/03

Test ID: B+S#1-125-#1

125-hr. interval emissions testing with orig SAI check valve, fixed jet #2 (0.027in.), and catalyst C

DESCRIPTION	UNIT					
Mode	—	1	2	3	4	5
Weight Factor	—	0.09	0.21	0.31	0.32	0.07
DF Mode Interval (sec)	—	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85
Load Set	%Rated	100	75	50	25	10
ENGINE DATA						
Obs. Speed	rpm	3055	3062	3062	[illegible]	[illegible]
Obs. Power	hp	3.16	2.39	[illegible]	[illegible]	[illegible]
Obs. Torque	ft-lb	5.36	[illegible]	2.66	[illegible]	[illegible]
Calc. Power (Obs. Torque*Speed)	hp	3.12	2.36	1.55	0.75	0.31
Work (5 min Interval)	hp-hr	0.263	0.200	0.131	0.064	0.026
Fuel Flow	lb/hr	2.231	1.803	1.464	1.129	0.943
TEMPERATURES						
Catalyst Mid-bed	deg F	1353	1355	1295	1273	1273
Oil	deg F	253	228	208	185	177
Exhaust Gas (muffler-in/manifold)	deg F	1042	998	928	883	867
Exhaust Gas (muffler out)	deg F	835	788	694	615	578
Catalyst/Muffler Surface	deg F	769	733	677	634	613
Intake Air (EPA)	deg F	81	80	78	76	76
Intake Air DewPoint (EPA)	deg F	48	47	45	44	44
Cyl Head (Spark Plug)	deg F	450	406	358	321	305
PRESSURES						
Exhaust BP Before Cat	psig	—	—	—	—	—
Barometer	"Hg	29.032	29.037	29.044	29.048	29.041
F Factor	—	1.025	1.023	1.019	1.016	1.016
GASEOUS EMISSIONS		*EMISSIONS ARE UNWEIGHTED[1] (ETIS)*				
Dilute HC conc (wet)	ppm	137.13	102.36	98.40	62.09	34.50
Dilute CO conc (dry)	%	0.15	0.10	0.09	0.06	0.04
Dilute CO_2 conc (dry)	%	0.63	0.54	0.43	0.35	0.31
Dilute NO_x conc (dry)	ppm	11.71	6.05	2.51	0.88	0.44
Measured A/F	—	13.42	13.54	13.29	13.37	13.43
Dry/Wet Correction	—	0.98	0.98	0.99	0.99	0.99
NO_x Humidity Correction	—	0.90	0.89	0.88	0.87	0.87
Raw O_2 conc $(dry)_{measured}$	%	1.31	1.57	1.77	1.93	2.10
HC Mass	g/hr	17.61	13.10	12.68	7.86	4.14
NO_x Mass	g/hr	4.54	2.33	0.94	0.30	0.13
CO Mass	g/hr	399.1	253.2	236.7	155.3	101.0
CO_2 Mass	g/hr	2444	2087	1639	1313	1150
BSHC	g/hp-hr	5.56	5.49	8.01	10.24	13.29
$BSNO_x$	g/hp-hr	1.43	0.98	0.59	0.39	0.41
BSCO	g/hp-hr	126.03	106.04	149.49	202.26	323.94
$BSCO_2$	g/hp-hr	771.57	874.16	1035.14	1710.02	3685.58

Emission Test Results	—	HC	NO_x	HC+NO_x	CO	CO_2	BSFC (lb/hp-hr)
Weighted Specific Emissions[3]	g/hp-hr	7.27	0.85	8.12	144.0	1094.5	0.959

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: B+S#1 6.5 hp**

Date: 2/6/03

Test ID: B+S #1-125-#2

125-hr. interval emissions testing with replacement SAI check valve, fixed jet #2 (0.027in.), and catalyst C

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[illegible]	rpm		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	hp		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	ft-lb		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Calc. Power (Obs. Torque*Speed)	hp		3.21	2.39	1.60	0.83	0.32	
Work (5 min Interval)	hp-hr		0.271	0.202	0.135	0.070	0.027	
Fuel Flow	lb/hr		2.291	1.876	1.461	1.185	0.958	
TEMPERATURES								
Catalyst Mid-bed	deg F		1325	1317	1272	1260	1251	
Oil	deg F		247	224	197	182	173	
Exhaust Gas (muffler-in/manifold)	deg F		1045	998	922	878	860	
Exhaust Gas (muffler out)	deg F		820	767	679	615	566	
Catalyst/Muffler Surface	deg F		763	726	666	634	608	
Intake Air (EPA)	deg F		78	76	75	74	73	
Intake Air DewPoint (EPA)	deg F		49	49	49	49	49	
Cyl Head (Spark Plug)	deg F		447	401	351	316	299	
PRESSURES								
Exhaust BP Before Cat	psig		—	—	—	—	—	
Barometer	"Hg		29.042	29.051	29.065	29.068	29.068	
F Factor	—		1.021	1.018	1.016	1.014	1.013	
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		143.71	107.49	96.18	68.20	40.75	
Dilute CO conc (dry)	%		0.16	0.10	0.09	0.06	0.04	
Dilute CO_2 conc (dry)	%		0.64	0.54	0.43	0.37	0.32	
Dilute NO_x conc (dry)	ppm		13.23	6.80	2.61	0.92	0.61	
Measured A/F	—		13.42	13.51	13.32	13.33	13.48	
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	
NO_x Humidity Correction	—		0.91	0.91	0.90	0.90	0.91	
Raw O_2 conc $(dry)_{measured}$	%		1.19	1.42	1.61	1.85	1.96	
HC Mass	g/hr		18.94	14.51	12.58	8.86	5.17	
NO_x Mass	g/hr		5.24	2.75	1.00	0.32	0.20	
CO Mass	g/hr		412.6	277.7	244.7	163.4	99.8	
CO_2 Mass	g/hr		2502	2147	1623	1376	1169	
BSHC	g/hp-hr		5.82	5.93	7.77	10.55	15.95	
$BSNO_x$	g/hp-hr		1.61	1.12	0.62	0.38	0.61	
BSCO	g/hp-hr		126.86	113.38	151.15	194.56	308.22	
$BSCO_2$	g/hp-hr		769.26	876.68	1002.37	1638.98	3609.19	
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**7.51**	**0.94**	**8.45**	**146.2**	**1078.5**	**0.950**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: B+S#1 6.5 hp

Date: 2/7/03

Test ID: B+S#1-125-BSLN

Fixed Jet #2 (0.027 in.) and stock muffler, tested after 125-hr. service accumulation

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
Obs. Speed	rpm		3058	3061	3058	3062	3046	
Obs. Power	hp		3.18	2.41	1.59	0.79	[illegible]	
Obs. Torque	ft-lb		5.39	4.07	2.70	1.33	0.53	
Calc. Power (Obs. Torque*Speed)	hp		3.14	2.37	1.57	0.78	0.31	
Work (5 min interval)	hp-hr		0.265	0.201	0.133	0.066	0.026	
Fuel Flow	lb/hr		2.309	1.886	1.509	1.125	1.057	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		244	229	201	179	173	
Exhaust Gas (muffler-in/manifold)	deg F		1287	1256	1221	1224	1234	
Exhaust Gas (muffler out)	deg F		777	683	563	467	420	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		77	81	77	71	77	
Intake Air DewPoint (EPA)	deg F		30	30	30	30	29	
Cyl Head (Spark Plug)	deg F		440	405	355	314	302	
PRESSURES								
Exhaust BP Before Cat	psig		—	—	—	—	—	
Barometer	"Hg		29.461	29.453	29.444	29.451	29.449	
F Factor	—		0.998	1.004	0.999	0.991	0.999	
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		244.53	228.89	198.03	126.25	104.38	
Dilute CO conc (dry)	%		0.20	0.16	0.13	0.10	0.10	
Dilute CO_2 conc (dry)	%		0.58	0.48	0.38	0.29	0.27	
Dilute NO_x conc (dry)	ppm		57.68	37.84	16.57	4.94	2.91	
Measured A/F	—		13.20	13.17	13.00	12.92	12.82	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.81	0.81	0.81	0.81	0.81	
Raw O_2 conc $(dry)_{measured}$	%		0.57	0.63	0.66	0.55	0.55	
HC Mass	g/hr		32.59	30.53	26.66	17.04	14.02	
NO_x Mass	g/hr		20.86	13.75	6.04	1.76	1.01	
CO Mass	g/hr		532.3	427.7	364.0	284.6	284.6	
CO_2 Mass	g/hr		2297	1875	1459	1076	990	
BSHC	g/hp-hr		10.25	12.72	16.70	21.52	43.29	
$BSNO_x$	g/hp-hr		6.56	5.73	3.78	2.23	3.12	
BSCO	g/hp-hr		167.32	178.19	228.02	359.36	878.58	
$BSCO_2$	g/hp-hr		722.17	781.24	913.56	1358.23	3055.16	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp-hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**15.63**	**4.73**	**20.35**	**235.0**	**952.9**	**0.978**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: B+S#1 6.5 hp

Date: 2/7/03

Test ID: B+S#1-125-STK-BSLN

Stock fixed jet and muffler, tested after 125-hr. service accumulation

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.21	2.44	1.61	0.82	0.32	
Work (5 min Interval)	hp-hr		0.271	0.206	0.136	0.070	0.027	
Fuel Flow	lb/hr		2.506	2.066	1.631	1.339	1.176	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		224	208	184	169	163	
Exhaust Gas (muffler-in/manifold)	deg F		1242	1210	1176	1180	1198	
Exhaust Gas (muffler out)	deg F		755	658	539	456	408	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		71	69	67	68	70	
Intake Air DewPoint (EPA)	deg F		30	29	29	30	30	
Cyl Head (Spark Plug)	deg F		411	376	332	301	286	
PRESSURES								
Exhaust BP Before Cat	psig		—	—	—	—	—	
Barometer	"Hg		29.445	29.426	29.424	29.425	29.431	
F Factor	—		0.991	0.989	0.986	0.988	0.990	
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		282.83	258.24	215.57	166.37	142.72	
Dilute CO conc (dry)	%		0.30	0.25	0.20	0.16	0.15	
Dilute CO_2 conc (dry)	%		0.53	0.44	0.35	0.29	0.25	
Dilute NO_x conc (dry)	ppm		24.49	16.91	8.30	3.43	2.12	
Measured A/F	—		12.32	12.30	12.16	11.94	11.75	
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	
NO_x Humidity Correction	—		0.81	0.81	0.81	0.81	0.81	
Raw O_2 conc $(dry)_{measured}$	%		0.56	0.60	0.58	0.55	0.54	
HC Mass	g/hr		37.32	34.27	28.70	22.08	18.82	
NO_x Mass	g/hr		8.91	6.19	3.07	1.28	0.79	
CO Mass	g/hr		827.3	679.6	544.1	459.4	429.9	
CO_2 Mass	g/hr		2094	1720	1341	1085	914	
BSHC	g/hp-hr		11.31	13.94	17.37	26.29	58.09	
$BSNO_x$	g/hp-hr		2.70	2.52	1.86	1.53	2.45	
BSCO	g/hp-hr		250.77	276.33	329.24	547.04	1326.80	
$BSCO_2$	g/hp-hr		634.81	699.56	811.26	1292.21	2819.68	
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**17.46**	**2.21**	**19.67**	**353.1**	**863.4**	**1.051**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

APPENDIX B

BRIGGS AND STRATTON INTEK NO. 2 EMISSION DATA SHEETS

Steady-State SORE Engine Test Information Engine: B+S#2 6.5HP
Date: 10/21/02
Test ID: B+S #2 BSLN1

Baseline emissions test with "lighter" governor spring and stock jetting

DESCRIPTION	UNIT						
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA							
Obs. Speed	rpm		3050	3065	3058	3053	3079	
Obs. Power	hp		4.31	3.27	2.17	1.08	0.43	
Obs. Torque	ft-lb		7.32	5.52	3.68	1.84	0.73	
Calc. Power (Obs. Torque*Speed)	hp		4.25	3.22	2.14	1.07	0.43	
Work (5 min Interval)	hp-hr		0.359	0.272	0.181	0.090	0.036	
Fuel Flow	lb/hr		2.857	2.357	1.865	1.501	1.214	
TEMPERATURES							
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		245	250	231	208	190	
Exhaust Gas (muffler-in/manifold)	deg F		1320	1312	1339	1326	1344	
Exhaust Gas (muffler out)	deg F		825	722	628	486	399	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		74	74	73	72	71	
Intake Air DewPoint (EPA)	deg F		60	60	60	60	60	
Cyl.Head (Spark Plug)	deg F		431	411	372	329	303	
PRESSURES							
Exhaust BP Before Cat	psig		0.88	0.64	0.44	0.25	0.15	
Barometer	"Hg		29.048	29.036	29.038	29.040	29.035	
F Factor	—		1.021	1.022	1.020	1.019	1.018	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		110.67	113.92	94.84	109.35	119.43	
Dilute CO conc (dry)	%		0.41	0.32	0.24	0.21	0.16	
Dilute CO_2 conc (dry)	%		0.57	0.49	0.40	0.31	0.26	
Dilute NO_x conc (dry)	ppm		13.99	12.05	6.87	3.15	1.88	
Measured A/F	—		12.50	12.55	12.61	12.44	12.54	
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	
NO_x Humidity Correction	—		1.02	1.02	1.02	1.02	1.02	
Raw O_2 conc $(dry)_{measured}$	%		0.30	0.20	0.20	0.20	0.50	
HC Mass	g/hr		14.52	15.01	12.55	14.64	16.24	
NO_x Mass	g/hr		6.13	5.36	3.03	1.39	0.82	
CO Mass	g/hr		1075.6	844.2	646.2	559.7	434.4	
CO_2 Mass	g/hr		2215	1886	1524	1150	947	
BSHC	g/hp-hr		3.35	4.58	5.74	13.56	37.58	
$BSNO_x$	g/hp-hr		1.42	1.64	1.39	1.29	1.89	
BSCO	g/hp-hr		248.45	257.79	295.77	518.23	1005.65	
$BSCO_2$	g/hp-hr		511.75	575.96	697.66	1065.13	2191.40	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.75**	**1.48**	**8.23**	**325.6**	**715.3**	**0.903**

1 Emissions results are based on bag sample emissions through ETIS
2 Raw emissions are calculated using the dilution factor and dilute concentrations
3 Based on the 5-mode CARB Generator Test Cycle
SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: B+S#2 6.5HP**

Date: 10/22/02

Test ID: B+S #2 BSLN2

Baseline emissions testing with "lighter" governor spring and stock jetting

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		4.24	3.19	2.12	1.06	0.42	
Work (5 min Interval)	hp-hr		0.358	0.270	0.179	0.090	0.036	
Fuel Flow	lb/hr		2.819	2.396	1.929	1.485	1.110	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		260	256	228	208	193	
Exhaust Gas (muffler-in/manifold)	deg F		1333	1316	1350	1332	1341	
Exhaust Gas (muffler out)	deg F		825	727	626	488	397	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		78	78	72	74	74	
Intake Air DewPoint (EPA)	deg F		61	64	61	62	60	
Cyl Head (Spark Plug)	deg F		441	418	373	331	306	
PRESSURES								
Exhaust BP Before Cat	psig		0.64	0.54	0.38	0.21	0.12	
Barometer	"Hg		29.125	29.116	29.112	29.105	29.096	
F Factor	—		1.025	1.028	1.018	1.020	1.021	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		104.37	115.08	94.23	106.69	104.15	
Dilute CO conc (dry)	%		0.40	0.33	0.24	0.20	0.15	
Dilute CO_2 conc (dry)	%		0.57	0.50	0.42	0.31	0.24	
Dilute NO_x conc (dry)	ppm		14.85	12.29	7.65	3.06	1.86	
Measured A/F	—		12.33	12.44	12.57	12.53	12.69	
Dry/Wet Correction	—		0.98	0.97	0.98	0.98	0.98	
NO_x Humidity Correction	—		1.04	1.08	1.04	1.05	1.03	
Raw O_2 conc $(dry)_{measured}$	%		0.10	0.10	0.10	0.20	0.60	
HC Mass	g/hr		13.62	15.08	12.49	14.31	14.01	
NO_x Mass	g/hr		6.58	5.69	3.50	1.39	0.83	
CO Mass	g/hr		1042.2	853.7	638.8	537.0	396.8	
CO_2 Mass	g/hr		2218	1925	1624	1165	868	
BSHC	g/hp-hr		3.16	4.67	5.79	13.17	32.43	
$BSNO_x$	g/hp-hr		1.53	1.76	1.62	1.28	1.91	
BSCO	g/hp-hr		241.99	264.56	295.92	494.22	918.40	
$BSCO_2$	g/hp-hr		515.11	596.42	752.58	1072.06	2008.62	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.64**	**1.62**	**8.26**	**322.1**	**740.1**	**0.916**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: B+S#2 6.5HP**

Date: 10/22/02

Test ID: B+S #2 BSLN3

667

Baseline emissions test with "lighter" governor spring and stock jetting (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	
Weight Factor	—		0.09	0.21	0.31	0.32	0.07	
DF Mode Interval (sec)	—		300	300	300	300	300	
Speed Set	%Rated		85	85	85	85	85	
Load Set	%Rated		100	75	50	25	10	
ENGINE DATA								
Obs. Speed	rpm		3064	3051	3053	3079	3070	
Obs. Power	hp		4.35	3.24	2.18	1.09	0.45	
Obs. Torque	ft-lb		7.36	5.51	3.70	1.84	0.77	
Calc. Power (Obs. Torque*Speed)	hp		4.29	3.20	2.15	1.08	0.45	
Work (5 min Interval)	hp-hr		0.363	0.270	0.182	0.091	0.038	
Fuel Flow	lb/hr		2.850	2.430	1.863	1.438	1.121	
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	
Oil	deg F		244	246	225	201	188	
Exhaust Gas (muffler-in/manifold)	deg F		1317	1297	1325	1305	1309	
Exhaust Gas (muffler out)	deg F		830	713	626	490	403	
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	
Intake Air (EPA)	deg F		74	75	73	73	72	
Intake Air DewPoint (EPA)	deg F		62	62	62	62	62	
Cyl Head (Spark Plug)	deg F		436	413	375	331	306	
PRESSURES								
Exhaust BP Before Cat	psig		0.85	0.60	0.38	0.21	0.11	
Barometer	"Hg		29.097	29.129	29.125	29.121	29.120	
F Factor	—		1.022	1.021	1.019	1.019	1.018	
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		103.80	104.67	84.30	97.20	105.28	
Dilute CO conc (dry)	%		0.39	0.32	0.23	0.19	0.15	
Dilute CO_2 conc (dry)	%		0.58	0.51	0.41	0.30	0.24	
Dilute NO_x conc (dry)	ppm		14.95	13.28	7.33	3.13	1.78	
Measured A/F	—		12.38	12.29	12.49	12.57	12.69	
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	
NO_x Humidity Correction	—		1.05	1.06	1.05	1.05	1.05	
Raw O_2 conc $(dry)_{measured}$	%		NA	NA	NA	NA	NA	
HC Mass	g/hr		13.70	13.88	11.17	13.08	14.24	
NO_x Mass	g/hr		6.88	6.23	3.40	1.45	0.81	
CO Mass	g/hr		1033.9	842.9	610.2	523.8	405.7	
CO_2 Mass	g/hr		2274	1993	1582	1125	869	
BSHC	g/hp-hr		3.14	4.27	5.11	11.97	32.09	
$BSNO_x$	g/hp-hr		1.58	1.92	1.56	1.33	1.83	
BSCO	g/hp-hr		237.13	259.29	279.03	479.63	914.30	
$BSCO_2$	g/hp-hr		521.55	612.92	723.40	1030.32	1957.83	
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.08**	**1.67**	**7.75**	**311.6**	**729.8**	**0.896**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 5-mode CARB Generator Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

APPENDIX C

TECUMSEH OVRM120 EMISSION DATA SHEETS

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 12/26/02

Test ID: TEC2 BSLN #1

671

Baseline testing of Tecumseh engine #2 with Carb. sent on engine from Tecumseh (w/methane analysis)

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp	3.26	2.50	1.66	0.82	0.33	0.06
Work (5 min Interval)	hp-hr	0.275	0.211	0.140	0.069	0.028	0.005
Fuel Flow	lb/hr	2.539	2.174	1.658	1.292	1.070	0.801
TEMPERATURES							
Catalyst Mid-bed	deg F	NA	NA	NA	NA	NA	NA
Oil	deg F	317	288	262	242	238	216
Exhaust Gas (muffler-in/manifold)	deg F	1251	1123	1060	1036	1054	786
Exhaust Gas (muffler out)	deg F	NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F	NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F	72	71	70	70	70	69
Intake Air DewPoint (EPA)	deg F	36	36	37	37	38	38
Cyl Head (Spark Plug)	deg F	522	459	417	388	385	340
PRESSURES							
Exhaust BP Before Cat	psig	1.73	1.24	0.89	0.65	0.55	0.26
Barometer	"Hg	29.425	29.417	29.418	29.414	29.406	29.398
F Factor	—	0.995	0.994	0.993	0.994	0.994	0.993
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	80.59	83.28	68.91	54.97	35.03	52.54
Dilute CO conc (dry)	%	0.28	0.30	0.21	0.14	0.07	0.10
Dilute CO_2 conc (dry)	%	0.61	0.46	0.37	0.32	0.32	0.20
Dilute NO_x conc (dry)	ppm	26.67	8.76	5.11	3.22	2.72	1.18
Measured A/F	—	12.71	11.86	12.10	12.58	13.52	12.10
Dry/Wet Correction	—	0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—	0.83	0.83	0.83	0.84	0.84	0.84
Raw O_2 conc $(dry)_{measured}$	%	0.12	0.13	0.13	0.12	0.12	0.44
HC Mass	g/hr	10.42	10.90	9.05	7.18	4.48	6.96
NO_x Mass	g/hr	9.51	3.17	1.87	1.18	1.00	0.42
CO Mass	g/hr	733.7	792.0	568.7	379.5	182.8	274.1
CO_2 Mass	g/hr	2372	1767	1400	1192	1197	670
BSHC	g/hp-hr	3.11	4.31	5.39	8.55	13.32	—
$BSNO_x$	g/hp-hr	2.83	1.25	1.11	1.40	2.97	—
BSCO	g/hp-hr	218.58	312.92	338.49	451.60	543.99	—
$BSCO_2$	g/hp-hr	706.61	698.11	833.46	1418.23	3562.51	—

Emission Test Results	—	HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**5.45**	**1.58**	**7.02**	**337.1**	**921.5**	**1.048**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**
Date: 12/27/02
Test ID: TEC2 BSLN #2

Baseline testing of Tecumseh engine #2 with Carb. sent on engine from Tecumseh

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.33	2.52	1.68	0.82	0.33	0.07
Work (5 min Interval)	hp-hr		0.281	0.213	0.142	0.069	0.028	0.006
Fuel Flow	lb/hr		2.585	2.179	1.748	1.268	1.096	0.772
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		310	291	264	244	238	205
Exhaust Gas (muffler-in/manifold)	deg F		1257	1128	1079	1038	1064	755
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		73	70	68	70	70	68
Intake Air DewPoint (EPA)	deg F		45	45	45	44	44	43
Cyl Head (Spark Plug)	deg F		512	460	414	382	381	335
PRESSURES								
Exhaust BP Before Cat	psig		1.75	1.27	0.94	0.66	0.58	0.29
Barometer	"Hg		29.511	29.509	29.508	29.505	29.502	29.497
F Factor	—		0.996	0.993	0.990	0.993	0.993	0.989
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		89.70	84.42	87.18	57.17	35.31	64.57
Dilute CO conc (dry)	%		0.27	0.30	0.23	0.14	0.06	0.11
Dilute CO_2 conc (dry)	%		0.64	0.46	0.38	0.31	0.33	0.17
Dilute NO_x conc (dry)	ppm		28.90	8.31	4.97	2.97	2.72	0.94
Measured A/F	—		12.78	11.83	12.00	12.55	13.59	11.25
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.88	0.88	0.88	0.87	0.87	0.86
Raw O_2 conc $(dry)_{measured}$	%		0.13	0.13	0.13	0.14	0.14	0.42
HC Mass	g/hr		11.54	11.01	11.49	7.46	4.45	8.61
NO_x Mass	g/hr		10.93	3.16	1.91	1.14	1.05	0.34
CO Mass	g/hr		698.6	793.4	613.6	376.8	174.7	312.4
CO_2 Mass	g/hr		2487	1772	1448	1161	1248	565
BSHC	g/hp-hr		3.41	4.33	6.79	8.89	13.26	—
$BSNO_x$	g/hp-hr		3.23	1.24	1.13	1.36	3.13	—
BSCO	g/hp-hr		206.45	312.06	362.64	448.69	519.86	—
$BSCO_2$	g/hp-hr		734.86	696.91	855.84	1382.11	3712.90	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.05**	**1.65**	**7.70**	**342.2**	**925.7**	**1.058**

1 Emissions results are based on bag sample emissions through ETIS
2 Raw emissions are calculated using the dilution factor and dilute concentrations
3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 12/30/02

Test ID: TEC2 BSLN #3

Baseline testing of Tecumseh engine #2 with Carb. sent on engine from Tecumseh

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]					
[redacted]	hp	[redacted]	[redacted]					
[redacted]	ft-lb	[redacted]	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp		3.00	2.26	1.50	0.75	0.29	0.01
Work (5 min Interval)	hp-hr		0.253	0.191	0.127	0.063	0.025	0.001
Fuel Flow	lb/hr		2.527	2.186	1.616	1.301	1.059	0.772
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		314	285	270	253	245	214
Exhaust Gas (muffler-in/manifold)	deg F		1230	1114	1060	1037	1036	780
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		80	80	81	80	79	77
Intake Air DewPoint (EPA)	deg F		63	63	64	63	63	62
Cyl. Head (Spark Plug)	deg F		505	450	418	392	383	345
PRESSURES								
Exhaust BP Before Cat	psig		1.73	1.28	0.95	0.73	0.64	0.37
Barometer	"Hg		28.801	28.759	28.745	28.740	28.744	28.743
F Factor	—		1.040	1.043	1.044	1.042	1.041	1.039
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		93.31	94.06	72.44	60.62	43.87	65.80
Dilute CO conc (dry)	%		0.32	0.34	0.23	0.16	0.09	0.11
Dilute CO_2 conc (dry)	%		0.60	0.45	0.36	0.32	0.31	0.18
Dilute NO_x conc (dry)	ppm		16.01	6.05	3.97	2.82	2.24	0.94
Measured A/F	—		12.31	11.42	11.77	12.39	13.26	11.45
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.08	1.08	1.09	1.07	1.07	1.07
Raw O_2 conc (dry)$_{measured}$	%		0.12	0.13	0.13	0.13	0.13	0.33
HC Mass	g/hr		11.65	11.91	9.15	7.65	5.42	8.44
NO_x Mass	g/hr		7.14	2.75	1.81	1.27	1.01	0.41
CO Mass	g/hr		810.7	870.4	593.4	413.0	228.2	302.7
CO_2 Mass	g/hr		2229	1657	1303	1149	1108	579
BSHC	g/hp-hr		3.84	5.24	6.00	10.12	18.09	—
$BSNO_x$	g/hp-hr		2.35	1.21	1.19	1.68	3.37	—
BSCO	g/hp-hr		267.42	382.91	389.48	546.52	760.88	—
$BSCO_2$	g/hp-hr		735.42	729.05	855.00	1520.36	3693.65	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.48**	**1.54**	**8.02**	**405.2**	**960.5**	**1.155**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 1/7/03

Test ID: TEC2-C-DEV1

Testing of Tecumseh engine #2 with Carb. sent on engine from Tecumseh w/Catalyst C

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.69	2.78	1.85	0.92	0.37	0.07
Work (5 min Interval)	hp-hr		0.312	0.235	0.157	0.078	0.031	0.006
Fuel Flow	lb/hr		2.554	2.165	1.758	1.331	1.056	0.799
TEMPERATURES								
Catalyst Mid-bed	deg F		1289	1119	1050	1009	1012	807
Oil	deg F		304	273	257	241	231	215
Exhaust Gas (muffler-in/manifold)	deg F		1315	1195	1193	1217	1273	1003
Exhaust Gas (muffler out)	deg F		842	686	596	515	450	410
Catalyst/Muffler Surface	deg F		765	675	647	625	591	605
Intake Air (EPA)	deg F		71	71	71	71	70	75
Intake Air DewPoint (EPA)	deg F		38	39	39	39	38	38
Cyl Head (Spark Plug)	deg F		504	445	405	375	366	328
PRESSURES								
Exhaust BP Before Cat	psig		0.84	0.59	0.45	0.35	0.31	0.22
Barometer	"Hg		29.528	29.518	29.517	29.516	29.517	29.511
F Factor	—		0.991	0.991	0.991	0.991	0.990	0.997
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		60.62	66.61	50.09	35.10	20.07	46.36
Dilute CO conc (dry)	%		0.16	0.20	0.15	0.08	0.03	0.08
Dilute CO_2 conc (dry)	%		0.72	0.54	0.46	0.39	0.35	0.21
Dilute NO_x conc (dry)	ppm		9.73	2.68	1.75	1.12	0.86	0.68
Measured A/F	—		13.34	12.44	12.51	12.91	13.62	11.03
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.84	0.84	0.84	0.84	0.84	0.84
Raw O_2 conc (dry)$_{measured}$	%		0.16	0.14	0.12	0.12	0.12	0.24
HC Mass	g/hr		7.79	8.72	6.52	4.47	2.39	6.10
NO_x Mass	g/hr		3.47	0.87	0.53	0.29	0.19	0.12
CO Mass	g/hr		426.5	549.5	401.4	214.3	81.2	226.7
CO_2 Mass	g/hr		2883	2142	1812	1514	1344	744
BSHC	g/hp-hr		2.08	3.09	3.46	4.78	6.43	—
$BSNO_x$	g/hp-hr		0.93	0.31	0.28	0.31	0.52	—
BSCO	g/hp-hr		113.90	194.85	213.04	228.99	218.19	—
$BSCO_2$	g/hp-hr		769.96	759.63	961.83	1617.36	3612.07	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.51**	**0.43**	**3.93**	**197.2**	**1025.4**	**0.961**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 1/14/03

Test ID: TEC2-C-BSLN1m

LE Developed Baseline Test #1 (Stock Jetting, Catalyst C, and Modified 4-hole Venturi SAI) with methane analysis

DESCRIPTION	UNIT		1	2	3	4	5	6
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3065	3066	3057	3068	3066	2471
Obs. Power	hp		3.58	2.73	1.79	0.90	0.36	-0.02
Obs. Torque	ft-lb		6.06	4.62	3.04	1.52	0.62	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.53	2.70	1.77	0.89	0.36	-0.02
Work (5 min Interval)	hp-hr		0.299	0.228	0.150	0.075	0.030	-0.002
Fuel Flow	lb/hr		2.512	2.077	1.656	1.262	1.081	0.782
TEMPERATURES								
Catalyst Mid-bed	deg F		1366	1280	1242	1236	1237	1128
Oil	deg F		298	277	253	237	231	194
Exhaust Gas (muffler-in/manifold)	deg F		1215	1118	1068	1042	1048	812
Exhaust Gas (muffler out)	deg F		964	831	740	664	601	482
Catalyst/Muffler Surface	deg F		789	758	734	712	694	603
Intake Air (EPA)	deg F		65	65	65	65	65	65
Intake Air DewPoint (EPA)	deg F		42	42	42	42	42	42
Cyl Head (Spark Plug)	deg F		506	451	405	376	370	317
PRESSURES								
Exhaust BP Before Cat	psig		1.68	1.45	1.31	1.22	1.18	1.10
Barometer	"Hg		29.493	29.484	29.485	29.478	29.485	29.476
F Factor	—		0.986	0.985	0.986	0.986	0.986	0.986
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		54.83	48.80	39.44	24.67	15.24	33.44
Dilute CO conc (dry)	%		0.21	0.18	0.13	0.06	0.02	0.05
Dilute CO_2 conc (dry)	%		0.65	0.53	0.44	0.38	0.36	0.23
Dilute NO_x conc (dry)	ppm		4.30	1.50	0.63	0.33	0.37	0.20
Measured A/F	—		13.02	12.82	12.80	13.33	13.94	12.56
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.86	0.86	0.86	0.86	0.86	0.86
Raw O_2 conc $(dry)_{measured}$	%		0.52	0.67	0.81	0.94	1.00	1.70
HC Mass	g/hr		7.11	6.35	5.10	3.06	1.73	4.35
NO_x Mass	g/hr		1.62	0.55	0.22	0.10	0.12	0.05
CO Mass	g/hr		561.2	486.1	350.4	162.1	56.0	155.2
CO_2 Mass	g/hr		2615	2125	1753	1504	1421	838
BSHC	g/hp-hr		1.97	2.35	2.83	3.43	4.80	—
$BSNO_x$	g/hp-hr		0.45	0.20	0.12	0.11	0.32	—
BSCO	g/hp-hr		155.88	179.97	194.69	181.73	155.60	—
$BSCO_2$	g/hp-hr		726.40	786.81	974.14	1686.45	3947.18	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**2.77**	**0.21**	**2.98**	**184.4**	**1049.2**	**0.962**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 1/14/03

Test ID: TEC2-C-BSLN2m

LE Developed Baseline Test #2 (Stock Jetting, Catalyst C, and Modified 4-hole Venturi SAI)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3093	[illegible]	3053	3051	[illegible]	2509
[illegible]	hp		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ft-lb		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calc. Power (Obs. Torque*Speed)	hp		3.54	2.64	1.75	0.88	0.35	-0.03
Work (5 min Interval)	hp-hr		0.299	0.223	0.148	0.074	0.030	-0.003
Fuel Flow	lb/hr		2.627	2.047	1.623	1.241	1.094	0.752
TEMPERATURES								
Catalyst Mid-bed	deg F		1368	1286	1253	1252	1222	1168
Oil	deg F		302	281	261	244	239	213
Exhaust Gas (muffler-in/manifold)	deg F		1223	1128	1084	1068	1095	851
Exhaust Gas (muffler out)	deg F		963	829	737	656	550	492
Catalyst/Muffler Surface	deg F		810	769	742	719	668	624
Intake Air (EPA)	deg F		71	71	72	71	72	71
Intake Air DewPoint (EPA)	deg F		42	42	41	42	41	42
Cyl Head (Spark Plug)	deg F		509	451	414	386	383	334
PRESSURES								
Exhaust BP Before Cat	psig		1.71	1.47	1.34	1.25	1.21	1.13
Barometer	"Hg		29.398	29.393	29.391	29.390	29.395	29.391
F Factor	—		0.996	0.996	0.998	0.996	0.998	0.996
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		54.65	46.08	32.64	19.39	10.15	23.60
Dilute CO conc (dry)	%		0.22	0.17	0.10	0.03	0.01	0.03
Dilute CO_2 conc (dry)	%		0.69	0.54	0.47	0.41	0.39	0.25
Dilute NO_x conc (dry)	ppm		4.90	1.61	0.85	0.57	2.11	0.26
Measured A/F	—		13.02	12.88	13.22	13.86	14.57	13.14
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.86	0.86	0.86	0.86	0.86	0.86
Raw O_2 conc (dry)$_{measured}$	%		0.50	0.71	0.83	0.97	0.95	1.76
HC Mass	g/hr		6.93	5.83	4.03	2.22	0.94	2.82
NO_x Mass	g/hr		1.82	0.59	0.31	0.20	0.80	0.08
CO Mass	g/hr		588.3	460.0	267.2	88.3	13.7	96.1
CO_2 Mass	g/hr		2734	2126	1841	1593	1508	893
BSHC	g/hp-hr		1.95	2.18	2.27	2.50	2.61	—
$BSNO_x$	g/hp-hr		0.51	0.22	0.17	0.23	2.22	—
BSCO	g/hp-hr		165.63	171.85	150.48	99.42	38.06	—
$BSCO_2$	g/hp-hr		769.71	794.06	1036.84	1793.58	4187.76	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**2.31**	**0.30**	**2.60**	**153.3**	**1103.2**	**0.965**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 3/18/03

Test ID: TEC2-125-#1

125-hour interval emission test "as-received" from durability with catalyst C, and passive SAI system. Test run prior to scheduled maintenance.

DESCRIPTION	UNIT		1	2	3	4	5	6
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3042	[illegible]	3055	3055	3062	2530
Obs. Power	hp		3.36	2.52	1.69	0.85	0.32	0.00
Obs. Torque	ft-lb		5.73	[illegible]	2.87	[illegible]	0.55	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.32	2.49	1.67	0.84	0.32	0.00
Work (5 min Interval)	hp-hr		0.280	0.210	0.141	0.071	0.027	0.000
Fuel Flow	lb/hr		2.489	2.134	1.742	1.377	1.222	0.833
TEMPERATURES								
Catalyst Mid-bed	deg F		1380	1314	1286	1274	1248	1174
Oil	deg F		333	303	280	260	251	220
Exhaust Gas (muffler-in/manifold)	deg F		1183	1092	1047	1021	997	845
Exhaust Gas (muffler out)	deg F		969	839	744	648	561	468
Catalyst/Muffler Surface	deg F		812	667	635	601	570	499
Intake Air (EPA)	deg F		76	71	70	69	69	68
Intake Air DewPoint (EPA)	deg F		52	51	49	49	50	51
Cyl Head (Spark Plug)	deg F		521	470	433	404	385	355
PRESSURES								
Exhaust BP Before Cat	psig		0.13	0.12	0.07	0.03	0.01	-0.02
Barometer	"Hg		28.675	28.662	28.663	28.659	28.655	28.678
F Factor	—		1.032	1.027	1.024	1.023	1.023	1.022
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		94.71	79.86	57.72	40.65	30.44	31.31
Dilute CO conc (dry)	%		0.22	0.23	0.17	0.10	0.06	0.05
Dilute CO_2 conc (dry)	%		0.66	0.51	0.44	0.39	0.38	0.25
Dilute NO_x conc (dry)	ppm		5.84	1.24	0.65	0.38	0.49	0.20
Measured A/F	—		13.10	12.48	12.67	13.10	13.64	13.03
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		0.94	0.93	0.91	0.91	0.92	0.92
Raw O_2 conc $(dry)_{measured}$	%		0.61	0.72	0.90	1.04	1.20	1.80
HC Mass	g/hr		11.92	10.08	7.18	4.90	3.53	3.69
NO_x Mass	g/hr		2.33	0.48	0.24	0.13	0.17	0.05
CO Mass	g/hr		565.9	623.8	454.7	266.1	151.8	144.0
CO_2 Mass	g/hr		2560	1978	1703	1496	1463	929
BSHC	g/hp-hr		3.51	3.98	4.24	5.71	10.91	—
$BSNO_x$	g/hp-hr		0.69	0.19	0.14	0.15	0.54	—
BSCO	g/hp-hr		166.70	246.55	268.75	310.22	468.50	—
$BSCO_2$	g/hp-hr		754.17	781.54	1006.65	1744.00	4514.68	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.47**	**0.27**	**4.74**	**256.1**	**1085.4**	**1.072**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Tecumseh OVRM120 #2

Date: 3/19/03

Test ID: TEC2-125-#2

125-hour interval emission test with catalyst C, and passive SAI system. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.17	2.37	1.59	0.79	0.33	0.00
Work (5 min Interval)	hp-hr		0.268	0.200	0.135	0.067	0.027	0.000
Fuel Flow	lb/hr		2.467	2.114	1.656	1.278	1.106	0.763
TEMPERATURES								
Catalyst Mid-bed	deg F		1410	1352	1327	1273	1273	1237
Oil	deg F		337	329	315	292	273	250
Exhaust Gas (muffler-in/manifold)	deg F		1195	1116	1084	1005	999	868
Exhaust Gas (muffler out)	deg F		980	884	790	690	628	536
Catalyst/Muffler Surface	deg F		840	790	765	727	708	666
Intake Air (EPA)	deg F		88	89	88	84	83	81
Intake Air DewPoint (EPA)	deg F		36	34	35	33	33	33
Cyl Head (Spark Plug)	deg F		548	508	477	427	407	371
PRESSURES								
Exhaust BP Before Cat	psig		0.15	0.10	0.06	0.03	0.02	-0.01
Barometer	"Hg		28.679	28.673	28.677	28.678	28.678	28.678
F Factor	—		1.042	1.044	1.042	1.036	1.034	1.033
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		101.76	95.44	52.60	38.05	25.06	23.36
Dilute CO conc (dry)	%		0.22	0.23	0.13	0.10	0.05	0.05
Dilute CO_2 conc (dry)	%		0.65	0.51	0.45	0.35	0.34	0.23
Dilute NO_x conc (dry)	ppm		10.53	2.65	1.17	0.41	0.50	0.18
Measured A/F	—		13.24	12.72	13.25	12.95	13.52	12.92
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.83	0.83	0.83	0.82	0.82	0.82
Raw O_2 conc $(dry)_{measured}$	%		0.63	0.83	0.90	1.16	1.27	1.83
HC Mass	g/hr		12.77	12.10	6.55	4.68	2.96	2.77
NO_x Mass	g/hr		3.78	0.95	0.42	0.14	0.17	0.06
CO Mass	g/hr		559.5	596.1	349.4	277.2	148.3	137.8
CO_2 Mass	g/hr		2537	1987	1750	1340	1307	844
BSHC	g/hp-hr		3.98	5.02	4.04	5.82	9.15	—
$BSNO_x$	g/hp-hr		1.18	0.39	0.26	0.17	0.54	—
BSCO	g/hp-hr		174.54	247.13	215.52	344.92	457.94	—
$BSCO_2$	g/hp-hr		791.40	823.75	1079.31	1667.13	4036.05	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.80**	**0.47**	**5.27**	**246.8**	**1108.9**	**1.079**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2** 679

Date: 3/20/03

Test ID: TEC2-125-#3

125-hour interval emission test with catalyst C, and passive SAI system. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	----		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3059	3058	3074	3081	3050	2485
Obs. Power	hp		3.18	2.40	1.60	0.80	0.33	0.00
Obs. Torque	ft-lb		5.39	4.06	2.71	1.35	0.56	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.14	2.37	1.58	0.79	0.32	0.00
Work (5 min Interval)	hp-hr		0.265	0.200	0.134	0.067	0.027	0.000
Fuel Flow	lb/hr		2.412	2.136	1.719	1.248	1.040	0.788
TEMPERATURES								
Catalyst Mid-bed	deg F		1421	1337	1314	1270	1277	1242
Oil	deg F		326	331	312	287	270	251
Exhaust Gas (muffler-in/manifold)	deg F		1202	1101	1065	1003	1010	869
Exhaust Gas (muffler out)	deg F		985	868	779	687	622	529
Catalyst/Muffler Surface	deg F		844	776	754	721	705	675
Intake Air (EPA)	deg F		87	95	92	87	81	77
Intake Air DewPoint (EPA)	deg F		43	43	44	44	45	43
Cyl Head (Spark Plug)	deg F		543	501	469	426	410	376
PRESSURES								
Exhaust BP Before Cat	psig		0.10	0.04	0.01	-0.02	-0.03	-0.06
Barometer	"Hg		28.977	28.987	28.990	28.993	28.993	28.996
F Factor	—		1.033	1.043	1.039	1.032	1.025	1.019
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		83.49	90.71	61.63	35.78	18.34	25.85
Dilute CO conc (dry)	%		0.19	0.24	0.15	0.09	0.04	0.06
Dilute CO_2 conc (dry)	%		0.66	0.50	0.45	0.35	0.34	0.24
Dilute NO_x conc (dry)	ppm		9.38	1.82	1.02	0.33	0.32	0.24
Measured A/F	—		13.36	12.49	13.02	12.97	13.77	12.78
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.87	0.87	0.87	0.87	0.88	0.87
Raw O_2 conc $(dry)_{measured}$	%		0.65	0.83	0.95	1.13	1.26	1.85
HC Mass	g/hr		10.52	11.71	7.92	4.49	2.12	3.18
NO_x Mass	g/hr		3.51	0.69	0.39	0.12	0.12	0.09
CO Mass	g/hr		492.2	647.3	406.1	256.0	100.9	153.4
CO_2 Mass	g/hr		2572	1939	1745	1332	1292	853
BSHC	g/hp-hr		3.28	4.88	4.93	5.59	6.80	—
$BSNO_x$	g/hp-hr		1.10	0.29	0.24	0.15	0.38	—
BSCO	g/hp-hr		153.68	269.73	252.58	318.35	323.35	—
$BSCO_2$	g/hp-hr		802.96	807.76	1084.94	1657.21	4142.14	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.84**	**0.41**	**5.25**	**255.8**	**1107.0**	**1.088**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 3/19/03

Test ID: TEC2-125-STK-#1

125-hour interval emission test "as-received" from durability with stock muffler. Test run prior to scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.11	2.38	1.55	0.79	0.32	0.00
Work (5 min Interval)	hp-hr		0.263	0.201	0.131	0.067	0.027	0.000
Fuel Flow	lb/hr		2.515	2.166	1.697	1.205	1.010	0.757
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		347	342	327	311	299	277
Exhaust Gas (muffler-in/manifold)	deg F		1207	1138	1090	1048	1044	829
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		83	83	84	83	84	83
Intake Air DewPoint (EPA)	deg F		38	37	39	38	38	37
Cyl Head (Spark Plug)	deg F		523	487	455	429	416	373
PRESSURES								
Exhaust BP Before Cat	psig		0.49	0.33	0.22	0.13	0.10	0.02
Barometer	"Hg		28.761	28.762	28.761	28.765	28.762	28.763
F Factor	—		1.033	1.033	1.035	1.033	1.035	1.033
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		129.31	125.15	105.05	63.54	53.77	68.28
Dilute CO conc (dry)	%		0.31	0.33	0.23	0.13	0.07	0.11
Dilute CO_2 conc (dry)	%		0.57	0.43	0.36	0.30	0.29	0.17
Dilute NO_x conc (dry)	ppm		19.55	7.18	4.90	3.23	2.55	1.04
Measured A/F	—		12.79	11.60	11.92	12.72	13.46	11.89
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.84	0.84	0.85	0.84	0.84	0.84
Raw O_2 conc $(dry)_{measured}$	%		0.24	0.30	0.30	0.30	0.43	0.79
HC Mass	g/hr		16.52	16.07	13.58	8.15	6.88	8.95
NO_x Mass	g/hr		6.99	2.44	1.66	1.04	0.80	0.22
CO Mass	g/hr		804.0	859.9	620.5	349.6	199.6	292.4
CO_2 Mass	g/hr		2208	1633	1360	1113	1080	573
BSHC	g/hp-hr		5.16	6.73	8.57	10.14	21.24	—
$BSNO_x$	g/hp-hr		2.18	1.02	1.05	1.29	2.47	—
BSCO	g/hp-hr		250.97	360.23	391.74	435.03	616.16	—
$BSCO_2$	g/hp-hr		689.11	683.97	858.54	1384.28	3334.21	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**8.07**	**1.33**	**9.40**	**374.6**	**911.9**	**1.089**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 3/19/03

Test ID: TEC2-125-STK-#2

125-hour interval emission test with stock muffler. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3059	3042	3066	3076	3060	2542
Obs. Power	hp		2.96	2.22	1.48	0.75	0.29	0.00
Obs. Torque	ft-lb		5.01	3.78	2.50	1.27	0.49	0.00
Calc. Power (Obs. Torque*Speed)	hp		2.92	2.19	1.46	0.74	0.28	0.00
Work (5 min Interval)	hp-hr		0.247	0.185	0.123	0.063	0.024	0.000
Fuel Flow	lb/hr		2.366	2.060	1.656	1.280	1.052	0.796
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		347	333	310	294	269	248
Exhaust Gas (muffler-in/manifold)	deg F		1209	1111	1062	1035	978	845
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		88	84	81	81	80	80
Intake Air DewPoint (EPA)	deg F		33	33	34	33	32	33
Cyl Head (Spark Plug)	deg F		535	486	454	426	396	375
PRESSURES								
Exhaust BP Before Cat	psig		0.48	0.31	0.23	0.16	0.10	0.03
Barometer	"Hg		28.734	28.729	28.732	28.719	28.713	28.712
F Factor	—		1.040	1.034	1.031	1.030	1.029	1.029
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		142.87	139.09	99.34	77.41	60.87	57.83
Dilute CO conc (dry)	%		0.30	0.32	0.22	0.15	0.11	0.11
Dilute CO_2 conc (dry)	%		0.53	0.39	0.35	0.30	0.26	0.18
Dilute NO_x conc (dry)	ppm		20.26	6.62	5.00	3.15	2.10	1.14
Measured A/F	—		12.39	11.50	11.97	12.46	12.68	11.92
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.82	0.82	0.82	0.82	0.82	0.82
Raw O_2 conc $(dry)_{measured}$	%		0.33	0.43	0.23	0.22	0.24	0.45
HC Mass	g/hr		18.17	18.01	12.85	10.00	7.87	7.52
NO_x Mass	g/hr		7.18	2.38	1.83	1.16	0.78	0.42
CO Mass	g/hr		771.0	850.8	602.6	403.7	307.2	296.6
CO_2 Mass	g/hr		2046	1493	1333	1128	967	626
BSHC	g/hp-hr		6.06	8.07	8.63	13.45	27.31	—
$BSNO_x$	g/hp-hr		2.39	1.07	1.23	1.55	2.69	—
BSCO	g/hp-hr		256.99	381.17	404.99	542.76	1066.59	—
$BSCO_2$	g/hp-hr		682.08	668.77	895.76	1516.53	3355.97	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**9.27**	**1.49**	**10.76**	**411.0**	**939.2**	**1.152**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Tecumseh OVRM120 #2

Date: 4/21/03

Test ID: TEC2-250-#1

250-hour interval emission test with catalyst C, and passive SAI system. Test run before scheduled maintenance.

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp	3.27	2.43	1.64	0.80	0.32	0.00
Work (5 min Interval)	hp-hr	0.276	0.205	0.138	0.067	0.027	0.000
Fuel Flow	lb/hr	2.368	2.030	1.676	1.331	1.075	0.778
TEMPERATURES							
Catalyst Mid-bed	deg F	1423	1335	1317	1303	1293	1211
Oil	deg F	303	272	252	239	230	214
Exhaust Gas (muffler-in/manifold)	deg F	1208	1111	1074	1048	1041	903
Exhaust Gas (muffler out)	deg F	954	827	748	694	627	520
Catalyst/Muffler Surface	deg F	882	812	787	776	752	685
Intake Air (EPA)	deg F	79	79	79	79	78	77
Intake Air DewPoint (EPA)	deg F	50	50	50	50	50	50
Cyl Head (Spark Plug)	deg F	539	476	442	415	398	364
PRESSURES							
Exhaust BP Before Cat	psig	0.48	0.33	0.23	0.16	0.12	0.05
Barometer	"Hg	29.230	29.197	29.181	29.169	29.165	29.168
F Factor	—	1.016	1.017	1.018	1.018	1.017	1.016
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	65.47	61.58	42.03	28.69	16.85	19.02
Dilute CO conc (dry)	%	0.16	0.21	0.15	0.09	0.04	0.04
Dilute CO_2 conc (dry)	%	0.65	0.49	0.43	0.37	0.34	0.25
Dilute NO_x conc (dry)	ppm	8.10	1.16	0.69	0.40	0.30	0.24
Measured A/F	—	13.50	12.68	12.88	13.04	13.61	13.27
Dry/Wet Correction	—	0.98	0.98	0.98	0.98	0.98	0.99
NO_x Humidity Correction	—	0.91	0.91	0.92	0.92	0.91	0.92
Raw O_2 conc (dry)$_{measured}$	%	0.67	0.81	0.92	1.00	1.07	1.51
HC Mass	g/hr	8.35	7.89	5.27	3.44	1.81	2.12
NO_x Mass	g/hr	3.26	0.45	0.26	0.14	0.10	0.07
CO Mass	g/hr	435.2	556.1	399.3	255.6	110.4	96.0
CO_2 Mass	g/hr	2607	1946	1703	1451	1327	932
BSHC	g/hp-hr	2.52	3.19	3.18	4.16	5.58	—
$BSNO_x$	g/hp-hr	0.98	0.18	0.16	0.17	0.30	—
BSCO	g/hp-hr	131.45	224.87	241.30	308.74	340.96	—
$BSCO_2$	g/hp-hr	787.36	786.86	1029.27	1753.50	4096.04	—
Emission Test Results	—	HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	3.32	0.33	3.65	230.3	1096.7	1.049

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

683

Date: 4/21/03

Test ID: TEC2-250-#2

250-hour interval emission test with catalyst C, and passive SAI system. Test run before scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3070	3067	3065	3054	3046	2535
Obs. Power	hp		3.30	2.46	1.62	0.81	0.30	0.00
Obs. Torque	ft-lb		5.57	4.15	2.74	1.37	0.51	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.26	2.42	1.60	0.80	0.30	0.00
Work (5 min Interval)	hp-hr		0.275	0.205	0.135	0.067	0.025	0.000
Fuel Flow	lb/hr		2.327	2.092	1.721	1.378	1.018	0.774
TEMPERATURES								
Catalyst Mid-bed	deg F		1426	1338	1318	1300	1287	1212
Oil	deg F		307	279	255	239	231	215
Exhaust Gas (muffler-in/manifold)	deg F		1208	1111	1073	1041	1030	897
Exhaust Gas (muffler out)	deg F		957	833	753	701	623	520
Catalyst/Muffler Surface	deg F		885	812	785	776	748	681
Intake Air (EPA)	deg F		82	82	81	80	80	80
Intake Air DewPoint (EPA)	deg F		52	52	52	52	52	52
Cyl Head (Spark Plug)	deg F		543	482	444	414	398	364
PRESSURES								
Exhaust BP Before Cat	psig		0.47	0.32	0.23	0.16	0.11	0.04
Barometer	"Hg		29.161	29.161	29.145	29.139	29.133	29.100
F Factor	—		1.024	1.023	1.023	1.022	1.022	1.023
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		59.48	64.77	45.29	33.96	16.11	18.44
Dilute CO conc (dry)	%		0.16	0.21	0.16	0.11	0.04	0.04
Dilute CO_2 conc (dry)	%		0.65	0.51	0.44	0.37	0.33	0.25
Dilute NO_x conc (dry)	ppm		7.36	1.42	0.71	0.41	0.29	0.21
Measured A/F	—		13.50	12.69	12.78	12.76	13.60	13.20
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		0.93	0.93	0.93	0.93	0.93	0.94
Raw O_2 conc $(dry)_{measured}$	%		0.68	0.80	0.90	0.98	1.05	1.51
HC Mass	g/hr		7.45	8.27	5.66	4.13	1.67	2.01
NO_x Mass	g/hr		2.97	0.53	0.23	0.11	0.06	0.02
CO Mass	g/hr		425.2	570.6	426.4	311.3	101.8	99.5
CO_2 Mass	g/hr		2568	2007	1724	1428	1261	921
BSHC	g/hp-hr		2.28	3.38	3.45	5.06	5.56	—
$BSNO_x$	g/hp-hr		0.91	0.21	0.14	0.13	0.19	—
BSCO	g/hp-hr		129.80	233.09	259.45	381.63	339.28	—
$BSCO_2$	g/hp-hr		783.84	819.99	1048.78	1750.62	4201.72	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.55**	**0.31**	**3.86**	**249.9**	**1110.3**	**1.081**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 4/22/03

Test ID: TEC2-250-STK-#1

250-hour interval emission test with stock muffler and stock jetting. Test run before scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		2.97	2.20	1.48	0.74	0.32	0.00
Work (5 min Interval)	hp-hr		0.251	0.186	0.125	0.063	0.027	0.000
Fuel Flow	lb/hr		2.448	2.196	1.722	1.496	1.201	0.779
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		300	275	257	242	231	216
Exhaust Gas (muffler-in/manifold)	deg F		1246	1166	1144	1090	1063	895
Exhaust Gas (muffler out)	deg F		916	759	655	556	490	351
Catalyst/Muffler Surface	deg F		871	793	738	657	607	478
Intake Air (EPA)	deg F		79	79	78	76	76	75
Intake Air DewPoint (EPA)	deg F		62	62	63	62	62	61
Cyl Head (Spark Plug)	deg F		518	472	446	411	393	361
PRESSURES								
Exhaust BP Before Cat	psig		1.40	1.06	0.82	0.63	0.49	0.24
Barometer	"Hg		29.072	29.070	29.074	29.074	29.079	29.080
F Factor	—		1.029	1.029	1.027	1.026	1.024	1.022
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		126.57	120.97	85.87	81.28	58.51	45.29
Dilute CO conc (dry)	%		0.27	0.30	0.19	0.20	0.13	0.08
Dilute CO_2 conc (dry)	%		0.59	0.47	0.42	0.33	0.30	0.21
Dilute NO_x conc (dry)	ppm		16.39	6.25	4.88	2.74	1.92	1.07
Measured A/F	—		12.58	11.89	12.58	11.96	12.56	12.59
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.06	1.06	1.06	1.06	1.06	1.04
Raw O_2 conc $(dry)_{measured}$	%		0.26	0.21	0.19	0.17	0.16	0.38
HC Mass	g/hr		16.38	15.79	11.18	10.64	7.57	5.80
NO_x Mass	g/hr		7.21	2.60	1.99	1.00	0.62	0.21
CO Mass	g/hr		705.0	785.3	495.3	529.7	350.2	226.7
CO_2 Mass	g/hr		2271	1794	1599	1230	1109	716
BSHC	g/hp-hr		5.44	7.00	7.39	14.07	24.27	—
$BSNO_x$	g/hp-hr		2.40	1.15	1.32	1.33	1.98	—
BSCO	g/hp-hr		234.16	348.19	327.56	700.61	1122.93	—
$BSCO_2$	g/hp-hr		754.19	795.34	1057.59	1626.81	3555.65	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**8.43**	**1.49**	**9.93**	**396.6**	**1071.0**	**1.228**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2** 685

Date: 4/22/03

Test ID: TEC2-250-STK-#2

250-hour interval emission test with stock muffler and stock jetting. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		2.85	2.17	1.42	0.71	0.30	0.00
Work (5 min Interval)	hp-hr		0.241	0.183	0.120	0.060	0.025	0.000
Fuel Flow	lb/hr		2.447	2.195	1.846	1.487	1.265	0.830
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		305	280	257	243	235	217
Exhaust Gas (muffler-in/manifold)	deg F		1254	1167	1123	1083	1058	936
Exhaust Gas (muffler out)	deg F		923	774	658	556	498	374
Catalyst/Muffler Surface	deg F		879	799	733	654	615	504
Intake Air (EPA)	deg F		80	79	79	78	77	76
Intake Air DewPoint (EPA)	deg F		63	63	62	62	61	61
Cyl Head (Spark Plug)	deg F		528	479	445	416	399	377
PRESSURES								
Exhaust BP Before Cat	psig		1.34	1.05	0.81	0.63	0.49	0.26
Barometer	"Hg		29.057	29.043	29.041	29.034	29.027	29.017
F Factor	—		1.032	1.031	1.030	1.028	1.027	1.026
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		130.40	126.03	101.58	89.34	64.22	40.44
Dilute CO conc (dry)	%		0.26	0.32	0.25	0.19	0.16	0.08
Dilute CO_2 conc (dry)	%		0.60	0.45	0.39	0.33	0.29	0.22
Dilute NO_x conc (dry)	ppm		18.39	5.96	4.09	2.67	2.01	1.12
Measured A/F	—		12.70	11.70	11.80	12.00	12.08	12.82
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.07	1.06	1.06	1.05	1.04	1.04
Raw O_2 conc $(dry)_{measured}$	%		0.24	0.21	0.19	0.14	0.10	0.30
HC Mass	g/hr		16.81	16.42	13.27	11.67	8.28	5.07
NO_x Mass	g/hr		8.42	2.74	1.89	1.22	0.92	0.50
CO Mass	g/hr		678.7	830.8	676.1	516.4	429.6	222.6
CO_2 Mass	g/hr		2310	1718	1482	1236	1072	797
BSHC	g/hp-hr		5.79	7.48	9.21	16.21	27.37	—
$BSNO_x$	g/hp-hr		2.90	1.25	1.32	1.69	3.03	—
BSCO	g/hp-hr		234.03	378.33	469.52	717.49	1420.21	—
$BSCO_2$	g/hp-hr		796.38	782.14	1029.02	1717.01	3542.04	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**9.58**	**1.70**	**11.28**	**457.2**	**1082.5**	**1.307**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 4/23/03

Test ID: TEC2-250-#3

250-hour interval emission test with catalyst C, and passive SAI system. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	----		1	2	3	4	5	6
Weight Factor	---		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	----		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.14	2.35	1.56	0.79	0.31	0.00
Work (5 min Interval)	hp-hr		0.266	0.199	0.131	0.067	0.026	0.000
Fuel Flow	lb/hr		2.335	2.091	1.692	1.401	1.172	0.789
TEMPERATURES								
Catalyst Mid-bed	deg F		1440	1368	1349	1339	1333	1298
Oil	deg F		303	276	257	242	231	215
Exhaust Gas (muffler-in/manifold)	deg F		1196	1108	1071	1040	1019	930
Exhaust Gas (muffler out)	deg F		953	850	774	712	651	545
Catalyst/Muffler Surface	deg F		827	795	791	782	770	708
Intake Air (EPA)	deg F		82	81	80	80	79	78
Intake Air DewPoint (EPA)	deg F		63	62	62	62	61	61
Cyl Head (Spark Plug)	deg F		544	486	450	419	395	372
PRESSURES								
Exhaust BP Before Cat	psig		0.45	0.31	0.22	0.15	0.11	0.04
Barometer	"Hg		28.932	28.929	28.928	28.925	28.924	28.918
F Factor	---		1.038	1.037	1.036	1.035	1.034	1.033
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		64.04	63.88	44.32	33.64	27.70	18.29
Dilute CO conc (dry)	%		0.18	0.24	0.17	0.13	0.10	0.03
Dilute CO_2 conc (dry)	%		0.65	0.50	0.43	0.37	0.33	0.27
Dilute NO_x conc (dry)	ppm		7.39	1.21	0.61	0.31	0.26	0.21
Measured A/F	---		13.46	12.57	12.68	12.61	12.75	13.46
Dry/Wet Correction	---		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	---		1.07	1.06	1.06	1.05	1.05	1.04
Raw O_2 conc $(dry)_{measured}$	%		0.85	0.99	1.11	1.27	1.40	1.89
HC Mass	g/hr		8.14	8.21	5.61	4.21	3.41	2.14
NO_x Mass	g/hr		3.39	0.54	0.26	0.12	0.09	0.07
CO Mass	g/hr		460.6	624.2	453.0	349.9	251.9	74.4
CO_2 Mass	g/hr		2522	1923	1640	1400	1235	982
BSHC	g/hp-hr		2.55	3.46	3.54	5.31	10.98	---
$BSNO_x$	g/hp-hr		1.06	0.23	0.16	0.15	0.30	---
BSCO	g/hp-hr		144.34	262.80	285.98	441.83	810.49	---
$BSCO_2$	g/hp-hr		790.21	809.41	1035.55	1767.32	3974.60	---
Emission Test Results	---		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.79**	**0.36**	**4.15**	**286.3**	**1109.2**	**1.121**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Tecumseh OVRM120 #2**

Date: 4/23/03

Test ID: TEC2-250-#4

687

250-hour interval emission test with catalyst C, and passive SAI system. Test run after scheduled maintenance.

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.11	2.33	1.57	0.77	0.29	0.00
Work (5 min Interval)	hp-hr		0.262	0.197	0.133	0.065	0.024	0.000
Fuel Flow	lb/hr		2.216	2.033	1.720	1.300	1.087	0.770
TEMPERATURES								
Catalyst Mid-bed	deg F		1432	1370	1351	1331	1343	1326
Oil	deg F		301	281	261	240	231	214
Exhaust Gas (muffler-in/manifold)	deg F		1194	1121	1084	1032	1042	916
Exhaust Gas (muffler out)	deg F		941	852	782	679	630	539
Catalyst/Muffler Surface	deg F		822	801	796	773	764	710
Intake Air (EPA)	deg F		84	83	82	81	80	79
Intake Air DewPoint (EPA)	deg F		63	63	63	62	62	61
Cyl Head (Spark Plug)	deg F		539	491	456	413	401	365
PRESSURES								
Exhaust BP Before Cat	psig		0.43	0.31	0.22	0.13	0.10	0.03
Barometer	"Hg		28.895	28.893	28.887	28.886	28.879	28.874
F Factor	—		1.042	1.041	1.040	1.039	1.037	1.036
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		53.96	55.28	43.81	26.04	18.12	22.87
Dilute CO conc (dry)	%		0.17	0.22	0.16	0.10	0.05	0.03
Dilute CO_2 conc (dry)	%		0.62	0.50	0.45	0.37	0.35	0.26
Dilute NO_x conc (dry)	ppm		6.32	1.40	0.65	0.64	0.51	0.34
Measured A/F	—		13.44	12.68	12.83	13.00	13.58	13.44
Dry/Wet Correction	—		0.97	0.97	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.08	1.08	1.07	1.06	1.05	1.05
Raw O_2 conc (dry)$_{measured}$	%		0.82	0.99	1.12	1.28	1.33	1.95
HC Mass	g/hr		6.68	6.92	5.45	3.08	2.01	2.67
NO_x Mass	g/hr		2.94	0.64	0.29	0.29	0.22	0.15
CO Mass	g/hr		444.3	581.7	425.0	260.7	123.9	74.9
CO_2 Mass	g/hr		2384	1912	1724	1402	1322	952
BSHC	g/hp-hr		2.12	2.93	3.44	3.95	6.69	—
$BSNO_x$	g/hp-hr		0.93	0.27	0.18	0.37	0.75	—
BSCO	g/hp-hr		140.74	245.99	268.29	334.32	412.86	—
$BSCO_2$	g/hp-hr		755.27	808.73	1088.43	1797.76	4407.43	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.24**	**0.40**	**3.64**	**251.6**	**1126.7**	**1.094**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

APPENDIX D

HONDA GCV160 EMISSION DATA SHEETS

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 3/25/03

Test ID: HON-160-BSLN#1

Baseline test with stock jetting and stock muffler after 1 hour break-in (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.37	2.53	1.71	0.85	0.33	0.00
Work (5 min interval)	hp-hr		0.284	0.214	0.144	0.072	0.028	0.000
Fuel Flow	lb/hr		2.352	1.809	1.509	1.084	0.910	0.438
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		236	214	194	179	164	136
Exhaust Gas (muffler-in/manifold)	deg F		1260	1195	1108	1079	1043	816
Exhaust Gas (muffler out)	deg F		845	700	590	494	418	261
Catalyst/Muffler Surface	deg F		571	508	441	393	350	245
Intake Air (EPA)	deg F		95	92	88	86	84	79
Intake Air DewPoint (EPA)	deg F		64	63	63	64	63	63
Cyl Head (Spark Plug)	deg F		440	402	356	322	295	246
PRESSURES								
Exhaust BP Before Cat	psig		0.29	0.20	0.14	0.10	0.08	0.04
Barometer	"Hg		29.000	29.000	29.003	28.997	28.997	28.998
F Factor	—		1.054	1.049	1.044	1.041	1.039	1.033
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		113.03	80.67	82.30	70.85	75.18	66.72
Dilute CO conc (dry)	%		0.29	0.21	0.21	0.13	0.12	0.06
Dilute CO_2 conc (dry)	%		0.55	0.44	0.33	0.26	0.21	0.12
Dilute NO_x conc (dry)	ppm		30.08	19.28	5.26	2.37	1.55	0.47
Measured A/F	—		12.22	12.52	11.83	12.24	11.84	11.94
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.08	1.07	1.07	1.08	1.08	1.08
Raw O_2 conc $(dry)_{measured}$	%		0.16	0.19	0.27	0.41	0.73	2.47
HC Mass	g/hr		14.41	10.32	10.69	9.23	9.89	8.82
NO_x Mass	g/hr		13.26	8.38	1.96	0.60	0.21	0.00
CO Mass	g/hr		750.0	542.5	552.9	358.7	334.8	156.8
CO_2 Mass	g/hr		2071	1650	1212	926	718	340
BSHC	g/hp-hr		4.17	4.00	6.23	10.68	29.50	—
$BSNO_x$	g/hp-hr		3.84	3.25	1.14	0.70	0.63	—
BSCO	g/hp-hr		217.15	210.29	322.18	415.06	998.67	—
$BSCO_2$	g/hp-hr		599.79	639.43	706.32	1071.27	2142.61	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		6.45	2.26	8.71	295.7	754.7	0.885

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 3/25/03

Test ID: HON-160-BSLN#2

Baseline test with stock jetting and stock muffler after 1 hour break-in

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.32	2.51	1.65	0.82	0.32	0.00
Work (5 min Interval)	hp-hr		0.281	0.212	0.140	0.069	0.027	0.000
Fuel Flow	lb/hr		2.292	1.848	1.502	1.124	0.923	0.432
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		231	211	191	176	166	138
Exhaust Gas (muffler-in/manifold)	deg F		1258	1192	1106	1072	1057	792
Exhaust Gas (muffler out)	deg F		840	696	576	484	434	250
Catalyst/Muffler Surface	deg F		570	508	440	391	361	237
Intake Air (EPA)	deg F		97	93	90	87	85	80
Intake Air DewPoint (EPA)	deg F		63	63	62	63	63	62
[redacted]	deg F	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
PRESSURES								
Exhaust BP Before Cat	psig		0.31	0.22	0.15	0.12	0.10	0.06
Barometer	"Hg		28.984	28.967	28.965	28.964	28.959	28.960
F Factor	—		1.057	1.053	1.048	1.045	1.042	1.034
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
[redacted]	ppm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	%	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ppm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Measured A/F	—		12.14	12.51	11.93	12.18	12.02	12.12
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.08	1.08	1.06	1.07	1.07	1.05
Raw O_2 conc $(dry)_{measured}$	%		0.18	0.19	0.25	0.43	0.65	2.95
HC Mass	g/hr		12.86	10.86	11.54	9.68	9.61	8.70
NO_x Mass	g/hr		11.41	7.98	1.94	0.68	0.24	0.00
CO Mass	g/hr		754.5	553.1	546.6	367.1	320.0	145.7
CO_2 Mass	g/hr		1985	1686	1209	968	760	350
BSHC	g/hp-hr		3.83	4.29	6.87	11.53	27.62	—
$BSNO_x$	g/hp-hr		3.40	3.15	1.15	0.81	0.69	—
BSCO	g/hp-hr		224.63	218.45	325.23	437.12	919.63	—
$BSCO_2$	g/hp-hr		591.09	665.99	719.56	1152.87	2183.34	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.80**	**2.17**	**8.97**	**303.3**	**780.8**	**0.913**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 3/26/03

Test ID: HON-160-BSLN#3

Baseline test with stock jetting and stock muffler after 1 hour break-in

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3084	[illegible]	3060	[illegible]	[illegible]	1828
Obs. Power	hp		3.54	2.65	[illegible]	[illegible]	[illegible]	[illegible]
Obs. Torque	ft-lb		5.95	4.48	2.95	[illegible]	[illegible]	[illegible]
Calc. Power (Obs. Torque*Speed)	hp		3.50	2.61	1.72	0.89	0.34	0.00
Work (5 min Interval)	hp-hr		0.295	0.221	0.145	0.075	0.029	0.000
Fuel Flow	lb/hr		2.445	1.883	1.528	1.129	0.876	0.434
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		235	216	196	179	167	147
Exhaust Gas (muffler-in/manifold)	deg F		1264	1200	1112	1079	1027	794
Exhaust Gas (muffler out)	deg F		863	722	595	501	420	251
Catalyst/Muffler Surface	deg F		569	507	438	390	339	234
Intake Air (EPA)	deg F		87	86	83	79	81	78
Intake Air DewPoint (EPA)	deg F		44	43	42	43	39	39
Cyl Head (Spark Plug)	deg F		444	406	358	322	292	243
PRESSURES								
Exhaust BP Before Cat	psig		0.23	0.15	0.09	0.06	0.02	-0.02
Barometer	"Hg		29.182	29.182	29.178	29.175	29.171	29.171
F Factor	—		1.025	1.024	1.020	1.015	1.016	1.012
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		98.52	80.52	82.06	71.37	65.00	58.68
Dilute CO conc (dry)	%		0.29	0.20	0.19	0.13	0.12	0.05
Dilute CO_2 conc (dry)	%		0.56	0.45	0.34	0.27	0.20	0.13
Dilute NO_x conc (dry)	ppm		35.41	23.61	6.85	3.02	1.49	0.72
Measured A/F	—		12.35	12.64	12.17	12.41	11.83	12.59
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.87	0.87	0.86	0.86	0.85	0.84
Raw O_2 conc $(dry)_{measured}$	%		0.15	0.18	0.23	0.31	0.50	1.70
HC Mass	g/hr		12.74	10.48	10.85	9.49	8.60	7.87
NO_x Mass	g/hr		13.39	8.96	2.55	1.06	0.45	0.15
CO Mass	g/hr		764.3	548.8	516.1	350.0	320.2	127.9
CO_2 Mass	g/hr		2184	1743	1296	1002	698	383
BSHC	g/hp-hr		3.62	3.95	6.15	10.69	23.90	—
$BSNO_x$	g/hp-hr		3.81	3.38	1.45	1.19	1.25	—
BSCO	g/hp-hr		217.31	207.17	292.66	394.59	889.86	—
$BSCO_2$	g/hp-hr		620.83	657.93	734.89	1129.54	1938.85	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.20**	**2.48**	**8.69**	**280.2**	**782.0**	**0.886**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Honda GCV160**

Date: 3/27/03

Test ID: HON-160-J-#1

Development using catalyst J in place of stock muffler

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.57	2.66	1.78	0.89	0.36	0.00
Work (5 min Interval)	hp-hr		0.301	0.225	0.150	0.075	0.031	0.000
Fuel Flow	lb/hr		2.419	1.835	1.537	1.129	0.927	0.501
TEMPERATURES								
Catalyst Mid-bed	deg F		1211	1110	969	869	808	619
Oil	deg F		230	210	188	170	162	144
Exhaust Gas (muffler-in/manifold)	deg F		1192	1148	1088	1104	1096	897
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		504	453	391	335	304	246
Intake Air (EPA)	deg F		94	92	90	86	83	79
Intake Air DewPoint (EPA)	deg F		54	52	53	54	54	54
Cyl Head (Spark Plug)	deg F		440	404	357	319	296	252
PRESSURES								
Exhaust BP Before Cat	psig		0.25	0.23	0.22	0.21	0.20	0.19
Barometer	"Hg		28.838	28.812	28.807	28.799	28.792	28.784
F Factor	—		1.052	1.050	1.047	1.043	1.039	1.035
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		86.10	67.47	78.61	65.07	61.92	54.19
Dilute CO conc (dry)	%		0.21	0.14	0.16	0.11	0.10	0.04
Dilute CO_2 conc (dry)	%		0.63	0.50	0.37	0.29	0.23	0.15
Dilute NO_x conc (dry)	ppm		6.72	3.95	1.17	0.42	0.15	0.11
Measured A/F	—		12.54	12.84	12.10	12.35	11.86	12.27
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		0.95	0.94	0.94	0.95	0.95	0.95
Raw O_2 conc (dry)$_{measured}$	%		0.13	0.14	0.14	0.14	0.16	0.33
HC Mass	g/hr		11.07	8.73	10.31	8.57	8.17	7.19
NO_x Mass	g/hr		2.74	1.59	0.45	0.15	0.03	0.01
CO Mass	g/hr		554.4	365.0	437.8	289.3	273.0	101.9
CO_2 Mass	g/hr		2483	1970	1432	1100	844	519
BSHC	g/hp-hr		3.06	3.24	5.69	9.52	21.97	—
$BSNO_x$	g/hp-hr		0.76	0.59	0.25	0.16	0.08	—
BSCO	g/hp-hr		153.43	135.26	241.67	321.48	733.88	—
$BSCO_2$	g/hp-hr		687.26	730.17	790.80	1222.77	2268.96	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**5.48**	**0.44**	**5.92**	**214.0**	**858.8**	**0.865**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Honda GCV160**

Date: 4/8/03

Test ID: HON-160-J-BSLN#1

Final 0-hr development tests with catalyst J, stock jetting, and passive SAI system (methane analysis)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.68	2.65	1.76	0.88	0.34	0.00
Work (5 min Interval)	hp-hr		0.311	0.224	0.149	0.074	0.028	0.000
Fuel Flow	lb/hr		2.347	1.762	1.416	1.042	0.877	0.403
TEMPERATURES								
Catalyst Mid-bed	deg F		1441	1361	1251	1200	1134	762
Oil	deg F		240	216	200	181	167	161
Exhaust Gas (muffler-in/manifold)	deg F		1277	1196	1121	1089	991	815
Exhaust Gas (muffler out)	deg F		766	655	552	479	413	242
Catalyst/Muffler Surface	deg F		698	631	556	505	449	314
Intake Air (EPA)	deg F		90	86	84	81	78	76
Intake Air DewPoint (EPA)	deg F		34	36	35	37	36	34
Cyl.Head (Spark Plug)	deg F		428	382	342	308	275	250
PRESSURES								
Exhaust BP Before Cat	psig		0.17	0.12	0.07	0.04	0.02	-0.02
Barometer	"Hg		29.416	29.415	29.414	29.410	29.406	29.400
F Factor	—		1.018	1.013	1.010	1.007	1.003	1.001
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		38.97	33.52	29.74	24.62	36.19	16.93
Dilute CO conc (dry)	%		0.14	0.07	0.08	0.04	0.06	0.00
Dilute CO_2 conc (dry)	%		0.68	0.54	0.42	0.33	0.26	0.17
Dilute NO_x conc (dry)	ppm		4.27	2.28	0.74	0.23	0.11	0.83
Measured A/F	—		13.10	13.46	13.17	13.40	12.76	16.37
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.82	0.83	0.83	0.84	0.83	0.82
Raw O_2 conc $(dry)_{measured}$	%		0.85	1.06	1.20	1.40	1.63	5.00
HC Mass	g/hr		4.87	4.23	3.76	3.10	4.74	2.06
NO_x Mass	g/hr		1.54	0.85	0.27	0.08	0.03	0.31
CO Mass	g/hr		367.4	197.6	204.0	112.3	154.1	0.0
CO_2 Mass	g/hr		2696	2145	1651	1274	971	559
BSHC	g/hp-hr		1.32	1.58	2.10	3.51	13.17	—
$BSNO_x$	g/hp-hr		0.42	0.32	0.15	0.09	0.09	—
BSCO	g/hp-hr		99.72	73.88	114.11	127.16	428.23	—
$BSCO_2$	g/hp-hr		731.68	801.77	923.56	1442.73	2698.57	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**2.23**	**0.25**	**2.49**	**105.2**	**972.1**	**0.817**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 4/8/03

Test ID: HON-160-J-BSLN#2

Final 0-hr development tests with catalyst J, stock jetting, and passive SAI system (methane analysis)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.53	2.64	1.75	0.88	0.35	0.00
Work (5 min Interval)	hp-hr		0.298	0.223	0.148	0.074	0.029	0.000
Fuel Flow	lb/hr		2.375	1.770	1.446	1.047	0.870	0.352
TEMPERATURES								
Catalyst Mid-bed	deg F		1432	1356	1248	1205	1159	773
Oil	deg F		247	218	195	180	168	149
Exhaust Gas (muffler-in/manifold)	deg F		1271	1192	1113	1085	1015	814
Exhaust Gas (muffler out)	deg F		760	650	555	484	422	238
Catalyst/Muffler Surface	deg F		672	623	563	528	480	363
Intake Air (EPA)	deg F		89	86	83	81	79	74
Intake Air DewPoint (EPA)	deg F		36	35	37	34	37	37
Cyl Head (Spark Plug)	deg F		431	387	342	309	281	248
PRESSURES								
Exhaust BP Before Cat	psig		0.16	0.11	0.07	0.04	0.02	-0.02
Barometer	"Hg		29.388	29.382	29.385	29.390	29.385	29.383
F Factor	—		1.018	1.014	1.011	1.007	1.005	0.999
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		41.13	29.58	34.22	25.83	26.62	9.87
Dilute CO conc (dry)	%		0.15	0.08	0.08	0.05	0.04	0.00
Dilute CO_2 conc (dry)	%		0.68	0.54	0.42	0.34	0.28	0.15
Dilute NO_x conc (dry)	ppm		5.92	2.93	0.88	0.39	0.21	0.72
Measured A/F	—		13.13	13.48	13.07	13.39	13.24	16.34
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.83	0.83	0.83	0.82	0.84	0.84
Raw O_2 conc $(dry)_{measured}$	%		0.80	1.00	1.13	1.31	1.52	5.00
HC Mass	g/hr		5.12	3.63	4.32	3.08	3.33	0.98
NO_x Mass	g/hr		2.16	1.08	0.32	0.13	0.06	0.27
CO Mass	g/hr		383.6	203.8	227.4	118.3	93.7	0.0
CO_2 Mass	g/hr		2708	2148	1654	1271	1061	491
BSHC	g/hp-hr		1.43	1.36	2.43	3.46	9.25	—
$BSNO_x$	g/hp-hr		0.60	0.40	0.18	0.14	0.18	—
BSCO	g/hp-hr		107.34	76.50	128.00	133.27	260.21	—
$BSCO_2$	g/hp-hr		757.68	806.42	931.11	1430.77	2947.06	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**2.19**	**0.34**	**2.53**	**110.3**	**983.0**	**0.830**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 4/25/03

Test ID: HON-160-J-125-#1

125-hour interval testing with catalyst J, stock jetting, and passive SAI system (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.35	2.52	1.70	0.82	0.34	0.00
Work (5 min Interval)	hp-hr		0.283	0.213	0.143	0.070	0.029	0.000
Fuel Flow	lb/hr		2.081	1.661	1.373	1.036	0.834	0.424
TEMPERATURES								
Catalyst Mid-bed	deg F		1427	1359	1261	1217	1145	831
Oil	deg F		234	208	188	178	167	144
Exhaust Gas (muffler-in/manifold)	deg F		1268	1196	1152	1127	1054	861
Exhaust Gas (muffler out)	deg F		694	589	491	430	378	243
Catalyst/Muffler Surface	deg F		610	556	497	465	423	320
Intake Air (EPA)	deg F		90	89	84	83	83	77
Intake Air DewPoint (EPA)	deg F		45	46	46	45	46	46
Cyl Head (Spark Plug)	deg F		430	385	343	318	292	250
PRESSURES								
Exhaust BP Before Cat	psig		0.17	0.11	0.07	0.04	0.02	-0.01
Barometer	"Hg		28.880	28.893	28.896	28.898	28.904	28.899
F Factor	—		1.041	1.039	1.033	1.031	1.030	1.023
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		28.81	23.77	22.32	13.19	13.90	25.09
Dilute CO conc (dry)	%		0.07	0.05	0.05	0.01	0.02	0.00
Dilute CO_2 conc (dry)	%		0.66	0.53	0.43	0.36	0.29	0.17
Dilute NO_x conc (dry)	ppm		7.40	3.01	1.57	0.68	0.30	0.73
Measured A/F	—		13.86	13.81	13.71	14.02	13.77	16.89
Dry/Wet Correction	—		0.98	0.98	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.88	0.89	0.88	0.88	0.89	0.89
Raw O_2 conc $(dry)_{measured}$	%		0.82	0.96	1.15	1.24	1.38	5.50
HC Mass	g/hr		3.56	2.90	2.74	1.49	1.59	3.19
NO_x Mass	g/hr		2.86	1.15	0.58	0.23	0.07	0.25
CO Mass	g/hr		175.5	147.9	149.1	39.8	51.7	6.6
CO_2 Mass	g/hr		2628	2085	1680	1384	1082	573
BSHC	g/hp-hr		1.05	1.14	1.60	1.77	4.66	—
$BSNO_x$	g/hp-hr		0.84	0.45	0.34	0.27	0.22	—
BSCO	g/hp-hr		51.49	58.11	86.90	47.33	151.38	—
$BSCO_2$	g/hp-hr		771.26	819.44	979.29	1648.16	3165.85	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.52**	**0.47**	**1.99**	**65.8**	**1044.9**	**0.823**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 4/25/03

Test ID: HON-160-J-125-#2

125-hour interval testing with catalyst J, stock jetting, and passive SAI system (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.31	2.50	1.66	0.83	0.33	0.00
Work (5 min Interval)	hp-hr		0.279	0.211	0.140	0.070	0.028	0.000
Fuel Flow	lb/hr		1.943	1.691	1.319	1.052	0.867	0.423
TEMPERATURES								
Catalyst Mid-bed	deg F		1427	1353	1259	1218	1135	835
Oil	deg F		230	209	191	177	167	147
Exhaust Gas (muffler-in/manifold)	deg F		1268	1192	1149	1127	1036	875
Exhaust Gas (muffler out)	deg F		686	585	490	432	378	243
Catalyst/Muffler Surface	deg F		609	557	496	465	421	321
Intake Air (EPA)	deg F		91	88	86	83	82	79
Intake Air DewPoint (EPA)	deg F		46	46	45	45	45	45
Cyl Head (Spark Plug)	deg F		432	384	346	320	290	254
PRESSURES								
Exhaust BP Before Cat	psig		0.17	0.11	0.07	0.04	0.02	-0.01
Barometer	"Hg		28.904	28.904	28.903	28.901	28.894	28.887
F Factor	—		1.041	1.038	1.034	1.031	1.030	1.026
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		19.12	24.23	24.36	17.95	19.78	18.56
Dilute CO conc (dry)	%		0.04	0.06	0.05	0.02	0.03	0.00
Dilute CO_2 conc (dry)	%		0.65	0.54	0.42	0.36	0.29	0.18
Dilute NO_x conc (dry)	ppm		9.80	4.63	1.40	0.53	0.32	0.77
Measured A/F	—		14.06	13.78	13.69	13.96	13.55	16.80
Dry/Wet Correction	—		0.98	0.98	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.89	0.89	0.88	0.88	0.88	0.88
Raw O_2 conc $(dry)_{measured}$	%		0.87	1.10	1.13	1.23	1.45	5.50
HC Mass	g/hr		2.05	2.76	2.81	1.95	2.21	2.06
NO_x Mass	g/hr		3.77	1.79	0.51	0.17	0.08	0.27
CO Mass	g/hr		100.1	149.3	132.4	50.4	77.6	0.8
CO_2 Mass	g/hr		2558	2126	1631	1388	1085	585
BSHC	g/hp-hr		0.61	1.09	1.67	2.32	6.57	—
$BSNO_x$	g/hp-hr		1.12	0.70	0.30	0.20	0.24	—
BSCO	g/hp-hr		29.69	58.71	78.79	59.99	230.96	—
$BSCO_2$	g/hp-hr		758.75	835.92	971.04	1652.29	3228.41	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.52**	**0.58**	**2.10**	**62.1**	**1047.8**	**0.821**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 4/28/03

Test ID: HON-160-STK-125-#1

699

125-hour interval testing with stock jetting and stock muffler (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.14	2.35	1.55	0.78	0.32	0.00
Work (5 min Interval)	hp-hr		0.265	0.198	0.131	0.066	0.027	0.000
Fuel Flow	lb/hr		2.004	1.697	1.280	1.041	0.846	0.444
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		225	207	191	181	169	148
Exhaust Gas (muffler-in/manifold)	deg F		1281	1212	1170	1170	1127	971
Exhaust Gas (muffler out)	deg F		833	713	611	547	466	355
Catalyst/Muffler Surface	deg F		560	504	464	439	387	319
Intake Air (EPA)	deg F		90	88	86	84	83	79
Intake Air DewPoint (EPA)	deg F		60	60	60	59	59	58
Cyl Head (Spark Plug)	deg F		426	387	350	327	301	262
PRESSURES								
Exhaust BP Before Cat	psig		0.60	0.43	0.30	0.22	0.16	0.05
Barometer	"Hg		29.063	29.061	29.056	29.058	29.056	29.056
F Factor	—		1.043	1.040	1.038	1.035	1.033	1.027
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		82.44	72.62	59.71	45.71	37.84	70.98
Dilute CO conc (dry)	%		0.13	0.13	0.10	0.06	0.05	0.00
Dilute CO_2 conc (dry)	%		0.58	0.47	0.36	0.32	0.26	0.17
Dilute NO_x conc (dry)	ppm		67.32	34.16	11.87	4.91	2.35	1.10
Measured A/F	—		13.57	13.33	13.27	13.67	13.57	15.91
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.02	1.02	1.02	1.02	1.01	1.00
Raw O_2 conc $(dry)_{measured}$	%		0.20	0.33	0.24	0.30	0.43	5.00
HC Mass	g/hr		10.57	9.39	7.69	5.81	4.77	9.46
NO_x Mass	g/hr		29.74	15.35	5.37	2.20	1.04	0.46
CO Mass	g/hr		338.2	340.4	263.0	156.4	143.0	9.9
CO_2 Mass	g/hr		2243	1812	1356	1195	945	577
BSHC	g/hp-hr		3.35	3.95	4.89	7.33	15.29	—
$BSNO_x$	g/hp-hr		9.43	6.46	3.41	2.78	3.34	—
BSCO	g/hp-hr		107.18	143.27	167.22	197.00	458.40	—
$BSCO_2$	g/hp-hr		711.07	762.78	862.26	1505.63	3028.44	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**5.16**	**5.46**	**10.62**	**157.4**	**956.6**	**0.871**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 4/29/03

Test ID: HON-160-STK-125-#2

125-hour interval testing with stock jetting and stock muffler (methane test)

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp	3.09	2.31	1.55	0.77	0.31	0.00
Work (5 min Interval)	hp-hr	0.261	0.195	0.131	0.065	0.026	0.000
Fuel Flow	lb/hr	2.014	1.654	1.359	1.044	0.865	0.442
TEMPERATURES							
Catalyst Mid-bed	deg F	NA	NA	NA	NA	NA	NA
Oil	deg F	228	209	192	180	171	150
Exhaust Gas (muffler-in/manifold)	deg F	1277	1216	1171	1168	1139	937
Exhaust Gas (muffler out)	deg F	828	707	608	540	468	335
Catalyst/Muffler Surface	deg F	554	501	460	435	389	307
Intake Air (EPA)	deg F	92	91	88	86	85	80
Intake Air DewPoint (EPA)	deg F	64	64	64	64	64	64
Cyl Head (Spark Plug)	deg F	430	389	351	328	305	260
PRESSURES							
Exhaust BP Before Cat	psig	0.59	0.41	0.32	0.23	0.16	0.04
Barometer	"Hg	29.027	29.024	29.026	29.027	29.031	29.029
F Factor	—	1.050	1.047	1.043	1.041	1.039	1.033
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	81.22	71.77	63.85	47.48	39.43	86.29
Dilute CO conc (dry)	%	0.14	0.12	0.11	0.06	0.05	0.01
Dilute CO_2 conc (dry)	%	0.58	0.47	0.38	0.32	0.27	0.17
Dilute NO_x conc (dry)	ppm	61.33	33.76	11.36	4.75	2.61	0.98
Measured A/F	—	13.51	13.42	13.22	13.64	13.61	16.11
Dry/Wet Correction	—	0.97	0.97	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—	1.09	1.08	1.08	1.09	1.09	1.08
Raw O_2 conc $(dry)_{measured}$	%	0.22	0.32	0.25	0.30	0.41	4.50
HC Mass	g/hr	10.42	9.26	8.27	6.08	5.01	11.62
NO_x Mass	g/hr	28.58	15.72	5.18	2.04	1.01	0.21
CO Mass	g/hr	355.9	313.6	282.9	163.2	138.5	15.0
CO_2 Mass	g/hr	2229	1796	1433	1187	979	559
BSHC	g/hp-hr	3.32	3.94	5.26	7.80	16.05	—
$BSNO_x$	g/hp-hr	9.09	6.69	3.30	2.61	3.23	—
BSCO	g/hp-hr	113.24	133.44	179.93	209.23	444.08	—
$BSCO_2$	g/hp-hr	709.24	764.09	911.62	1521.99	3139.42	—
Emission Test Results	—	HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**5.43**	**5.40**	**10.83**	**161.3**	**975.0**	**0.889**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Honda GCV160** 701

Date: 5/16/03

Test ID: HON-160-J-250-#1

250-hour interval testing with catalyst J, stock jetting, and passive SAI system (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3054	3062	3069	3053	3076	[illegible]
Obs. Power	hp		3.55	2.69	1.79	0.90	0.35	0.00
Obs. Torque	ft-lb		6.02	4.55	3.02	1.52	0.59	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.50	2.65	1.76	0.88	0.35	0.00
Work (5 min Interval)	hp-hr		0.296	0.224	0.149	0.075	0.029	0.000
Fuel Flow	lb/hr		2.141	1.693	1.331	1.052	0.783	0.398
TEMPERATURES								
Catalyst Mid-bed	deg F		1440	1408	1303	1266	1183	821
Oil	deg F		235	216	199	187	174	155
Exhaust Gas (muffler-in/manifold)	deg F		1249	1207	1148	1125	1016	850
Exhaust Gas (muffler out)	deg F		693	603	503	438	377	241
Catalyst/Muffler Surface	deg F		661	624	553	519	466	299
Intake Air (EPA)	deg F		97	96	94	92	90	86
Intake Air DewPoint (EPA)	deg F		64	64	63	63	62	62
Cyl Head (Spark Plug)	deg F		441	400	357	329	294	265
PRESSURES								
Exhaust BP Before Cat	psig		0.16	0.11	0.07	0.04	0.02	-0.02
Barometer	"Hg		28.847	28.843	28.844	28.842	28.843	28.838
F Factor	—		1.063	1.061	1.058	1.056	1.052	1.047
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		56.54	36.34	28.09	34.45	30.37	17.21
Dilute CO conc (dry)	%		0.10	0.05	0.06	0.02	0.03	0.00
Dilute CO_2 conc (dry)	%		0.67	0.56	0.42	0.36	0.26	0.16
Dilute NO_x conc (dry)	ppm		6.23	2.84	0.48	0.25	0.05	0.56
Measured A/F	—		13.58	13.80	13.46	13.82	13.33	16.84
Dry/Wet Correction	—		0.97	0.97	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.09	1.09	1.08	1.08	1.06	1.06
Raw O_2 conc (dry)$_{measured}$	%		0.87	1.15	1.24	1.31	1.51	5.50
HC Mass	g/hr		7.15	4.52	3.47	4.36	3.84	2.06
NO_x Mass	g/hr		2.85	1.27	0.18	0.08	0.00	0.22
CO Mass	g/hr		247.3	127.8	161.8	63.2	89.0	11.3
CO_2 Mass	g/hr		2589	2156	1599	1361	945	534
BSHC	g/hp-hr		2.00	1.69	1.94	4.91	11.03	—
$BSNO_x$	g/hp-hr		0.80	0.48	0.10	0.09	0.00	—
BSCO	g/hp-hr		69.15	47.78	90.50	71.20	255.84	—
$BSCO_2$	g/hp-hr		723.92	806.08	894.45	1531.64	2716.27	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**2.54**	**0.36**	**2.90**	**72.3**	**977.7**	**0.785**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Honda GCV160**

Date: 5/16/03

Test ID: HON-160-J-250-#2

250-hour interval testing with catalyst J, stock jetting, and passive SAI system

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.42	2.58	1.72	0.86	0.34	0.00
Work (5 min Interval)	hp-hr		0.289	0.218	0.145	0.073	0.029	0.000
Fuel Flow	lb/hr		2.115	1.705	1.359	1.034	0.829	0.414
TEMPERATURES								
Catalyst Mid-bed	deg F		1434	1398	1302	1259	1189	821
Oil	deg F		241	221	202	187	175	158
Exhaust Gas (muffler-in/manifold)	deg F		1244	1201	1147	1124	1021	861
Exhaust Gas (muffler out)	deg F		690	594	501	436	378	246
Catalyst/Muffler Surface	deg F		660	620	554	514	469	312
Intake Air (EPA)	deg F		100	98	95	94	92	88
Intake Air DewPoint (EPA)	deg F		63	62	62	62	61	61
Cyl Head (Spark Plug)	deg F		444	400	358	329	296	269
PRESSURES								
Exhaust BP Before Cat	psig		0.15	0.11	0.07	0.04	0.02	-0.02
Barometer	"Hg		28.827	28.824	28.821	28.818	28.816	28.809
F Factor	—		1.066	1.063	1.060	1.058	1.054	1.050
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		37.13	29.61	29.91	20.33	21.43	21.79
Dilute CO conc (dry)	%		0.10	0.06	0.06	0.02	0.03	0.00
Dilute CO_2 conc (dry)	%		0.66	0.56	0.43	0.36	0.28	0.17
Dilute NO_x conc (dry)	ppm		6.63	3.94	1.03	0.30	0.16	0.64
Measured A/F	—		13.56	13.73	13.46	13.80	13.38	16.78
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.07	1.06	1.05	1.05	1.04	1.04
Raw O_2 conc $(dry)_{measured}$	%		0.88	1.15	1.24	1.37	1.56	5.50
HC Mass	g/hr		4.52	3.57	3.64	2.39	2.55	2.63
NO_x Mass	g/hr		2.92	1.67	0.37	0.04	0.00	0.19
CO Mass	g/hr		266.2	149.1	169.5	58.5	85.2	9.5
CO_2 Mass	g/hr		2530	2144	1625	1349	1019	557
BSHC	g/hp-hr		1.30	1.37	2.09	2.72	7.33	—
$BSNO_x$	g/hp-hr		0.84	0.64	0.21	0.04	0.00	—
BSCO	g/hp-hr		76.48	57.27	97.41	66.62	244.72	—
$BSCO_2$	g/hp-hr		727.01	823.43	934.11	1535.95	2927.67	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.97**	**0.44**	**2.41**	**78.0**	**1003.3**	**0.808**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 5/14/03

Test ID: HON-160-STK-250-#1

250-hour interval testing with stock muffler and stock jetting (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3049	3062	3053	3062	3065	1856
Obs. Power	hp		3.28	2.47	1.65	0.82	0.33	0.00
Obs. Torque	ft-lb		5.57	4.18	2.81	1.39	0.55	0.00
Calc. Power (Obs. Torque*Speed)	hp		3.24	2.44	1.63	0.81	0.32	0.00
Work (5 min Interval)	hp-hr		0.273	0.206	0.138	0.069	0.027	0.000
Fuel Flow	lb/hr		2.083	1.695	1.325	1.008	0.845	0.416
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		228	213	190	177	168	145
Exhaust Gas (muffler-in/manifold)	deg F		1289	1281	1144	1116	1081	922
Exhaust Gas (muffler out)	deg F		914	827	619	526	451	364
Catalyst/Muffler Surface	deg F		489	464	383	369	356	292
Intake Air (EPA)	deg F		91	89	86	84	83	79
Intake Air DewPoint (EPA)	deg F		62	62	62	62	62	61
Cyl Head (Spark Plug)	deg F		434	408	353	322	297	262
PRESSURES								
Exhaust BP Before Cat	psig		0.70	0.54	0.29	0.20	0.15	0.04
Barometer	"Hg		28.976	28.966	28.969	28.964	28.959	28.962
F Factor	—		1.048	1.046	1.042	1.040	1.038	1.032
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		90.89	68.24	68.42	56.99	50.38	76.18
Dilute CO conc (dry)	%		0.14	0.07	0.11	0.07	0.07	0.00
Dilute CO_2 conc (dry)	%		0.60	0.53	0.36	0.29	0.24	0.16
Dilute NO_x conc (dry)	ppm		68.27	51.65	11.04	3.61	1.96	0.90
Measured A/F	—		13.57	14.12	13.11	13.32	13.17	15.99
Dry/Wet Correction	—		0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.06	1.06	1.05	1.05	1.05	1.04
Raw O_2 conc $(dry)_{measured}$	%		0.30	0.30	0.26	0.30	0.48	3.80
HC Mass	g/hr		11.64	8.73	8.89	7.41	6.54	10.19
NO_x Mass	g/hr		30.86	23.43	5.00	1.54	0.77	0.27
CO Mass	g/hr		361.9	191.8	297.4	199.7	188.6	8.9
CO_2 Mass	g/hr		2312	2045	1361	1075	867	538
BSHC	g/hp-hr		3.51	3.53	5.41	9.08	20.20	—
$BSNO_x$	g/hp-hr		9.31	9.48	3.04	1.89	2.38	—
BSCO	g/hp-hr		109.22	77.57	180.89	244.80	582.44	—
$BSCO_2$	g/hp-hr		697.96	827.45	828.05	1317.38	2675.39	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**5.57**	**6.14**	**11.72**	**150.1**	**925.3**	**0.841**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 5/14/03

Test ID: HON-160-STK-250-#2

250-hour interval testing with stock muffler and stock jetting (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.36	2.52	1.68	0.84	0.34	0.00
Work (5 min Interval)	hp-hr		0.284	0.213	0.142	0.071	0.029	0.000
Fuel Flow	lb/hr		2.146	1.669	1.327	0.989	0.760	0.419
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		235	220	194	182.	173	149
Exhaust Gas (muffler-in/manifold)	deg F		1245	1284	1151	1120	1089	921
Exhaust Gas (muffler out)	deg F		877	833	626	532	456	365
Catalyst/Muffler Surface	deg F		489	474	404	421	381	310
Intake Air (EPA)	deg F		94	93	90	89	88	83
Intake Air DewPoint (EPA)	deg F		61	61	61	62	62	61
Cyl Head (Spark Plug)	deg F		446	414	359	329	303	265
PRESSURES								
Exhaust BP Before Cat	psig		0.64	0.52	0.29	0.20	0.15	0.04
Barometer	"Hg		28.933	28.914	28.907	28.901	28.897	28.890
F Factor	—		1.053	1.052	1.049	1.049	1.047	1.041
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		97.54	60.79	66.58	50.81	40.28	73.10
Dilute CO conc (dry)	%		0.19	0.06	0.11	0.07	0.05	0.00
Dilute CO_2 conc (dry)	%		0.57	0.54	0.36	0.29	0.23	0.16
Dilute NO_x conc (dry)	ppm		55.65	59.42	11.70	3.91	1.77	0.89
Measured A/F	—		13.14	14.37	13.14	13.44	13.34	16.04
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.04	1.04	1.04	1.06	1.06	1.05
Raw O_2 conc $(dry)_{measured}$	%		0.19	0.30	0.22	0.32	0.50	4.00
HC Mass	g/hr		12.47	7.60	8.53	6.45	5.04	9.61
NO_x Mass	g/hr		24.67	26.38	5.19	1.70	0.70	0.28
CO Mass	g/hr		488.1	149.2	296.3	182.7	140.4	10.2
CO_2 Mass	g/hr		2200	2080	1367	1079	828	541
BSHC	g/hp-hr		3.66	2.97	5.01	7.57	14.99	—
$BSNO_x$	g/hp-hr		7.24	10.30	3.04	2.00	2.07	—
BSCO	g/hp-hr		143.18	58.25	173.84	214.46	417.92	—
$BSCO_2$	g/hp-hr		645.36	812.19	802.04	1266.42	2464.10	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.95**	**6.01**	**10.96**	**141.2**	**891.2**	**0.806**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Honda GCV160

Date: 5/20/03

Test ID: HON-160-J-250-#3

705

250-hour interval testing with catalyst J, stock jetting, and passive SAI system after carburetor maintenance

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]					
[redacted]	hp	[redacted]					
[redacted]	ft-lb	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp	3.62	2.72	1.81	0.90	0.37	0.01
Work (5 min Interval)	hp-hr	0.306	0.230	0.153	0.076	0.031	0.001
Fuel Flow	lb/hr	2.079	1.771	1.491	1.105	0.941	0.498
TEMPERATURES							
Catalyst Mid-bed	deg F	1450	1412	1278	1203	1136	1069
Oil	deg F	228	213	193	178	165	146
Exhaust Gas (muffler-in/manifold)	deg F	1276	1241	1146	1091	988	723
Exhaust Gas (muffler out)	deg F	712	622	512	439	381	255
Catalyst/Muffler Surface	deg F	656	614	530	477	430	352
Intake Air (EPA)	deg F	92	90	88	87	86	82
Intake Air DewPoint (EPA)	deg F	58	58	58	58	58	58
Cyl Head (Spark Plug)	deg F	440	404	359	322	287	253
PRESSURES							
Exhaust BP Before Cat	psig	0.18	0.13	0.09	0.05	0.03	-0.01
Barometer	"Hg	29.246	29.243	29.239	29.236	29.232	29.231
F Factor	—	1.037	1.035	1.032	1.031	1.029	1.025
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	35.31	32.54	37.53	31.83	41.31	22.70
Dilute CO conc (dry)	%	0.09	0.05	0.10	0.07	0.08	0.01
Dilute CO_2 conc (dry)	%	0.65	0.58	0.43	0.33	0.26	0.19
Dilute NO_x conc (dry)	ppm	5.45	6.06	1.36	0.66	0.61	0.59
Measured A/F	—	13.69	13.88	13.16	13.21	12.58	14.13
Dry/Wet Correction	—	0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—	1.00	0.99	0.99	0.99	1.00	0.99
Raw O_2 conc $(dry)_{measured}$	%	0.84	0.92	1.05	1.18	1.42	3.05
HC Mass	g/hr	4.27	3.94	4.68	3.94	5.27	2.71
NO_x Mass	g/hr	2.36	2.65	0.60	0.29	0.27	0.26
CO Mass	g/hr	229.3	125.3	260.1	181.2	221.6	31.0
CO_2 Mass	g/hr	2538	2272	1666	1252	953	641
BSHC	g/hp-hr	1.16	1.43	2.56	4.26	14.18	—
$BSNO_x$	g/hp-hr	0.64	0.96	0.33	0.32	0.73	—
BSCO	g/hp-hr	62.46	45.41	142.59	196.12	595.77	—
$BSCO_2$	g/hp-hr	691.41	823.83	913.11	1354.93	2562.49	—
Emission Test Results	—	HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**2.46**	**0.60**	**3.06**	**112.3**	**956.8**	**0.815**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/22/2003

Steady-State SORE Engine Test Information **Engine: Honda GCV160**

Date: 5/20/03

Test ID: HON-160-STK-250-#3

250-hour interval testing with stock muffler and stock jetting after carburetor maintenance

DESCRIPTION	UNIT		1	2	3	4	5	6
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		3.35	2.54	1.70	0.85	0.34	0.01
Work (5 min Interval)	hp-hr		0.283	0.215	0.143	0.072	0.029	0.000
Fuel Flow	lb/hr		2.126	1.789	1.546	1.100	1.020	0.484
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		235	215	198	176	166	144
Exhaust Gas (muffler-in/manifold)	deg F		1301	1283	1198	1100	1087	823
Exhaust Gas (muffler out)	deg F		874	776	636	489	440	275
Catalyst/Muffler Surface	deg F		573	538	479	400	371	214
Intake Air (EPA)	deg F		93	91	89	86	85	81
Intake Air DewPoint (EPA)	deg F		61	61	60	59	59	58
Cyl Head (Spark Plug)	deg F		447	413	369	318	298	252
PRESSURES								
Exhaust BP Before Cat	psig		0.67	0.51	0.34	0.20	0.16	0.03
Barometer	"Hg		29.197	29.220	29.223	29.231	29.236	29.241
F Factor	—		1.042	1.038	1.035	1.031	1.028	1.023
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		96.56	81.63	83.48	72.79	78.35	61.87
Dilute CO conc (dry)	%		0.16	0.11	0.14	0.11	0.11	0.04
Dilute CO_2 conc (dry)	%		0.59	0.52	0.40	0.28	0.25	0.15
Dilute NO_x conc (dry)	ppm		59.69	43.63	11.05	3.39	2.08	0.88
Measured A/F	—		13.36	13.58	12.90	12.67	12.44	13.25
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.03	1.03	1.02	1.01	1.01	1.00
Raw O_2 conc (dry)$_{measured}$	%		0.14	0.16	0.17	0.26	0.35	1.22
HC Mass	g/hr		12.38	10.50	10.86	9.54	10.39	8.17
NO_x Mass	g/hr		26.54	19.63	4.83	1.39	0.81	0.26
CO Mass	g/hr		425.2	295.9	386.8	307.6	312.0	102.8
CO_2 Mass	g/hr		2272	2009	1524	1029	906	491
BSHC	g/hp-hr		3.61	4.07	6.33	11.06	29.88	—
$BSNO_x$	g/hp-hr		7.74	7.61	2.82	1.61	2.33	—
BSCO	g/hp-hr		123.95	114.75	225.33	356.35	897.02	—
$BSCO_2$	g/hp-hr		662.24	779.16	887.70	1191.73	2605.00	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.46**	**5.11**	**11.57**	**204.8**	**899.9**	**0.886**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/22/2003

APPENDIX E

KAWASAKI FH601V EMISSION DATA SHEETS

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 2/14/03

Test ID: KAW2-BSLN#1

Baseline Test #1 of replacement Kawasaki engine after break-in (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.17	11.40	7.57	3.80	1.48	0.00
Work (5 min Interval)	hp-hr		1.282	0.964	0.640	0.321	0.125	0.000
Fuel Flow	lb/hr		9.660	8.101	6.849	5.943	3.992	1.613
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		259	251	232	215	206	185
Exhaust Gas (muffler-in/manifold)	deg F		1275	1258	1222	1194	1154	775
Exhaust Gas (muffler out)	deg F		828	737	641	534	423	180
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		95	88	85	84	83	84
Intake Air DewPoint (EPA)	deg F		65	65	66	65	65	64
Cyl Head (Spark Plug)	deg F		421	384	338	309	297	243
PRESSURES								
Exhaust BP Before Cat	psig		0.25	0.16	0.10	0.05	0.02	0.00
Barometer	"Hg		28.907	28.893	28.881	28.880	28.868	28.865
F Factor	—		1.059	1.050	1.047	1.045	1.044	1.044
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		97.64	88.79	104.77	161.32	83.37	82.08
Dilute CO conc (dry)	%		0.48	0.39	0.38	0.38	0.21	0.08
Dilute CO_2 conc (dry)	%		0.64	0.53	0.39	0.28	0.24	0.12
Dilute NO_x conc (dry)	ppm		20.45	12.40	4.73	1.38	1.41	0.23
Measured A/F	—		11.26	11.16	10.57	9.91	10.64	10.85
Dry/Wet Correction	—		0.97	0.97	0.97	0.98	0.98	0.98
NO_x Humidity Correction	—		1.12	1.11	1.12	1.11	1.11	1.08
Raw O_2 conc $(dry)_{measured}$	%		0.07	0.09	0.11	0.19	0.22	0.93
HC Mass	g/hr		38.47	35.61	42.88	67.69	34.97	35.12
NO_x Mass	g/hr		29.66	18.17	7.07	2.00	2.08	0.23
CO Mass	g/hr		3771.2	3180.7	3142.7	3162.4	1804.5	664.3
CO_2 Mass	g/hr		7485	6239	4522	3146	2647	1107
BSHC	g/hp-hr		2.52	3.08	5.59	17.63	23.12	—
$BSNO_x$	g/hp-hr		1.94	1.57	0.92	0.52	1.38	—
BSCO	g/hp-hr		246.68	274.85	409.85	823.53	1193.05	—
$BSCO_2$	g/hp-hr		489.63	539.15	589.69	819.38	1750.32	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.63**	**1.27**	**7.90**	**417.6**	**615.9**	**0.923**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V**

Date: 2/14/03

Test ID: KAW2-BSLN#2

Baseline Test #2 of replacement Kawasaki engine after break-in (TEST VOID-idle emissions invalid)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	~~6~~
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	~~0.05~~
DF Mode Interval (sec)	—		300	300	300	300	300	~~300~~
Speed Set	%Rated		85	85	85	85	85	~~Idle~~
Load Set	%Rated		100	75	50	25	10	~~0~~
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.23	11.42	7.57	3.80	1.47	~~0.00~~
Work (5 min Interval)	hp-hr		1.287	0.965	0.639	0.321	0.124	~~0.000~~
Fuel Flow	lb/hr		9.638	8.245	6.856	5.965	3.891	~~2.668~~
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	~~NA~~
Oil	deg F		270	256	236	217	207	~~191~~
Exhaust Gas (muffler-in/manifold)	deg F		1294	1248	1225	1191	1147	~~798~~
Exhaust Gas (muffler out)	deg F		848	736	642	531	420	~~190~~
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	~~NA~~
Intake Air (EPA)	deg F		93	89	87	85	84	~~84~~
Intake Air DewPoint (EPA)	deg F		64	64	64	63	63	~~62~~
Cyl Head (Spark Plug)	deg F		430	383	347	309	296	~~248~~
PRESSURES								
Exhaust BP Before Cat	psig		0.23	0.14	0.08	0.03	0.00	~~0.00~~
Barometer	"Hg		28.948	28.937	28.939	28.929	28.928	~~28.919~~
F Factor	—		1.053	1.048	1.045	1.043	1.042	~~1.042~~
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		88.59	86.71	95.29	155.01	77.47	~~128.92~~
Dilute CO conc (dry)	%		0.44	0.43	0.38	0.38	0.21	~~0.13~~
Dilute CO_2 conc (dry)	%		0.67	0.51	0.39	0.28	0.23	~~0.17~~
Dilute NO_x conc (dry)	ppm		27.32	10.88	4.92	1.47	1.34	~~0.40~~
Measured A/F	—		11.43	11.02	10.60	9.94	10.61	~~10.78~~
Dry/Wet Correction	—		0.97	0.97	0.98	0.98	0.98	~~0.98~~
NO_x Humidity Correction	—		1.09	1.09	1.08	1.08	1.08	~~1.06~~
Raw O_2 conc (dry)$_{measured}$	%		0.08	0.09	0.11	0.19	0.26	~~0.86~~
HC Mass	g/hr		34.91	34.85	39.18	65.25	32.61	~~56.09~~
NO_x Mass	g/hr		38.88	15.66	7.18	2.10	1.94	~~0.51~~
CO Mass	g/hr		3503.8	3460.4	3133.5	3174.9	1795.8	~~1119.9~~
CO_2 Mass	g/hr		7886	6003	4558	3165	2528	~~1804~~
BSHC	g/hp-hr		2.26	3.01	5.08	16.99	21.57	—
$BSNO_x$	g/hp-hr		2.52	1.35	0.93	0.55	1.28	—
BSCO	g/hp-hr		227.12	299.07	405.97	826.80	1187.73	—
$BSCO_2$	g/hp-hr		511.16	518.82	590.50	824.23	1671.91	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.41**	**1.32**	**7.73**	**423.7**	**618.0**	**0.931**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V

Date: 2/17/03

Test ID: KAW2-BSLN #3

711

Baseline Test #3 of replacement Kawasaki engine after break-in

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.90	11.96	7.94	3.96	1.59	0.04
Work (5 min Interval)	hp-hr		1.344	1.011	0.671	0.335	0.135	0.000
Fuel Flow	lb/hr		8.747	8.624	7.232	5.831	4.172	1.666
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		276	242	224	206	197	180
Exhaust Gas (muffler-in/manifold)	deg F		1381	1246	1225	1173	1143	758
Exhaust Gas (muffler out)	deg F		872	720	614	484	402	159
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		103	106	94	90	88	83
Intake Air DewPoint (EPA)	deg F		36	38	37	37	38	39
Cyl Head (Spark Plug)	deg F		452	380	331	297	288	238
PRESSURES								
Exhaust BP Before Cat	psig		0.18	0.09	0.03	0.00	0.00	0.00
Barometer	"Hg		29.328	29.319	29.318	29.319	29.310	29.305
F Factor	—		1.039	1.043	1.028	1.022	1.021	1.014
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		68.42	89.06	90.00	107.83	81.55	85.60
Dilute CO conc (dry)	%		0.20	0.44	0.37	0.33	0.22	0.08
Dilute CO_2 conc (dry)	%		0.77	0.49	0.40	0.28	0.23	0.12
Dilute NO_x conc (dry)	ppm		96.81	11.47	6.24	2.05	1.36	0.20
Measured A/F	—		12.68	10.88	10.64	10.15	10.45	10.74
Dry/Wet Correction	—		0.99	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.83	0.84	0.84	0.83	0.84	0.84
Raw O_2 conc $(dry)_{measured}$	%		0.07	0.08	0.10	0.18	0.19	0.94
HC Mass	g/hr		27.35	37.05	38.07	46.70	35.43	37.85
NO_x Mass	g/hr		110.37	13.51	7.51	2.49	1.67	0.23
CO Mass	g/hr		1661.6	3760.7	3243.6	2988.6	1966.2	705.7
CO_2 Mass	g/hr		9556	6056	4916	3327	2645	1108
BSHC	g/hp-hr		1.69	3.05	4.72	11.59	22.03	—
$BSNO_x$	g/hp-hr		6.84	1.11	0.93	0.62	1.04	—
BSCO	g/hp-hr		102.91	309.88	402.23	741.47	1222.76	—
$BSCO_2$	g/hp-hr		591.82	498.99	609.57	825.51	1644.80	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**5.21**	**2.08**	**7.29**	**386.1**	**628.0**	**0.893**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: FH601V 19 Hp**

Date: 2/17/03

Test ID: KAW2-BSLN#4

Baseline Test #4 of replacement Kawasaki engine after break-in (methane analysis)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.39	11.78	7.82	3.91	1.55	0.04
Work (5 min Interval)	hp-hr		1.300	0.996	0.660	0.331	0.131	0.000
Fuel Flow	lb/hr		8.405	7.836	6.624	5.506	3.920	1.620
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		286	251	226	208	201	182
Exhaust Gas (muffler-in/manifold)	deg F		1378	1288	1236	1174	1142	770
Exhaust Gas (muffler out)	deg F		846	731	621	491	400	171
Catalyst/Muffler Surface	deg F		NA	NA	NA	NA	NA	NA
Intake Air (EPA)	deg F		112	88	85	82	81	88
Intake Air DewPoint (EPA)	deg F		40	38	39	38	40	38
Cyl Head (Spark Plug)	deg F		462	390	337	302	291	236
PRESSURES								
Exhaust BP Before Cat	psig		0.27	0.14	0.08	0.04	0.01	0.00
Barometer	"Hg		29.182	29.229	29.222	29.210	29.200	29.197
F Factor	—		1.056	1.024	1.020	1.015	1.015	1.024
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		61.36	71.13	79.30	104.97	70.21	79.35
Dilute CO conc (dry)	%		0.20	0.32	0.32	0.32	0.20	0.08
Dilute CO_2 conc (dry)	%		0.75	0.54	0.39	0.27	0.23	0.12
Dilute NO_x conc (dry)	ppm		96.82	20.88	6.92	1.87	1.61	0.16
Measured A/F	—		12.60	11.40	10.95	10.10	10.74	10.73
Dry/Wet Correction	—		0.98	0.99	0.99	0.99	0.99	0.99
NO_x Humidity Correction	—		0.85	0.84	0.84	0.84	0.85	0.84
Raw O_2 conc $(dry)_{measured}$	%		0.08	0.09	0.10	0.16	0.19	0.94
HC Mass	g/hr		23.89	28.78	32.88	44.75	29.80	34.48
NO_x Mass	g/hr		111.41	24.52	8.29	2.25	1.94	0.15
CO Mass	g/hr		1607.1	2684.7	2812.0	2801.4	1759.3	705.7
CO_2 Mass	g/hr		9173	6668	4758	3172	2634	1054
BSHC	g/hp-hr		1.52	2.41	4.15	11.29	18.81	—
$BSNO_x$	g/hp-hr		7.11	2.06	1.05	0.57	1.23	—
BSCO	g/hp-hr		102.55	225.15	355.05	706.97	1110.31	—
$BSCO_2$	g/hp-hr		585.30	559.22	600.75	800.54	1662.62	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.69**	**2.46**	**7.15**	**337.7**	**639.6**	**0.846**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Test ID: KAW2-E-BSLN#1

Development testing with catalyst E, stock carburetion, and no SAI

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp	15.68	11.76	7.78	3.93	1.54	0.00
Work (5 min Interval)	hp-hr	1.325	0.993	0.657	0.332	0.130	0.000
Fuel Flow	lb/hr	9.735	8.554	7.279	6.163	3.940	1.713
TEMPERATURES							
Catalyst Mid-bed	deg F	1329	1247	1169	1107	1009	633
Oil	deg F	277	264	244	224	215	192
Exhaust Gas (muffler-in/manifold)	deg F	1281	1230	1200	1184	1145	747
Exhaust Gas (muffler out)	deg F	1040	940	838	737	560	297
Catalyst/Muffler Surface	deg F	649	598	550	512	427	267
Intake Air (EPA)	deg F	93	91	89	87	85	75
Intake Air DewPoint (EPA)	deg F	60	60	60	61	60	60
Cyl Head (Spark Plug)	deg F	424	385	335	305	292	238
PRESSURES							
Exhaust BP Before Cat	psig	0.26	0.19	0.14	0.10	0.07	0.02
Barometer	"Hg	29.182	29.184	29.188	29.195	29.193	29.183
F Factor	—	1.042	1.039	1.036	1.033	1.031	1.018
GASEOUS EMISSIONS		**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm	52.17	81.83	79.52	105.04	64.65	85.81
Dilute CO conc (dry)	%	0.28	0.27	0.26	0.24	0.11	0.06
Dilute CO_2 conc (dry)	%	0.85	0.70	0.56	0.44	0.34	0.15
Dilute NO_x conc (dry)	ppm	1.08	0.55	0.34	0.19	0.25	0.22
Measured A/F	—	11.81	10.83	10.17	9.15	11.00	10.71
Dry/Wet Correction	—	0.97	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—	1.02	1.02	1.02	1.03	1.02	1.02
Raw O_2 conc $(dry)_{measured}$	%	0.08	0.09	0.10	0.13	0.12	0.31
HC Mass	g/hr	20.82	33.41	33.13	44.67	27.84	37.91
NO_x Mass	g/hr	1.26	0.56	0.28	0.07	0.15	0.11
CO Mass	g/hr	2185.3	2204.3	2123.9	2051.6	914.1	498.3
CO_2 Mass	g/hr	10138	8414	6756	5270	3996	1499
BSHC	g/hp-hr	1.31	2.81	4.18	11.19	17.58	—
$BSNO_x$	g/hp-hr	0.08	0.05	0.03	0.02	0.10	—
BSCO	g/hp-hr	137.48	185.17	267.86	513.94	577.29	—
$BSCO_2$	g/hp-hr	637.80	706.81	852.02	1320.08	2523.39	—
Emission Test Results	—	HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**4.77**	**0.05**	**4.82**	**263.9**	**874.7**	**0.931**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 3/14/03

Test ID: KAW2-E03-#1

Development "engine-out" testing with stock muffler, SAI venturi pipe, and Tier 3 jetting (116/120)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.03	11.34	7.54	3.75	1.50	0.00
Work (5 min Interval)	hp-hr		1.269	0.958	0.637	0.317	0.126	0.000
Fuel Flow	lb/hr		8.898	6.732	5.906	4.535	3.616	1.192
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		289	281	261	239	222	199
Exhaust Gas (muffler-in/manifold)	deg F		1288	1317	1217	1145	1091	769
Exhaust Gas (muffler out)	deg F		NA	NA	NA	NA	NA	NA
Catalyst/Muffler Surface	deg F		524	507	435	364	330	195
Intake Air (EPA)	deg F		101	101	99	97	95	83
Intake Air DewPoint (EPA)	deg F		53	53	52	52	52	52
Cyl Head (Spark Plug)	deg F		459	428	368	329	307	249
PRESSURES								
Exhaust BP Before Cat	psig		0.71	0.58	0.47	0.36	0.07	0.00
Barometer	"Hg		29.030	29.023	29.018	29.016	29.013	29.010
F Factor	—		1.054	1.053	1.052	1.048	1.046	1.030
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		81.27	58.83	63.03	60.22	53.18	71.90
Dilute CO conc (dry)	%		0.34	0.15	0.22	0.19	0.14	0.02
Dilute CO_2 conc (dry)	%		0.67	0.61	0.43	0.31	0.26	0.13
Dilute NO_x conc (dry)	ppm		44.79	63.69	12.68	3.63	2.19	0.40
Measured A/F	—		12.09	13.68	12.64	12.33	12.59	15.03
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.99
NO_x Humidity Correction	—		0.95	0.94	0.94	0.93	0.94	0.93
Raw O_2 conc $(dry)_{measured}$	%		0.30	0.35	0.52	0.82	1.27	5.00
HC Mass	g/hr		31.82	23.16	25.44	24.72	21.93	30.51
NO_x Mass	g/hr		56.64	81.16	16.47	4.79	2.93	0.54
CO Mass	g/hr		2722.2	1215.7	1881.2	1605.0	1231.3	212.1
CO_2 Mass	g/hr		8087	7448	5237	3753	3062	1243
BSHC	g/hp-hr		2.08	2.01	3.32	6.48	14.28	—
$BSNO_x$	g/hp-hr		3.71	7.06	2.15	1.25	1.91	—
BSCO	g/hp-hr		178.26	105.75	245.72	420.61	801.86	—
$BSCO_2$	g/hp-hr		529.55	647.86	684.06	983.58	1994.34	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.55**	**3.89**	**7.43**	**225.6**	**719.1**	**0.774**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 3/14/03

Test ID: KAW2-E-DEV-FNL#1

Final development testing with catalyst E muffler, SAI venturi pipe, and Tier 3 jetting (116/120) w/methane

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.35	11.44	7.67	3.84	1.50	0.00
Work (5 min Interval)	hp-hr		1.297	0.967	0.648	0.324	0.127	0.000
Fuel Flow	lb/hr		8.953	6.567	5.689	4.664	3.430	1.407
TEMPERATURES								
Catalyst Mid-bed	deg F		1359	1390	1247	1175	1136	1067
Oil	deg F		283	269	251	227	214	190
Exhaust Gas (muffler-in/manifold)	deg F		1300	1344	1236	1154	1105	805
Exhaust Gas (muffler out)	deg F		1101	1016	884	743	627	398
Catalyst/Muffler Surface	deg F		474	460	440	403	395	311
Intake Air (EPA)	deg F		90	90	89	88	86	77
Intake Air DewPoint (EPA)	deg F		57	57	56	56	55	55
Cyl Head (Spark Plug)	deg F		453	419	359	317	298	247
PRESSURES								
Exhaust BP Before Cat	psig		0.66	0.54	0.43	0.11	0.07	0.02
Barometer	"Hg		29.179	29.180	29.177	29.172	29.171	29.166
F Factor	—		1.037	1.037	1.035	1.033	1.030	1.018
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		46.68	16.15	26.97	33.62	25.85	16.22
Dilute CO conc (dry)	%		0.19	0.04	0.11	0.11	0.07	0.00
Dilute CO_2 conc (dry)	%		0.84	0.71	0.53	0.41	0.32	0.18
Dilute NO_x conc (dry)	ppm		0.71	1.17	0.06	0.15	0.00	0.38
Measured A/F	—		12.88	13.95	12.67	12.07	12.24	14.61
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		0.98	0.98	0.98	0.97	0.96	0.96
Raw O_2 conc.(dry)$_{measured}$	%		0.46	0.54	0.57	0.82	1.05	3.00
HC Mass	g/hr		17.66	5.44	10.10	13.14	9.91	5.83
NO_x Mass	g/hr		0.92	1.54	0.08	0.20	0.00	0.53
CO Mass	g/hr		1519.7	350.8	921.6	950.1	599.9	27.3
CO_2 Mass	g/hr		10098	8631	6489	4999	3832	1909
BSHC	g/hp-hr		1.13	0.47	1.30	3.38	6.45	—
$BSNO_x$	g/hp-hr		0.06	0.13	0.01	0.05	0.00	—
BSCO	g/hp-hr		97.68	30.20	118.89	244.44	390.68	—
$BSCO_2$	g/hp-hr		649.01	742.86	837.06	1286.28	2495.45	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.45**	**0.07**	**1.52**	**110.8**	**880.6**	**0.756**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 3/14/03

Test ID: KAW2-E-DEV-FNL#2

Final development testing with catalyst E muffler, SAI venturi pipe, and Tier 3 jetting (116/120) w/methane

DESCRIPTION	UNIT		1	2	3	4	5	6
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]					
[redacted]	hp	[redacted]	[redacted]					
[redacted]	ft-lb	[redacted]	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp		15.14	11.43	7.62	3.80	1.51	0.00
Work (5 min Interval)	hp-hr		1.279	0.966	0.644	0.321	0.127	0.000
Fuel Flow	lb/hr		8.807	6.338	5.704	4.299	3.434	1.296
TEMPERATURES								
Catalyst Mid-bed	deg F		1368	1411	1237	1161	1121	1079
Oil	deg F		287	279	257	238	222	202
Exhaust Gas (muffler-in/manifold)	deg F		1301	1348	1226	1146	1096	795
Exhaust Gas (muffler out)	deg F		1118	1037	882	736	619	417
Catalyst/Muffler Surface	deg F		462	485	456	423	399	351
Intake Air (EPA)	deg F		96	96	95	94	92	83
Intake Air DewPoint (EPA)	deg F		53	54	54	53	53	53
Cyl Head (Spark Plug)	deg F		462	429	366	328	306	256
PRESSURES								
Exhaust BP Before Cat	psig		0.68	0.58	0.44	0.14	0.07	0.02
Barometer	"Hg		29.103	29.091	29.083	29.078	29.071	29.066
F Factor	—		1.045	1.046	1.044	1.042	1.041	1.029
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		33.78	10.65	29.11	28.71	30.24	16.57
Dilute CO conc (dry)	%		0.19	0.03	0.11	0.09	0.07	0.00
Dilute CO_2 conc (dry)	%		0.83	0.70	0.53	0.39	0.32	0.17
Dilute NO_x conc (dry)	ppm		1.11	0.14	0.33	0.15	0.07	0.30
Measured A/F	—		12.93	14.12	12.69	12.23	12.42	14.51
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		0.95	0.95	0.95	0.94	0.94	0.95
Raw O_2 conc $(dry)_{measured}$	%		0.44	0.59	0.60	0.75	1.01	3.00
HC Mass	g/hr		12.53	3.35	11.12	11.14	11.92	6.15
NO_x Mass	g/hr		1.38	0.18	0.43	0.20	0.09	0.41
CO Mass	g/hr		1469.4	224.8	925.6	790.3	587.3	14.5
CO_2 Mass	g/hr		9988	8514	6500	4745	3850	1773
BSHC	g/hp-hr		0.81	0.29	1.44	2.90	7.71	—
$BSNO_x$	g/hp-hr		0.09	0.02	0.06	0.05	0.06	—
BSCO	g/hp-hr		95.52	19.45	119.85	205.74	379.51	—
$BSCO_2$	g/hp-hr		649.27	736.79	841.69	1235.33	2488.07	—

Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.32**	**0.05**	**1.37**	**100.7**	**871.1**	**0.738**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

SwRI

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 4/14/03

Test ID: KAW2-125-E-#1

717

125-hour interval emission test "as-received" from durability with catalyst E, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.18	11.34	7.59	3.80	1.51	0.00
Work (5 min Interval)	hp-hr		1.282	0.959	0.641	0.321	0.128	0.000
Fuel Flow	lb/hr		8.877	6.653	5.801	4.477	3.459	1.263
TEMPERATURES								
Catalyst Mid-bed	deg F		1207	1187	1076	978	929	661
Oil	deg F		274	266	243	224	214	187
Exhaust Gas (muffler-in/manifold)	deg F		1317	1359	1259	1182	1137	796
Exhaust Gas (muffler out)	deg F		1075	993	841	694	600	337
Catalyst/Muffler Surface	deg F		707	694	614	545	510	347
Intake Air (EPA)	deg F		87	88	88	86	85	75
Intake Air DewPoint (EPA)	deg F		58	58	58	58	57	57
Cyl Head (Spark Plug)	deg F		432	407	350	312	296	248
PRESSURES								
Exhaust BP Before Cat	psig		1.17	0.72	0.43	0.20	0.11	-0.09
Barometer	"Hg		29.264	29.270	29.273	29.278	29.277	29.276
F Factor	—		1.030	1.031	1.030	1.027	1.026	1.013
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		38.56	24.27	33.97	37.84	30.16	12.17
Dilute CO conc (dry)	%		0.23	0.07	0.13	0.12	0.08	0.00
Dilute CO_2 conc (dry)	%		0.81	0.70	0.53	0.39	0.32	0.17
Dilute NO_x conc (dry)	ppm		0.30	1.49	0.44	0.29	0.22	0.45
Measured A/F	—		12.69	13.75	12.69	12.27	12.58	15.01
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.00	0.99	0.99	0.99	0.98	0.98
Raw O_2 conc $(dry)_{measured}$	%		0.35	0.47	0.55	0.71	0.88	2.70
HC Mass	g/hr		14.02	8.45	12.71	14.57	11.42	3.74
NO_x Mass	g/hr		0.34	1.93	0.56	0.36	0.26	0.59
CO Mass	g/hr		1763.8	547.1	1057.0	984.5	650.5	3.1
CO_2 Mass	g/hr		9618	8433	6425	4678	3788	1753
BSHC	g/hp-hr		0.91	0.73	1.65	3.78	7.38	—
$BSNO_x$	g/hp-hr		0.02	0.17	0.07	0.09	0.17	—
BSCO	g/hp-hr		114.96	47.49	137.36	255.67	420.34	—
$BSCO_2$	g/hp-hr		626.90	732.01	834.93	1214.90	2447.63	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.67**	**0.10**	**1.77**	**127.5**	**859.6**	**0.760**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 4/14/03

Test ID: KAW2-125-E-#2

125-hour interval emission test "as-received" from durability with catalyst E, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT						
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]					
[redacted]	hp	[redacted]					
[redacted]	ft-lb	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp	15.13	11.36	7.54	3.77	1.50	0.00
Work (5 min Interval)	hp-hr	1.278	0.960	0.637	0.319	0.127	0.000
Fuel Flow	lb/hr	9.074	6.797	5.656	4.366	3.490	1.221
TEMPERATURES							
Catalyst Mid-bed	deg F	1369	1385	1283	1229	1217	803
Oil	deg F	280	269	244	229	218	193
Exhaust Gas (muffler-in/manifold)	deg F	1315	1342	1252	1179	1143	808
Exhaust Gas (muffler out)	deg F	1085	1064	958	852	765	370
Catalyst/Muffler Surface	deg F	725	705	628	565	538	345
Intake Air (EPA)	deg F	91	92	91	90	89	80
Intake Air DewPoint (EPA)	deg F	57	57	57	57	56	55
Cyl Head (Spark Plug)	deg F	438	410	353	316	301	253
PRESSURES							
Exhaust BP Before Cat	psig	1.10	0.65	0.33	0.12	0.04	-0.17
Barometer	"Hg	29.269	29.233	29.223	29.214	29.215	29.212
F Factor	—	1.034	1.037	1.036	1.035	1.033	1.021
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	43.77	30.74	30.02	29.59	23.85	14.89
Dilute CO conc (dry)	%	0.23	0.08	0.12	0.10	0.06	0.00
Dilute CO_2 conc (dry)	%	0.83	0.71	0.53	0.40	0.34	0.16
Dilute NO_x conc (dry)	ppm	1.12	1.04	0.27	0.24	0.26	0.56
Measured A/F	—	12.74	13.65	12.82	12.46	12.80	15.96
Dry/Wet Correction	—	0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—	0.98	0.98	0.98	0.98	0.97	0.97
Raw O_2 conc $(dry)_{measured}$	%	0.55	0.66	0.80	1.04	1.25	4.43
HC Mass	g/hr	16.02	10.98	10.91	10.92	8.59	4.88
NO_x Mass	g/hr	1.27	1.18	0.19	0.15	0.18	0.60
CO Mass	g/hr	1779.1	629.4	961.5	828.3	531.1	9.1
CO_2 Mass	g/hr	9865	8498	6377	4780	4028	1681
BSHC	g/hp-hr	1.04	0.95	1.43	2.85	5.59	—
$BSNO_x$	g/hp-hr	0.08	0.10	0.03	0.04	0.12	—
BSCO	g/hp-hr	115.74	54.48	125.78	216.31	345.99	—
$BSCO_2$	g/hp-hr	641.74	735.64	834.26	1248.17	2623.82	—
Emission Test Results	—	HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**1.52**	**0.07**	**1.59**	**118.7**	**870.2**	**0.758**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

719

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 4/15/03

Test ID: KAW2-125-STK-#1

125-hr. testing of Kawasaki with stock muffler, no SAI system, and stock jetting (136/140)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		15.02	11.23	7.54	3.71	1.49	0.00
Work (5 min Interval)	hp-hr		1.269	0.949	0.637	0.314	0.126	0.000
Fuel Flow	lb/hr		10.742	8.044	6.686	5.039	3.478	1.141
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		260	249	237	222	215	187
Exhaust Gas (muffler-in/manifold)	deg F		1211	1228	1203	1165	1167	787
Exhaust Gas (muffler out)	deg F		182	657	570	461	380	157
Catalyst/Muffler Surface	deg F		478	437	397	339	305	166
Intake Air (EPA)	deg F		90	89	89	88	87	78
Intake Air DewPoint (EPA)	deg F		59	59	59	58	58	58
Cyl Head (Spark Plug)	deg F		404	378	336	305	298	238
PRESSURES								
Exhaust BP Before Cat	psig		0.54	0.30	0.16	0.04	-0.03	-0.13
Barometer	"Hg		29.130	29.126	29.123	29.110	29.107	29.099
F Factor	—		1.039	1.039	1.038	1.036	1.035	1.024
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		144.34	105.78	103.37	95.40	50.16	94.62
Dilute CO conc (dry)	%		0.68	0.43	0.37	0.29	0.14	0.01
Dilute CO_2 conc (dry)	%		0.54	0.47	0.37	0.27	0.26	0.13
Dilute NO_x conc (dry)	ppm		8.02	8.51	4.87	2.47	2.31	0.76
Measured A/F	—		10.15	11.13	10.72	10.41	12.28	14.70
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.00	1.01	1.00	1.00	0.99	1.00
Raw O_2 conc $(dry)_{measured}$	%		0.12	0.13	0.12	0.16	0.17	3.00
HC Mass	g/hr		56.47	41.80	41.45	38.65	19.60	39.58
NO_x Mass	g/hr		10.21	11.10	6.27	3.00	2.76	0.61
CO Mass	g/hr		5413.3	3525.7	3094.8	2441.3	1151.9	107.7
CO_2 Mass	g/hr		6365	5597	4373	3103	3000	1306
BSHC	g/hp-hr		3.71	3.68	5.44	10.23	12.96	—
$BSNO_x$	g/hp-hr		0.67	0.98	0.82	0.79	1.83	—
BSCO	g/hp-hr		355.77	310.15	406.15	645.84	761.81	—
$BSCO_2$	g/hp-hr		418.31	492.37	573.91	820.81	1984.35	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**5.70**	**0.86**	**6.55**	**410.0**	**587.5**	**0.892**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 4/15/03

Test ID: KAW2-125-STK-#2

125-hr. testing of Kawasaki with stock muffler, no SAI system, and stock jetting (136/140)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]					
[redacted]	hp	[redacted]	[redacted]					
[redacted]	ft-lb	[redacted]	[redacted]					
Calc. Power (Obs. Torque*Speed)	hp		14.95	11.24	7.51	3.73	1.49	0.00
Work (5 min Interval)	hp-hr		1.263	0.950	0.634	0.315	0.126	0.000
Fuel Flow	lb/hr		10.817	8.683	6.626	5.074	3.440	1.253
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		268	257	241	226	218	193
Exhaust Gas (muffler-in/manifold)	deg F		1203	1211	1200	1166	1167	826
Exhaust Gas (muffler out)	deg F		749	661	569	462	381	164
Catalyst/Muffler Surface	deg F		481	449	398	343	309	174
Intake Air (EPA)	deg F		93	92	91	89	89	80
Intake Air DewPoint (EPA)	deg F		58	58	58	57	58	57
Cyl Head (Spark Plug)	deg F		407	382	338	307	300	249
PRESSURES								
Exhaust BP Before Cat	psig		0.59	0.36	0.18	0.05	-0.02	-0.13
Barometer	"Hg		29.084	29.073	29.070	29.061	29.062	29.050
F Factor	—		1.045	1.043	1.042	1.039	1.039	1.027
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		151.56	131.35	103.33	98.03	50.47	83.94
Dilute CO conc (dry)	%		0.70	0.52	0.38	0.29	0.13	0.01
Dilute CO_2 conc (dry)	%		0.53	0.45	0.36	0.27	0.26	0.15
Dilute NO_x conc (dry)	ppm		7.59	6.55	4.71	2.49	2.49	0.86
Measured A/F	—		9.99	9.80	10.77	10.45	12.26	14.16
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.00	1.00	1.00	0.99	0.99	0.99
Raw O_2 conc $(dry)_{measured}$	%		0.10	0.12	0.12	0.16	0.17	2.80
HC Mass	g/hr		59.55	52.29	41.63	40.11	20.07	35.15
NO_x Mass	g/hr		9.59	8.35	5.99	2.97	3.02	0.76
CO Mass	g/hr		5565.3	4254.0	3127.1	2464.3	1118.8	106.8
CO_2 Mass	g/hr		6222	5316	4238	3111	2998	1479
BSHC	g/hp-hr		3.92	4.60	5.47	10.58	13.17	—
$BSNO_x$	g/hp-hr		0.63	0.73	0.79	0.78	1.98	—
BSCO	g/hp-hr		366.79	374.01	410.89	650.09	734.13	—
$BSCO_2$	g/hp-hr		410.04	467.41	556.84	820.69	1967.29	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**6.08**	**0.76**	**6.84**	**434.5**	**573.8**	**0.911**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 4/16/03

Test ID: KAW2-125-EO3-#3

721

125-hr. testing with stock muffler, passive SAI, and Tier 3 jetting (116/120)

DESCRIPTION	UNIT							
Mode	——		1	2	3	4	5	6
Weight Factor	——		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	——		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		14.95	11.21	7.54	3.74	1.49	0.00
Work (5 min Interval)	hp-hr		1.263	0.948	0.637	0.316	0.126	0.000
Fuel Flow	lb/hr		8.747	6.504	5.542	4.324	3.259	1.167
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		279	272	253	235	221	194
Exhaust Gas (muffler-in/manifold)	deg F		1312	1347	1250	1178	1136	742
Exhaust Gas (muffler out)	deg F		808	719	582	444	364	171
Catalyst/Muffler Surface	deg F		553	532	463	390	362	195
Intake Air (EPA)	deg F		98	99	97	94	93	82
Intake Air DewPoint (EPA)	deg F		57	57	56	55	56	56
Cyl Head (Spark Plug)	deg F		444	417	360	321	304	236
PRESSURES								
Exhaust BP Before Cat	psig		1.23	0.77	0.43	0.19	0.09	-0.11
Barometer	"Hg		28.989	28.984	28.980	28.977	28.973	28.964
F Factor	——		1.054	1.055	1.052	1.048	1.047	1.032
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		87.04	62.66	65.00	56.91	46.86	136.01
Dilute CO conc (dry)	%		0.32	0.13	0.20	0.17	0.12	0.01
Dilute CO_2 conc (dry)	%		0.69	0.62	0.43	0.32	0.26	0.14
Dilute NO_x conc (dry)	ppm		46.31	63.66	13.48	4.30	2.65	0.99
Measured A/F	——		12.88	13.84	12.83	12.56	12.96	17.09
Dry/Wet Correction	——		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	——		0.99	0.99	0.98	0.97	0.98	0.97
Raw O_2 conc $(dry)_{measured}$	%		0.29	0.41	0.53	0.80	1.11	5.80
HC Mass	g/hr		33.99	24.61	26.06	23.12	19.04	58.21
NO_x Mass	g/hr		60.06	83.63	18.04	5.77	3.63	1.39
CO Mass	g/hr		2519.6	1027.0	1643.1	1433.4	987.4	33.3
CO_2 Mass	g/hr		8187	7420	5100	3733	2955	1402
BSHC	g/hp-hr		2.24	2.17	3.43	6.10	12.49	——
$BSNO_x$	g/hp-hr		3.96	7.37	2.38	1.52	2.38	——
BSCO	g/hp-hr		166.11	90.57	216.38	378.00	647.90	——
$BSCO_2$	g/hp-hr		539.74	654.28	671.66	984.44	1938.91	——
Emission Test Results	——		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**3.77**	**4.16**	**7.93**	**199.1**	**719.9**	**0.746**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
4/22/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**
Date: 5/6/03
Test ID: KAW2-250-E-#1

250-hour interval emission test "as-received" from durability with catalyst E, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		14.76	11.08	7.41	3.72	1.50	0.00
Work (5 min Interval)	hp-hr		1.247	0.936	0.626	0.314	0.127	0.000
Fuel Flow	lb/hr		8.593	6.794	6.000	4.511	3.687	1.590
TEMPERATURES								
Catalyst Mid-bed	deg F		1381	1378	1249	1169	1150	904
Oil	deg F		283	274	249	229	221	196
Exhaust Gas (muffler-in/manifold)	deg F		1357	1372	1263	1190	1165	783
Exhaust Gas (muffler out)	deg F		1103	1020	852	701	616	342
Catalyst/Muffler Surface	deg F		717	730	664	598	570	410
Intake Air (EPA)	deg F		101	100	96	94	93	87
Intake Air DewPoint (EPA)	deg F		62	62	63	65	67	66
Cyl Head (Spark Plug)	deg F		443	415	358	321	308	244
PRESSURES								
Exhaust BP Before Cat	psig		1.20	0.78	0.45	0.23	0.13	-0.07
Barometer	"Hg		28.816	28.831	28.838	28.846	28.860	28.854
F Factor	—		1.068	1.066	1.062	1.060	1.059	1.050
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		41.80	27.70	38.60	33.00	30.00	17.40
Dilute CO conc (dry)	%		0.17	0.06	0.14	0.12	0.08	0.00
Dilute CO_2 conc (dry)	%		0.81	0.70	0.52	0.37	0.32	0.17
Dilute NO_x conc (dry)	ppm		1.10	1.20	0.39	0.24	0.34	0.69
Measured A/F	—		13.17	13.84	12.67	12.32	12.73	15.96
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.06	1.06	1.08	1.11	1.15	1.13
Raw O_2 conc $(dry)_{measured}$	%		0.45	0.55	0.60	0.76	0.88	4.50
HC Mass	g/hr		15.67	10.27	15.00	12.95	11.77	6.58
NO_x Mass	g/hr		1.48	1.62	0.53	0.33	0.50	1.07
CO Mass	g/hr		1330.5	507.0	1122.0	963.2	634.2	25.7
CO_2 Mass	g/hr		9897	8688	6595	4765	4131	2166
BSHC	g/hp-hr		1.04	0.91	2.01	3.45	7.72	—
$BSNO_x$	g/hp-hr		0.10	0.14	0.07	0.09	0.33	—
BSCO	g/hp-hr		88.63	44.96	150.27	256.52	416.01	—
$BSCO_2$	g/hp-hr		659.24	770.48	883.22	1269.07	2709.64	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.83**	**0.11**	**1.95**	**125.8**	**909.1**	**0.794**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 5/6/03

723

Test ID: KAW2-250-E-#2

250-hour interval emission test "as-received" from durability with catalyst E, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs. Speed	rpm		3060	3073	3054	3054	3079	1572
Obs. Power	hp		14.79	11.16	7.35	3.66	1.48	0.00
Obs. Torque	ft-lb		25.03	18.82	12.47	6.20	2.48	0.00
Calc. Power (Obs. Torque*Speed)	hp		14.59	11.01	7.25	3.61	1.46	0.00
Work (5 min Interval)	hp-hr		1.232	0.930	0.613	0.305	0.123	0.000
Fuel Flow	lb/hr		8.402	6.829	5.818	4.531	3.712	1.522
TEMPERATURES								
Catalyst Mid-bed	deg F		1394	1367	1246	1170	1154	862
Oil	deg F		287	275	252	232	224	198
Exhaust Gas (muffler-in/manifold)	deg F		1372	1368	1261	1193	1173	807
Exhaust Gas (muffler out)	deg F		1105	1006	845	700	620	332
Catalyst/Muffler Surface	deg F		723	721	658	597	567	378
Intake Air (EPA)	deg F		102	101	98	96	96	90
Intake Air DewPoint (EPA)	deg F		67	66	66	66	65	64
Cyl Head (SparkPlug)	deg F		447	416	359	324	313	250
PRESSURES								
Exhaust BP Before Cat	psig		1.19	0.79	0.42	0.20	0.13	-0.07
Barometer	"Hg		28.834	28.809	28.798	28.795	28.791	28.784
F Factor	—		1.073	1.071	1.067	1.065	1.064	1.055
GASEOUS EMISSIONS			**EMISSIONS ARE UNWEIGHTED[1] (ETIS)**					
Dilute HC conc (wet)	ppm		37.40	25.50	37.10	34.60	26.50	13.30
Dilute CO conc (dry)	%		0.15	0.08	0.14	0.12	0.07	0.00
Dilute CO_2 conc (dry)	%		0.83	0.70	0.51	0.38	0.33	0.16
Dilute NO_x conc (dry)	ppm		1.13	0.99	0.28	0.14	0.37	0.59
Measured A/F	—		13.35	13.70	12.66	12.39	12.81	15.94
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.16	1.13	1.13	1.13	1.12	1.10
Raw O_2 conc $(dry)_{measured}$	%		0.44	0.50	0.60	0.73	0.87	4.50
HC Mass	g/hr		13.75	9.27	14.23	13.45	10.18	4.73
NO_x Mass	g/hr		1.62	1.41	0.39	0.18	0.53	0.87
CO Mass	g/hr		1133.8	619.4	1096.6	945.3	606.4	17.1
CO_2 Mass	g/hr		9945	8564	6382	4819	4215	2091
BSHC	g/hp-hr		0.93	0.84	1.94	3.65	6.84	—
$BSNO_x$	g/hp-hr		0.11	0.13	0.05	0.05	0.36	—
BSCO	g/hp-hr		76.69	55.78	149.32	256.61	407.41	—
$BSCO_2$	g/hp-hr		672.65	771.20	869.05	1308.12	2831.90	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**1.77**	**0.10**	**1.87**	**126.4**	**914.9**	**0.799**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 5/7/03

Test ID: KAW2-250-E-#3

250-hour interval emission test "as-received" from durability with catalyst E, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		14.74	11.00	7.40	3.68	1.47	0.00
Work (5 min Interval)	hp-hr		1.245	0.929	0.625	0.311	0.125	0.000
Fuel Flow	lb/hr		8.531	6.612	5.862	4.649	3.898	1.633
TEMPERATURES								
Catalyst Mid-bed	deg F		1383	1379	1254	1169	1153	1053
Oil	deg F		285	270	252	232	221	196
Exhaust Gas (muffler-in/manifold)	deg F		1361	1377	1270	1195	1176	717
Exhaust Gas (muffler out)	deg F		1101	1010	855	700	618	377
Catalyst/Muffler Surface	deg F		721	723	652	582	556	460
Intake Air (EPA)	deg F		99	97	96	94	93	86
Intake Air DewPoint (EPA)	deg F		68	68	67	67	67	66
Cyl Head (Spark Plug)	deg F		441	413	360	323	311	228
PRESSURES								
Exhaust BP Before Cat	psig		1.18	0.74	0.43	0.20	0.12	-0.07
Barometer	"Hg		28.925	28.933	28.932	28.929	28.929	28.929
F Factor	—		1.067	1.063	1.060	1.058	1.056	1.047
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		40.20	23.50	35.70	35.30	27.20	24.10
Dilute CO conc (dry)	%		0.17	0.05	0.13	0.12	0.08	0.00
Dilute CO_2 conc (dry)	%		0.82	0.70	0.52	0.39	0.34	0.17
Dilute NO_x conc (dry)	ppm		0.98	1.39	0.28	0.14	0.16	0.72
Measured A/F	—		13.20	13.96	12.76	12.41	12.84	16.28
Dry/Wet Correction	—		0.98	0.98	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.18	1.18	1.15	1.15	1.15	1.14
Raw O_2 conc $(dry)_{measured}$	%		0.44	0.55	0.61	0.74	0.93	5.00
HC Mass	g/hr		15.00	8.61	13.80	13.91	10.63	9.51
NO_x Mass	g/hr		1.40	2.07	0.37	0.16	0.19	1.08
CO Mass	g/hr		1293.9	410.0	1051.4	958.6	677.3	34.2
CO_2 Mass	g/hr		9869	8591	6516	4962	4362	2204
BSHC	g/hp-hr		1.00	0.77	1.84	3.72	7.22	—
$BSNO_x$	g/hp-hr		0.09	0.18	0.05	0.04	0.13	—
BSCO	g/hp-hr		86.43	36.61	140.41	256.11	460.19	—
$BSCO_2$	g/hp-hr		659.23	767.02	870.21	1325.81	2963.68	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC (lb/hp-hr)
Weighted Specific Emissions[3]	g/hp-hr		**1.78**	**0.11**	**1.89**	**120.3**	**916.3**	**0.793**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

5/20/2003

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 5/7/03

Test ID: KAW2-250-EO3-#1

250-hour interval engine-out emission test with stock muffler, Tier 3 jetting (116/120), and passive SAI system. (methane test)

725

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
Obs Speed	rpm		3062	3063	3070	3069	3057	1580
Obs Power	hp		14.93	11.20	7.49	3.73	1.48	0.002
Obs Torque	ft-lb		25.26	18.93	12.64	6.29	2.51	0.005
Calc. Power (Obs. Torque*Speed)	hp		14.73	11.04	7.39	3.68	1.46	0.00
Work (5 min Interval)	hp-hr		1.244	0.933	0.624	0.311	0.123	0.000
Fuel Flow	lb/hr		8.837	6.573	5.744	4.560	3.699	1.530
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		284	271	256	237	226	194
Exhaust Gas (muffler-in/manifold)	deg F		1349	1383	1274	1200	1192	635
Exhaust Gas (muffler out)	deg F		814	715	576	440	375	158
Catalyst/Muffler Surface	deg F		820	772	643	528	495	229
Intake Air (EPA)	deg F		102	100	99	97	96	89
Intake Air DewPoint (EPA)	deg F		65	64	64	64	64	63
Cyl Head (Spark Plug)	deg F		440	415	363	327	317	209
PRESSURES								
Exhaust BP Before Cat	psig		1.28	0.80	0.45	0.20	0.12	-0.08
Barometer	"Hg		28.905	28.899	28.882	28.876	28.868	28.857
F Factor	—		1.068	1.065	1.065	1.062	1.061	1.051
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		90.50	55.90	65.60	57.20	43.60	248.00
Dilute CO conc (dry)	%		0.30	0.10	0.19	0.17	0.11	0.01
Dilute CO_2 conc (dry)	%		0.70	0.63	0.43	0.32	0.28	0.12
Dilute NO_x conc (dry)	ppm		45.30	65.40	12.20	3.90	2.40	1.00
Measured A/F	—		12.96	14.03	12.82	12.59	13.10	17.38
Dry/Wet Correction	—		0.97	0.97	0.98	0.98	0.98	0.98
NO_x Humidity Correction	—		1.11	1.09	1.10	1.10	1.09	1.08
Raw O_2 conc $(dry)_{measured}$	%		0.30	0.46	0.51	0.76	1.03	8.00
HC Mass	g/hr		35.20	21.82	26.21	23.15	17.59	105.90
NO_x Mass	g/hr		64.06	94.14	17.65	5.83	3.62	1.52
CO Mass	g/hr		2320.3	783.1	1574.8	1373.2	931.3	111.4
CO_2 Mass	g/hr		8623	7908	5491	4158	3663	1641
BSHC	g/hp-hr		2.36	1.95	3.49	6.18	11.83	—
$BSNO_x$	g/hp-hr		4.30	8.43	2.35	1.56	2.43	—
BSCO	g/hp-hr		155.61	70.12	209.56	366.78	626.06	—
$BSCO_2$	g/hp-hr		578.32	708.12	730.67	1110.45	2462.65	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.10**	**4.55**	**8.65**	**186.9**	**792.8**	**0.785**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL
5/20/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 5/8/03

Test ID: KAW2-250-EO3-#2

250-hour interval engine-out emission test with stock muffler, Tier 3 jetting (116/120), and passive SAI system. (methane test)

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		14.71	11.11	7.42	3.67	1.47	0.00
Work (5 min Interval)	hp-hr		1.243	0.939	0.627	0.310	0.124	0.000
Fuel Flow	lb/hr		8.586	6.287	5.504	4.231	3.380	1.218
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		283	271	250	230	221	188
Exhaust Gas (muffler-in/manifold)	deg F		1344	1385	1279	1204	1195	632
Exhaust Gas (muffler out)	deg F		819	725	577	442	377	153
Catalyst/Muffler Surface	deg F		816	772	644	526	494	225
Intake Air (EPA)	deg F		99	98	95	94	93	85
Intake Air DewPoint (EPA)	deg F		67	67	67	67	67	66
Cyl Head (Spark Plug)	deg F		437	414	359	323	313	203
PRESSURES								
Exhaust BP Before Cat	psig		1.26	0.79	0.45	0.20	0.11	-0.11
Barometer	"Hg		28.880	28.894	28.888	28.891	28.889	28.884
F Factor	—		1.067	1.064	1.061	1.059	1.058	1.047
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		96.75	59.47	70.07	60.45	47.06	264.32
Dilute CO conc (dry)	%		0.31	0.10	0.19	0.17	0.12	0.01
Dilute CO_2 conc (dry)	%		0.70	0.64	0.44	0.32	0.28	0.13
Dilute NO_x conc (dry)	ppm		42.81	64.64	12.12	3.88	2.48	1.12
Measured A/F	—		12.92	14.06	12.88	12.58	13.08	17.65
Dry/Wet Correction	—		0.97	0.97	0.97	0.97	0.97	0.98
NO_x Humidity Correction	—		1.14	1.15	1.15	1.16	1.16	1.13
Raw O_2 conc $(dry)_{measured}$	%		0.32	0.50	0.56	0.86	1.13	8.00
HC Mass	g/hr		37.03	22.62	27.48	23.93	18.42	112.85
NO_x Mass	g/hr		61.80	96.51	17.84	5.40	3.24	1.04
CO Mass	g/hr		2404.6	770.8	1590.0	1403.5	974.4	88.5
CO_2 Mass	g/hr		8133	7525	5126	3647	3147	1218
BSHC	g/hp-hr		2.48	2.01	3.66	6.41	12.38	—
$BSNO_x$	g/hp-hr		4.14	8.59	2.38	1.45	2.18	—
BSCO	g/hp-hr		161.03	68.59	211.80	376.18	654.81	—
$BSCO_2$	g/hp-hr		544.66	669.66	682.87	977.58	2114.75	—
Emission Test Results	—		HC	NO_x	$HC+NO_x$	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		**4.28**	**4.57**	**8.85**	**189.6**	**729.3**	**0.743**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

5/20/2003

Steady-State SORE Engine Test Information **Engine: Kawasaki FH601V #2**

Date: 5/8/03

Test ID: KAW2-250-STK-#1

727

250-hour interval stock engine-out emission test with stock muffler, and stock jetting (136/140).

DESCRIPTION	UNIT							
Mode	—		1	2	3	4	5	6
Weight Factor	—		0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—		300	300	300	300	300	300
Speed Set	%Rated		85	85	85	85	85	Idle
Load Set	%Rated		100	75	50	25	10	0
ENGINE DATA								
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp		14.80	10.94	7.31	3.66	1.46	0.00
Work (5 min Interval)	hp-hr		1.250	0.925	0.617	0.309	0.123	0.000
Fuel Flow	lb/hr		10.378	7.987	6.724	5.270	3.357	1.201
TEMPERATURES								
Catalyst Mid-bed	deg F		NA	NA	NA	NA	NA	NA
Oil	deg F		268	260	245	229	224	197
Exhaust Gas (muffler-in/manifold)	deg F		1238	1244	1212	1188	1224	653
Exhaust Gas (muffler out)	deg F		789	693	592	490	389	165
Catalyst/Muffler Surface	deg F		656	593	526	450	406	207
Intake Air (EPA)	deg F		95	96	95	94	93	85
Intake Air DewPoint (EPA)	deg F		66	65	65	65	65	65
Cyl Head (Spark Plug)	deg F		407	385	342	314	314	215
PRESSURES								
Exhaust BP Before Cat	psig		0.48	0.27	0.14	0.02	-0.04	-0.17
Barometer	"Hg		28.865	28.859	28.854	28.852	28.848	28.839
F Factor	—		1.061	1.062	1.061	1.059	1.059	1.048
GASEOUS EMISSIONS			EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm		160.98	124.36	121.67	132.04	49.19	264.78
Dilute CO conc (dry)	%		0.66	0.45	0.41	0.33	0.11	0.01
Dilute CO_2 conc (dry)	%		0.55	0.47	0.36	0.27	0.28	0.13
Dilute NO_x conc (dry)	ppm		8.29	7.58	3.99	2.08	2.66	1.16
Measured A/F	—		10.34	11.01	10.32	9.97	12.72	16.62
Dry/Wet Correction	—		0.97	0.97	0.97	0.98	0.98	0.98
NO_x Humidity Correction	—		1.12	1.12	1.12	1.11	1.11	1.12
Raw O_2 conc $(dry)_{measured}$	%		0.13	0.13	0.14	0.19	0.19	6.00
HC Mass	g/hr		61.94	48.52	48.19	53.24	19.05	111.68
NO_x Mass	g/hr		11.51	10.65	5.47	2.68	3.58	1.33
CO Mass	g/hr		5131.1	3581.8	3292.6	2686.5	952.3	65.7
CO_2 Mass	g/hr		6282	5409	4095	2996	3146	1235
BSHC	g/hp-hr		4.17	4.37	6.51	14.36	13.02	—
$BSNO_x$	g/hp-hr		0.77	0.96	0.74	0.72	2.44	—
BSCO	g/hp-hr		345.22	322.33	445.00	724.76	650.89	—
$BSCO_2$	g/hp-hr		422.65	486.81	553.48	808.26	2150.49	—
Emission Test Results	—		HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr		7.54	0.85	8.38	434.8	580.3	0.919

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

SwRI Proj: 08-05734

CCL

5/20/2003

Steady-State SORE Engine Test Information Engine: Kawasaki FH601V #2

Date: 5/8/03

Test ID: KAW2-250-STK-#2

250-hour interval stock engine-out emission test with stock muffler, and stock jetting (136/140). (methane test)

DESCRIPTION	UNIT	1	2	3	4	5	6
Mode	—	1	2	3	4	5	6
Weight Factor	—	0.09	0.20	0.29	0.30	0.07	0.05
DF Mode Interval (sec)	—	300	300	300	300	300	300
Speed Set	%Rated	85	85	85	85	85	Idle
Load Set	%Rated	100	75	50	25	10	0
ENGINE DATA							
[redacted]	rpm	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	hp	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	ft-lb	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Calc. Power (Obs. Torque*Speed)	hp	14.76	11.02	7.32	3.66	1.43	0.00
Work (5 min Interval)	hp-hr	1.247	0.931	0.618	0.309	0.121	0.000
Fuel Flow	lb/hr	10.395	8.124	6.697	5.212	3.235	1.229
TEMPERATURES							
Catalyst Mid-bed	deg F	NA	NA	NA	NA	NA	NA
Oil	deg F	268	261	247	232	226	194
Exhaust Gas (muffler-in/manifold)	deg F	1235	1244	1215	1191	1231	527
Exhaust Gas (muffler out)	deg F	792	690	594	491	414	150
Catalyst/Muffler Surface	deg F	656	593	529	452	406	187
Intake Air (EPA)	deg F	98	98	97	96	95	87
Intake Air DewPoint (EPA)	deg F	65	65	65	64	64	65
Cyl Head (Spark Plug)	deg F	407	386	344	316	316	184
PRESSURES							
Exhaust BP Before Cat	psig	0.47	0.26	0.14	0.02	-0.05	-0.17
Barometer	"Hg	28.835	28.828	28.821	28.816	28.811	28.806
F Factor	—	1.065	1.066	1.064	1.063	1.062	1.052
GASEOUS EMISSIONS		EMISSIONS ARE UNWEIGHTED[1] (ETIS)					
Dilute HC conc (wet)	ppm	163.46	127.01	121.21	128.57	47.31	379.68
Dilute CO conc (dry)	%	0.66	0.46	0.41	0.32	0.10	0.01
Dilute CO_2 conc (dry)	%	0.55	0.48	0.36	0.27	0.28	0.12
Dilute NO_x conc (dry)	ppm	8.28	7.61	4.04	2.08	2.61	1.25
Measured A/F	—	10.29	10.97	10.35	10.02	12.89	17.60
Dry/Wet Correction	—	0.97	0.97	0.97	0.98	0.98	0.98
NO_x Humidity Correction	—	1.11	1.12	1.11	1.10	1.10	1.11
Raw O_2 conc $(dry)_{measured}$	%	0.13	0.12	0.14	0.19	0.19	8.00
HC Mass	g/hr	62.25	48.80	47.28	51.02	17.68	159.78
NO_x Mass	g/hr	11.33	10.54	5.48	2.61	3.41	1.43
CO Mass	g/hr	5160.7	3643.3	3280.5	2647.2	854.8	99.5
CO_2 Mass	g/hr	6258	5503	4079	2983	3133	1072
BSHC	g/hp-hr	4.17	4.36	6.35	13.68	12.09	—
$BSNO_x$	g/hp-hr	0.76	0.94	0.74	0.70	2.33	—
BSCO	g/hp-hr	345.87	325.52	440.36	709.56	584.27	—
$BSCO_2$	g/hp-hr	419.44	491.66	547.61	799.58	2141.64	—
Emission Test Results	—	HC	NO_x	HC+NO_x	CO	CO_2	BSFC ($^{lb}/_{hp\text{-}hr}$)
Weighted Specific Emissions[3]	g/hp-hr	**7.70**	**0.83**	**8.53**	**431.3**	**576.5**	**0.912**

1 Emissions results are based on bag sample emissions through ETIS

2 Raw emissions are calculated using the dilution factor and dilute concentrations

3 Based on the 6-mode CARB-SORE Test Cycle

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CCL
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APPENDIX F

HONDA GX340 EMISSION DATA SHEETS