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

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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.

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[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

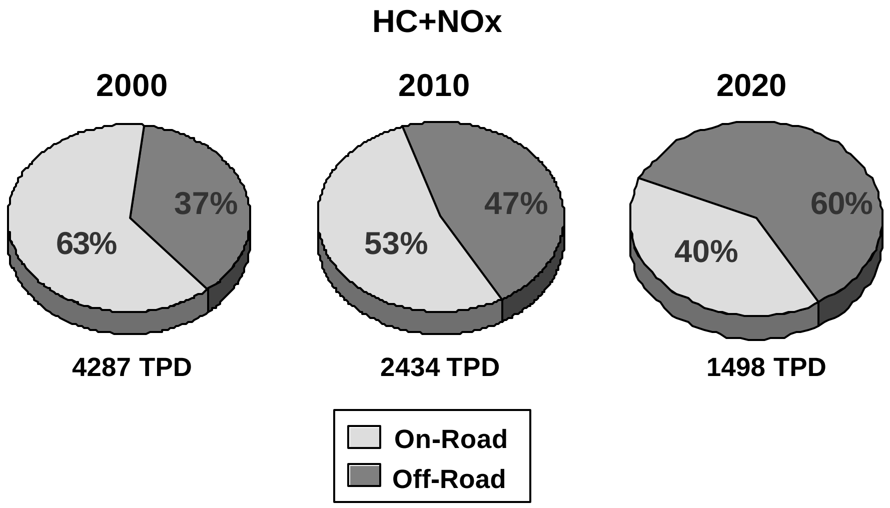
2.3.1 Mobile Source Emissions

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

Mobile Sources Statewide Emissions Inventory



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

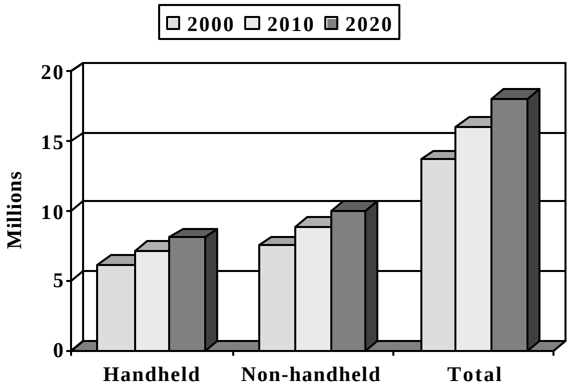
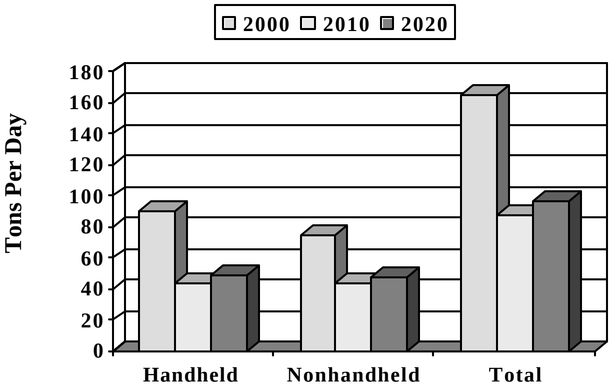


Figure 2.3

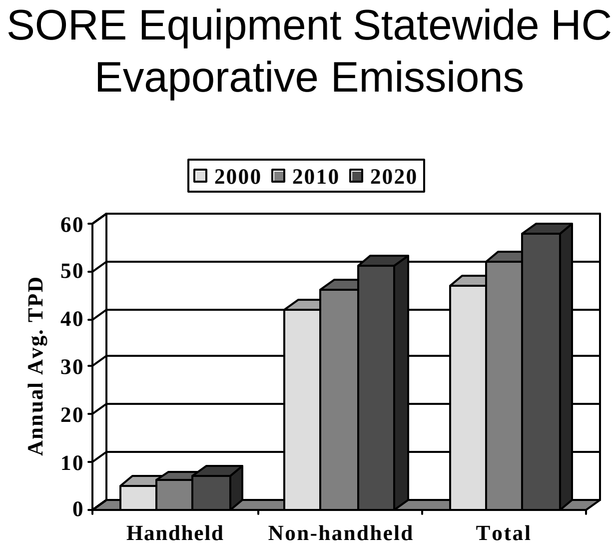
SORE HC+NOx Statewide Exhaust Emissions Inventory



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.

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

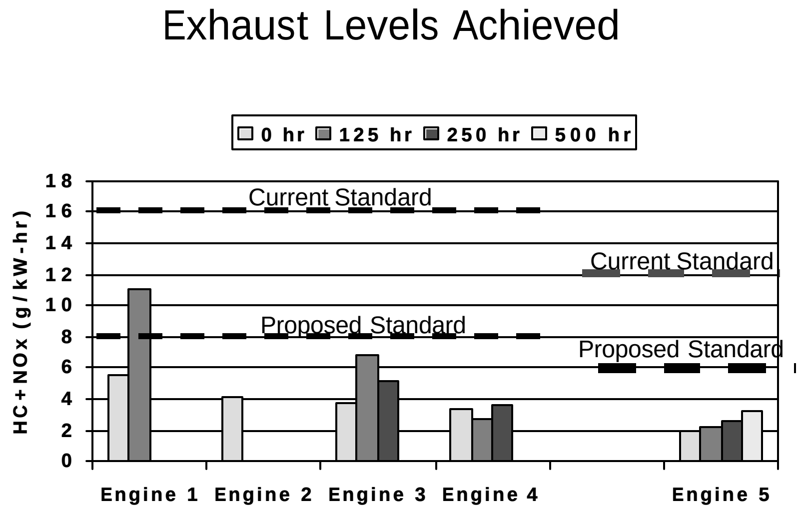
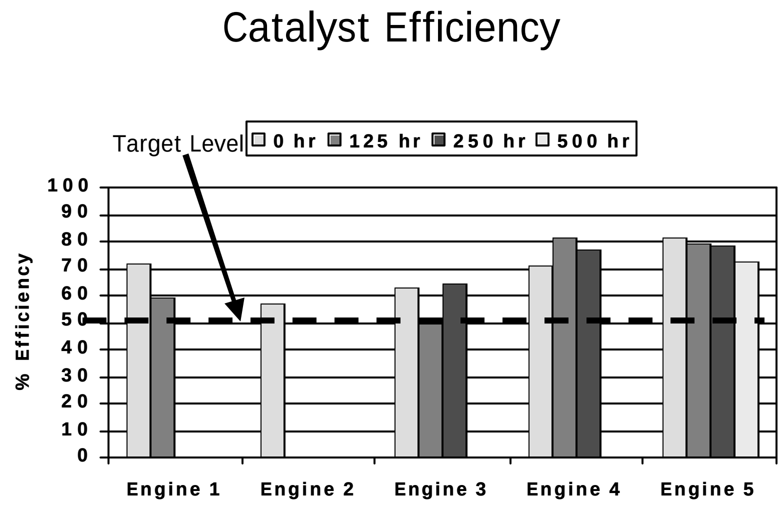


Figure 4.2



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.

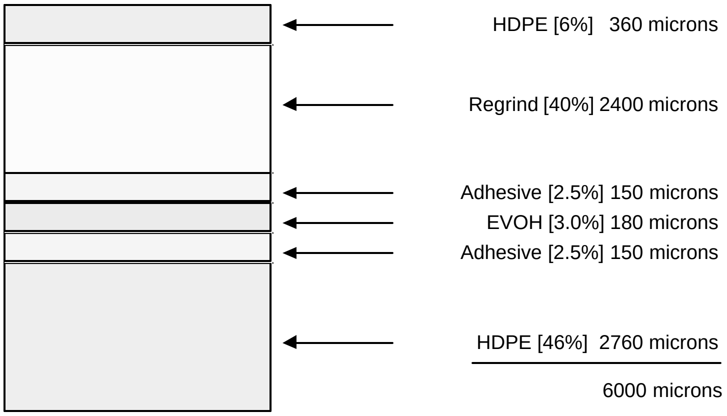
4.5.4 Technology to Control Permeation Emissions

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 40ºC.

Table 4.17
Permeation Properties Comparison
(Grams per 20 µm/ m^2/day@ 40^{o}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

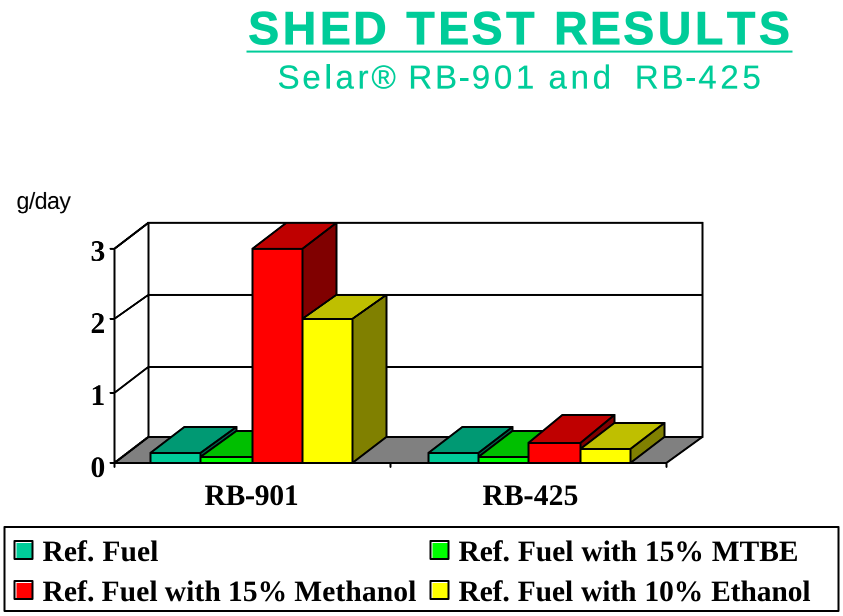
Permeation may also be controlled by modifying or substituting polymers and resins. Thermoplastic materials such as nylon and acetal copolymers have inherent permeation resistance characteristics superior to that of HDPE. Nylon was developed in the 1930s. Nylon 6 and Nylon 66 were the first commercial 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



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

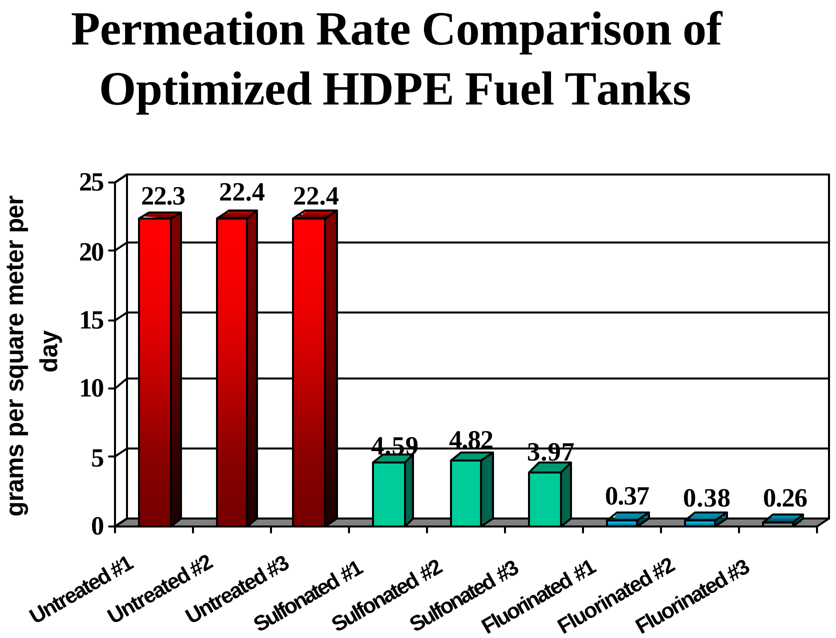
Another alternative that can be used to control permeation emissions from engine fuel tanks is the use of barrier surface treatments. It is possible to apply a barrier surface treatment on plastic fuel tanks to substantially mitigate the effects of permeation. Staff tested two such post production barrier 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.

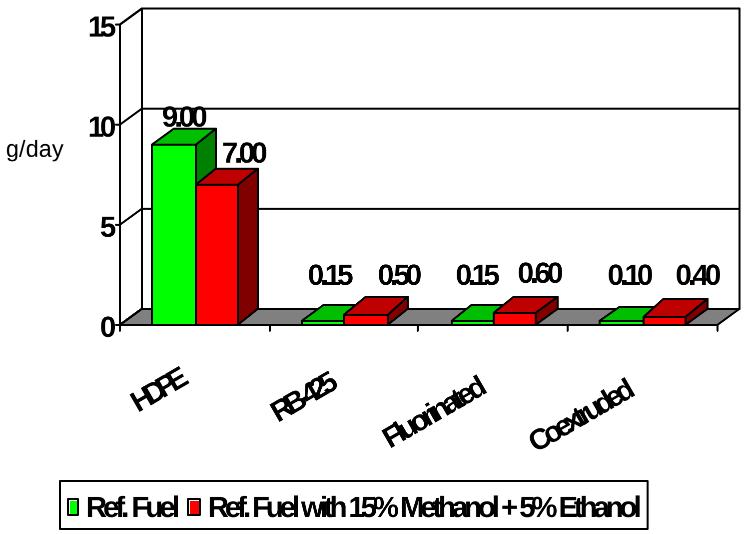
Figure 4.5 compares the permeation rates of the nine tanks tested at a constant 40°C. The data indicates that the super fluorinated tanks have permeation rates well below the proposed 2.0 gram/m^2/day permeation performance standard.

Figure 4.5



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



SHED TEST RESULTS

Untreated HDPE Tanks Compared to Selar® RB-425, Fluorinated, and Coxtruded Tanks

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 $\leq$ 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:

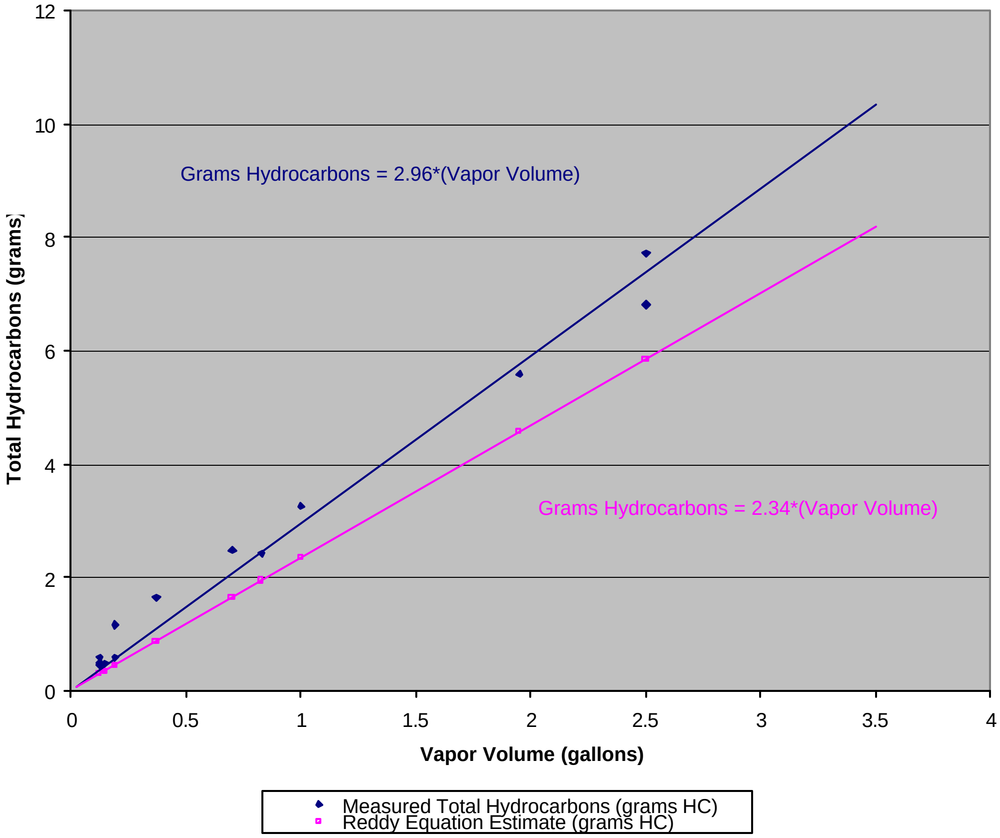
Background Emissions
Running Loss Emissions
Hot Soak Emissions
Diurnal Emissions (including permeation emissions)

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 (65ºF – 105ºF –65ºF) 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)

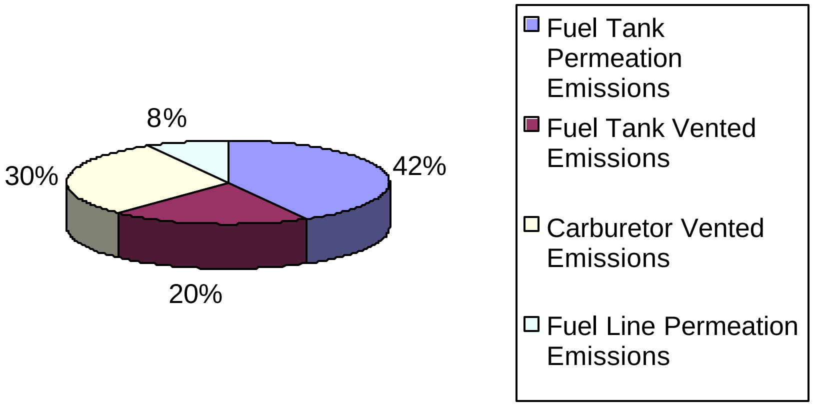
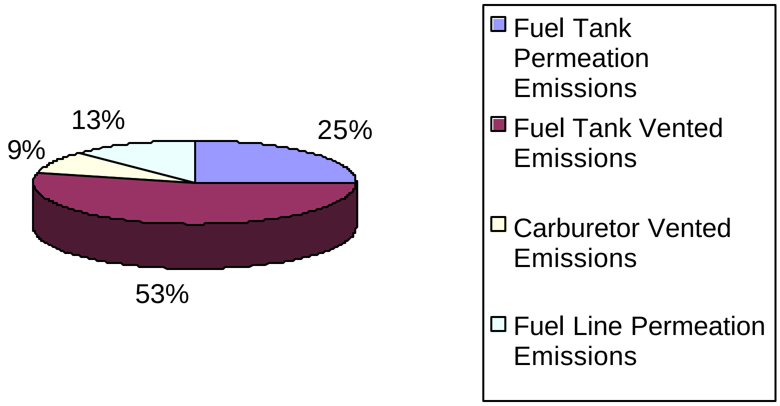


Figure 4.9
Sources of Diurnal Evaporative Emissions
(Typical Generator)



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 (18º C to 40º C) and extreme (18º C to 50º 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.

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[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

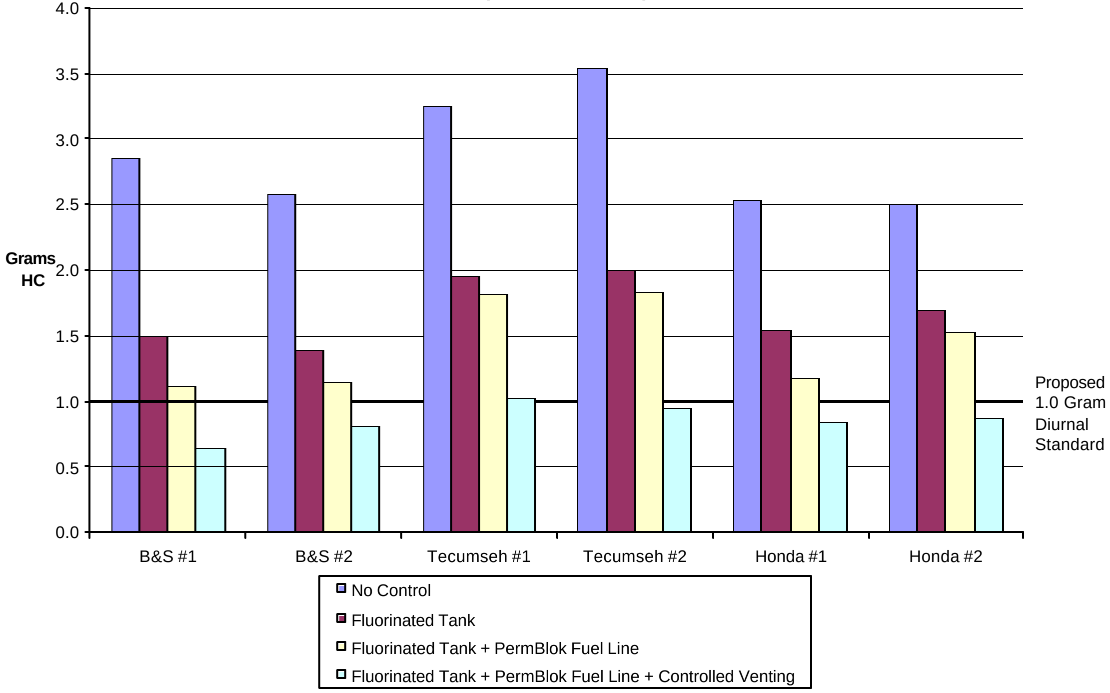
To evaluate likely emission reductions on walk-behind mowers, staff developed a control system that reduces fuel line and fuel tank permeation emissions and limits venting from the fuel tank. Staff focused on walk-behind mowers because they account for over 41 percent of the evaporative emissions from 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.

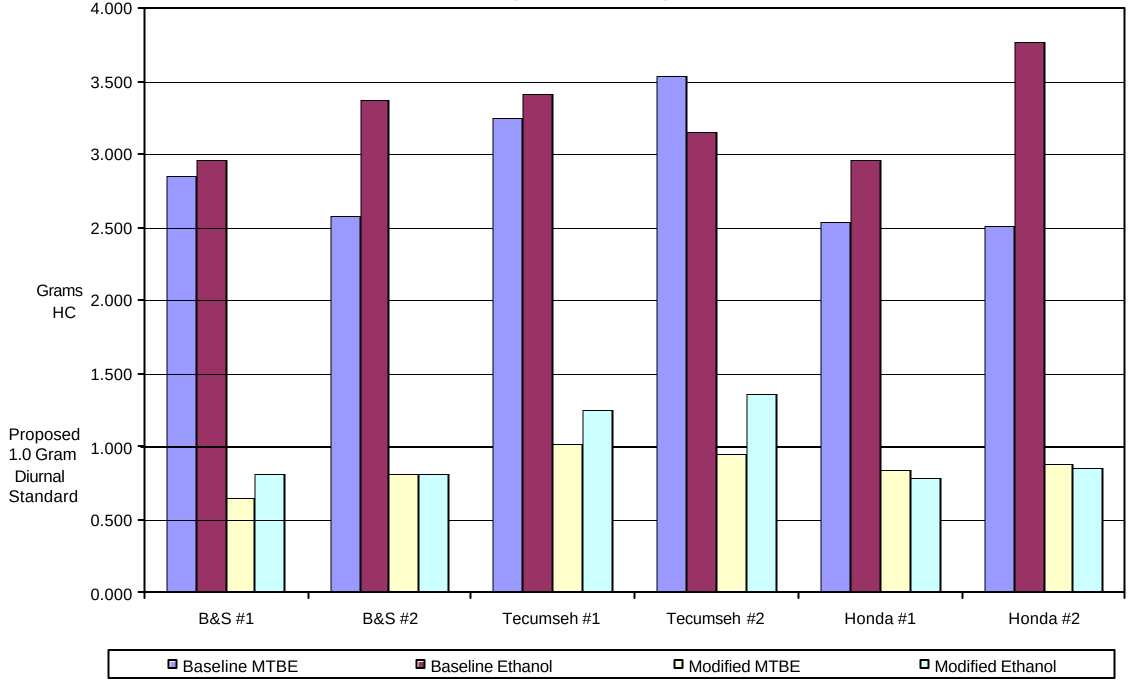
Figure 4.10 summarizes the results of the diurnal emission reduction testing with commercial pump fuel containing Methyl Tertiary Butyl Ether (MTBE) as an oxygenate. This figure compares three pairs of walk-behind mowers with systematically retrofitted control technology. Staff successfully controlled 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.

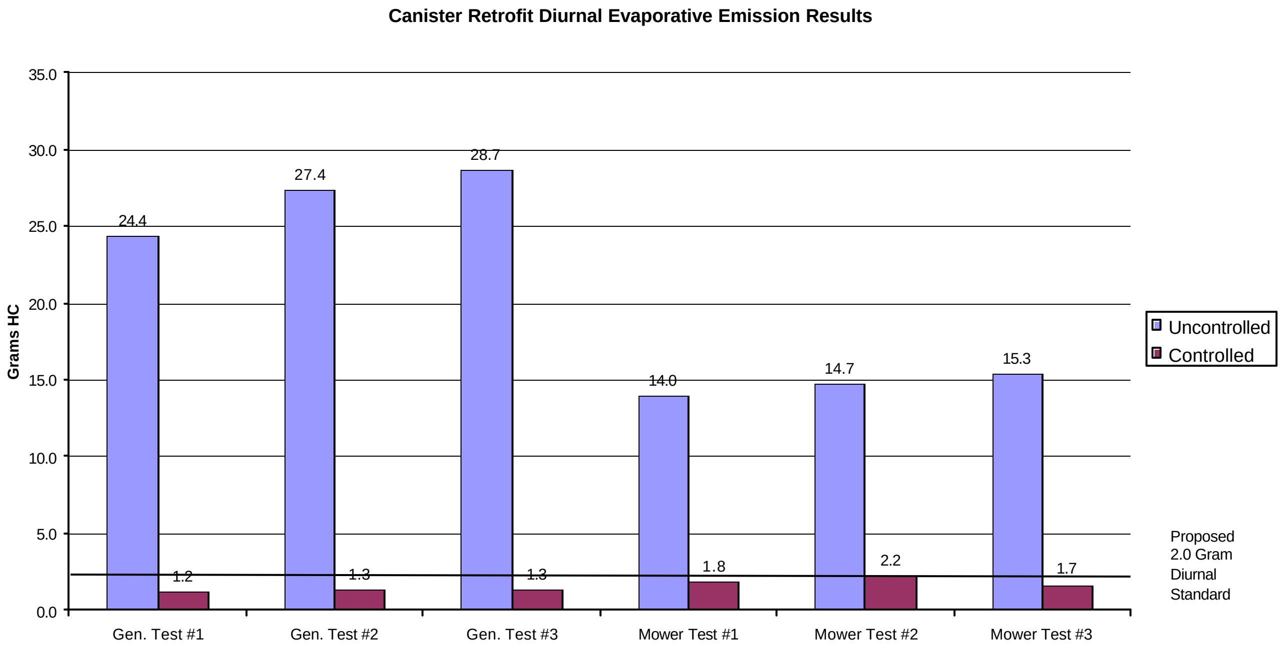
Figure 4.11
Mower Evaporative Emission Reduction Fuel Comparison Results
(24-hour Diurnal)



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.

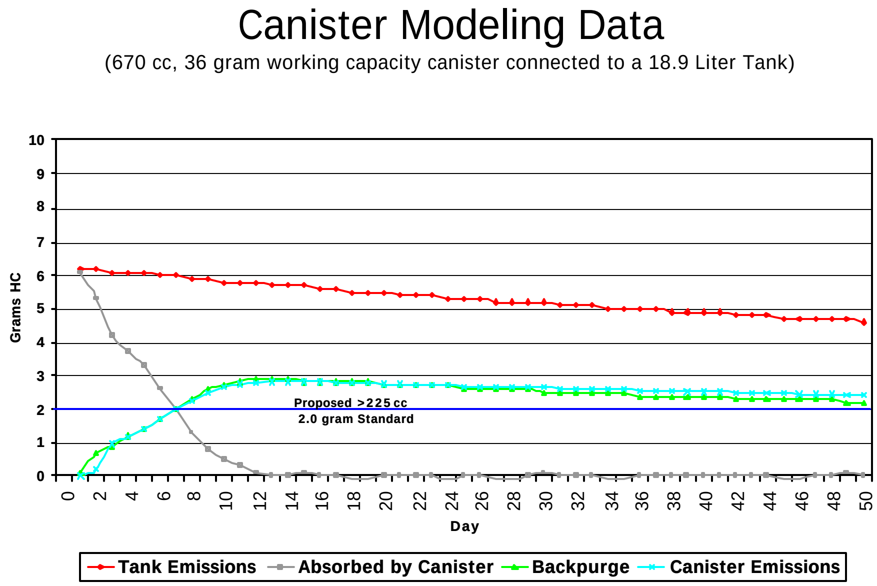
Figure 4.12



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

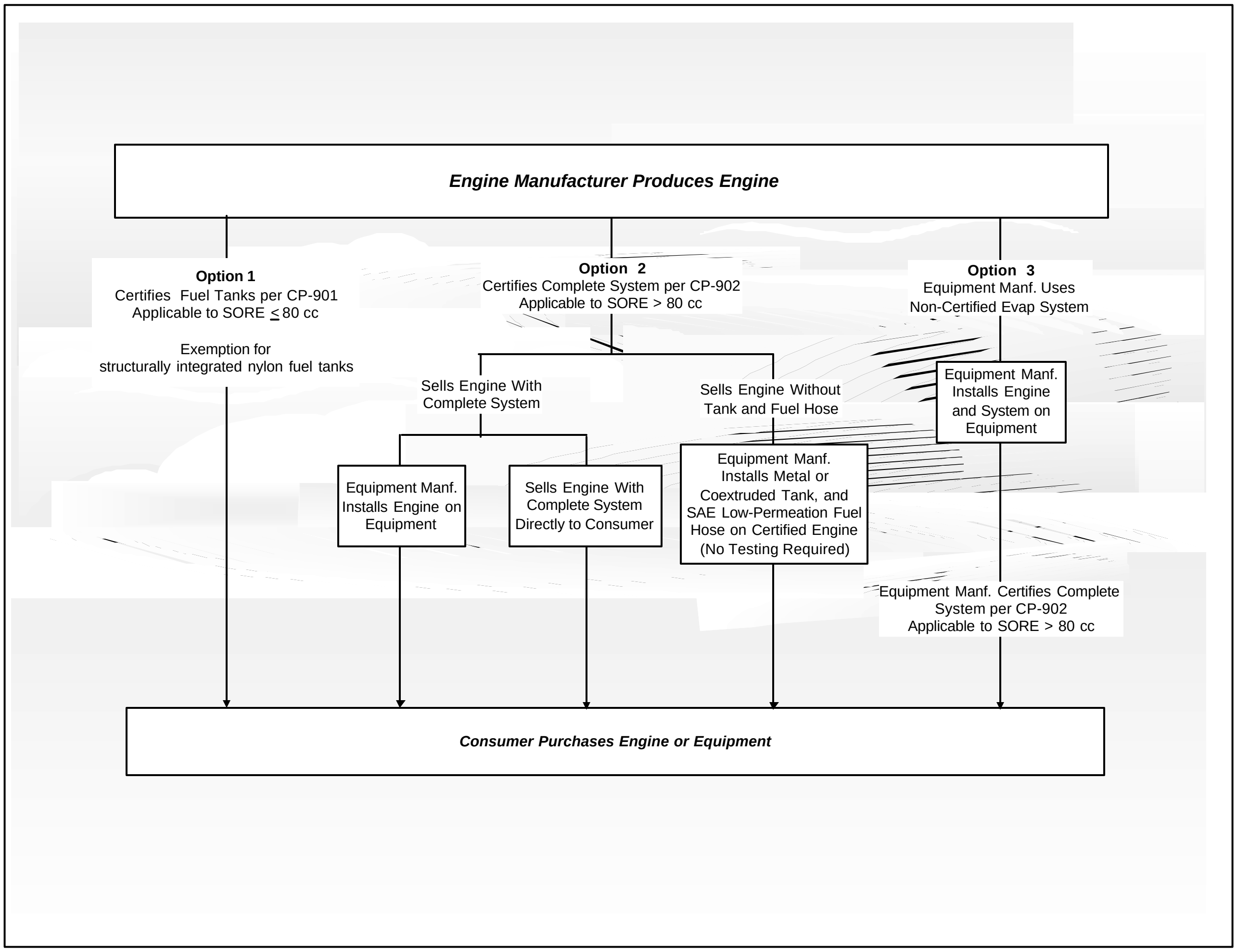
Equipment manufacturers electing to certify equipment to the proposed diurnal emission performance standards will be required to use Test Procedure for Determining Diurnal Evaporative Emissions from Small Off-Road Engines “TP-902.” TP-902 is included in Appendix D.

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.

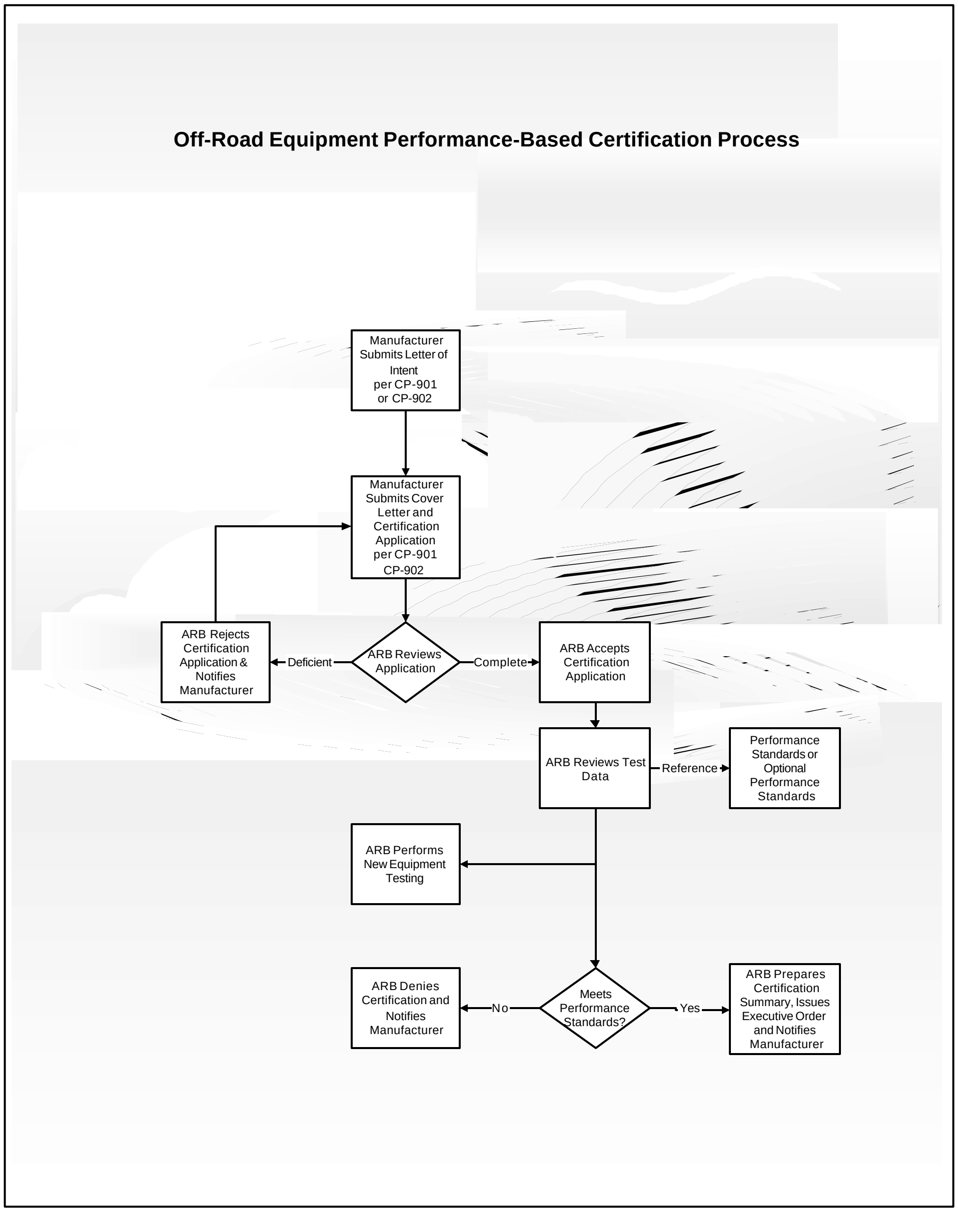
Figure 4.14
Options for Certifying Evaporative Emission Control Systems



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



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.

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.

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[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.

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[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 - 122ºF) 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

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[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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