State of California
AIR RESOURCES BOARD

STAFF REPORT

PUBLIC HEARING TO CONSIDER ADOPTION OF EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2001 AND LATER MODEL YEAR SPARK-IGNITION MARINE ENGINES

Date of Release: October 23, 1998
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Table of Contents

List of Tables

22. 2010 Pleasurecraft Inventory in the South Coast Air Basin (Summer Weekend Day)

23. 1994 SIP Emissions Estimate of 2010 Pleasurecraft Inventory (Typical Summer Day)

24. Current Inventory Emissions Estimate of 2010 Pleasurecraft Inventory in the South Cost Air Basin (Typical Summer Day)

25. Major Companies in the Marine Engine Industry

26. Exhaust Emission Standards as Proposed in the July 9, 1998 Workshop Package

27. Intermediate Staff Proposal HC + NOx Exhaust Emission Standards

28. Summary of Proposals Evaluated

List of Figures

EXECUTIVE SUMMARY

The Air Resources Board (ARB) staff is proposing regulations to reduce emissions of hydrocarbons (HC) and oxides of nitrogen (NOx) from spark-ignition marine engines, specifically, outboard marine and personal watercraft engines. Development of this proposal was undertaken to address the significant emissions impact from these categories of marine engines.

Based on the latest emissions estimates, outboard and personal watercraft engines account for 777 tons per day of reactive organic gas (ROG) and NOx emissions on weekend summer days (days which are associated with peak ozone episodes). An example of the impact of emissions from a single engine is the comparison between the operation of a personal watercraft to the emissions of a passenger car. The operation of a 100 horsepower personal watercraft for 7 hours results in more ozone precursor emissions (hydrocarbons + oxides of nitrogen) than the operation of a 1998 passenger car over 100,000 miles. Carbureted two-stroke engines, commonly used in outboard and personal watercraft engines discharge as much as 25 to 30 percent unburned fuel into the water and subsequently into the air. For example, a typical personal watercraft consuming five gallons of gasoline per hour and operated 41 hours per year, discharges between 50 and 60 gallons of unburned gasoline into the environment. Consequently, in addition to air quality impacts, since marine engines exhaust through the water, water quality is also impacted.

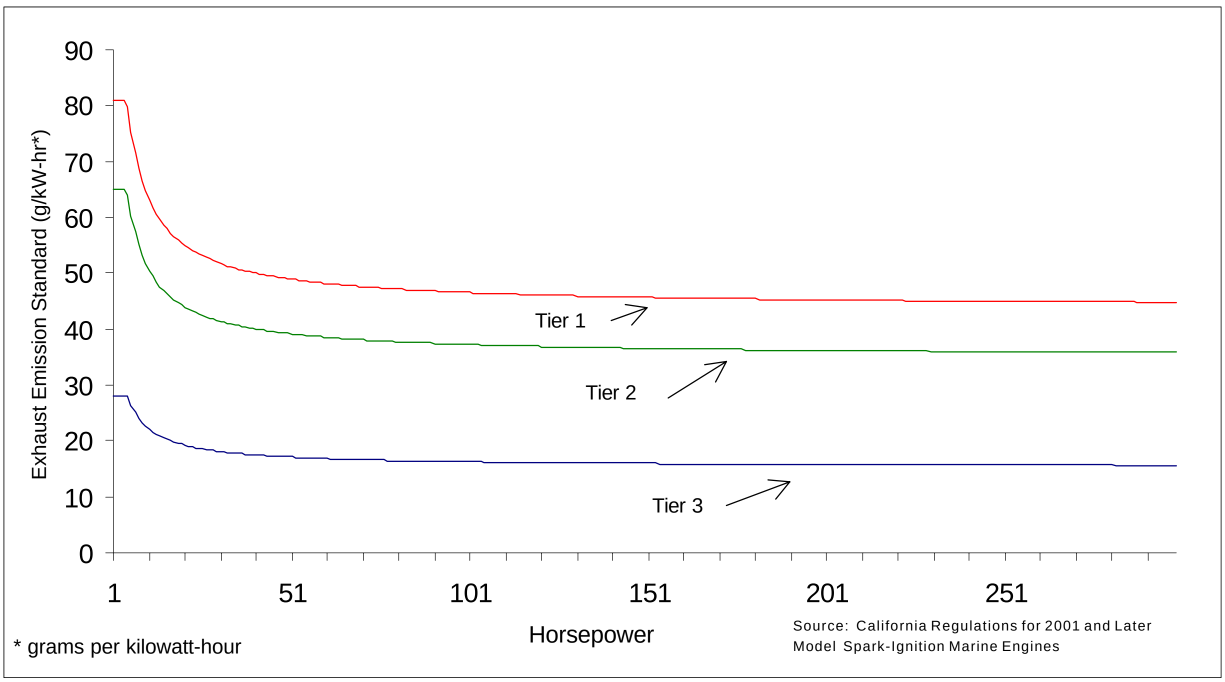
Although the United States Environmental Protection Agency (U.S. EPA) adopted regulations that reduce emissions from outboard and personal watercraft engines by 75 percent by 2025, the benefits of that program will not be sufficient to meet California's air quality goals.

The proposed regulation is designed to harmonize as closely as possible with the federal program through the following:

- Emission standards that are a percentage of the U.S. EPA 2006 standards curve.
- Use of U.S. EPA test procedures for certification and in-use testing.
- Acceptance of U.S. EPA test data for in-use compliance testing.
- Use of U.S. EPA's Cumulative Sum method and Selective Enforcement Audit procedures.
- Use of U.S. EPA's certification label format with additional language added for California, eliminating the need for a second California specific certification engine label.

Central to the proposal are the exhaust emission standards that are phased in over three tiers. The first tier, starting in model year 2001, implements the U.S. EPA 2006 standards. This effectively accelerates the U.S. EPA program by five years. Tier 2, implemented in model year 2004, sets the exhaust emission standards at 80 percent of U.S. EPA's 2006 standards. The Tier 2 standards were proposed by the National Marine Manufacturer's Association. Tier 3, implemented in model year 2008, lowers the standard to 35 percent of U.S. EPA's 2006 standard. The proposed standards are graphed in Figure 1 to illustrate the numerical values of the proposed standards across the available horsepower ranges.

Figure 1
Proposed Exhaust Emission Standards



Additional features of the proposal include establishment of an environmental label program, extended emission warranty requirements and flexible in-use compliance provisions.

The environmental label program is proposed in order to establish 3 tier designations for consumer awareness and water quality protection programs. The labels would establish criteria for low-, very low- and ultra low-emission engines. These designations serve to educate consumers about the relative emissions impact of new engines. The labels also establish a standardized mechanism for clearly identifying clean technology engines for use by water agencies to enforce water quality related activity restrictions.

In 1994, the Air Resources Board (ARB) approved a revision to the State Implementation Plan (SIP) which contains clean air strategies needed to meet the health-based, 1-hour, federal ozone air quality standard. The ozone SIP includes measures to reduce emissions from mobile sources under state control (including passenger cars, heavy-duty trucks, and off-road equipment) as well as federal assignments to control emissions from sources under exclusive or practical federal control (such as planes, marine vessels and locomotives). The responsibility to adopt emission standards for marine pleasurecraft (measure M16) was assigned to U.S. EPA. In addition to the mobile measures, the SIP relies on the development of additional advanced technology measures (the mobile source "Black Box") to provide another 75 tons per day ROG plus NOx needed for attainment in the South Coast Air Basin.

At the time the 1994 SIP was adopted staff believed that marine pleasurecraft emitted far fewer emissions than we know they do today. The dramatic four fold increase[a] in the emissions from pleasurecraft is a result of the explosive increase in the use and horsepower of personal watercraft. So, although U.S. EPA adopted the emission standards for pleasurecraft described in the 1994 SIP, staff believes that further emission reductions are feasible, cost-effective, and necessary. The staff's proposal will provide additional emission reductions to address the increased emission impact. The reductions will also provide progress toward meeting state and new federal air quality standards for ozone and particulate matter.

The estimated statewide benefits total 110 tons per day of ROG and NOx emission reductions in 2010 and 161 tons per day in 2020[b]. These estimated benefits are above and beyond the U.S. EPA program. The estimated benefits in the South Coast Air Basin from staff's proposal total 31 tons per day of ROG and NOx emission reductions in 2010 and 35 tons per day in 2020[b].

The cost-effectiveness of this proposal ranges from $0.32 to $3.57 per pound. This translates to average price increases ranging from approximately $150 to $2,300 per new engine to comply with this regulation. For the 1998 model year, the

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[a] Comparing the SIP inventory estimate to current typical summer day emissions inventory estimates.

[b] Emission reductions on a weekend summer day.

typical average suggested retail price for a personal watercraft is $6,700. The average cost of an outboard engine in 1997 was $6,600, with a range of $600 to $20,000 across the diverse horsepower ranges. The higher end of the estimate of the cost per engine applies to these higher horsepower outboard engines. The cost-effectiveness of the proposal is well within the range of other mobile source measure costs. The staff recommends that the Board adopt the staff proposal.

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I. Introduction

This report provides a description of the spark-ignition marine engine regulatory proposal. It includes a discussion of the technological feasibility for marine engines complying with the proposed emission standards and an analysis of the economic impacts engendered by them. Since marine engines emit into both air and water, this proposal considers multimedia environmental effects.

Although California's air quality has improved dramatically over the last 40 years, more progress is essential to meet the objective of meeting health-based ambient air quality standards. At present, six regions in California are in non-attainment for the federal one-hour standard for ozone: the South Coast Air Basin, the Sacramento Metropolitan area, the San Diego Air Basin, the San Joaquin Valley Air Basin, the South East Desert Air Basin, and Ventura County. With a new federal eight-hour standard for ozone in effect, these regions must meet a limit even more stringent than the one for which they are currently in non-attainment. It is also likely that additional areas that are in attainment for the one-hour standard will be designated as non-attainment under the new eight-hour standard. The following areas of California do not attain California's one-hour ambient air quality standard for ozone: the San Francisco Bay Area, the South Coast Air Basin, the South Central Coast, San Diego, the Sacramento Valley, the San Joaquin Valley, the South East Desert and the Mountain Counties.

Mobile sources, consisting of passenger cars, trucks, heavy-duty vehicles, off-road vehicles and equipment and marine engines, account for about 70 percent of ozone precursor emissions statewide[1]. Control of these mobile sources is vital to attaining health-based air quality standards. The California Clean Air Act (CCAA), as codified in Health and Safety Code Sections 43013 and 43018, grants the Air Resources Board (ARB) authority to regulate off-road mobile sources of emissions. These mobile sources include, but are not limited to marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. Spark-ignition marine engines are therefore a subcategory of off-road engines subject to ARB regulation.

The United States Environmental Protection Agency (U.S. EPA) adopted Title 40 Code of Federal Regulations Parts 89, 90, and 91: Air Pollution Control; Gasoline Spark-Ignition Marine Engines in 1996 with implementation in 1998 for outboard engines and 1999 for personal watercraft. These regulations are designed to reduce emissions of hydrocarbons (HC) from marine engines by 75 percent from baseline levels by 2025. As the staff report will show, the ARB proposal differs from the federal rule primarily with respect to timing and stringency, while the rest of the proposal is harmonized with the federal regulation wherever possible.

The ARB is pursuing exhaust emission standards through this proposed regulation, which will further reduce emissions from marine engines significantly beyond the federal standards. These reductions are a necessary step towards meeting the federal and state air quality standards in California.

A. Notes About This Report

The terms ROG and HC are used throughout this report. Reactive organic gases are a subset of hydrocarbons. In terms of emissions inventory, the ARB is mostly concerned with ROG, the hydrocarbons most involved with the formation of ozone. The exhaust emission standards and test procedures are established for HC, consistent with the U.S. EPA. Evaluation of emissions on an engine by engine basis has been performed in HC for this report. Differences between ROG and HC have been accounted for in the calculation of the emissions inventory estimates provided in this report.

Several tables in this report provide summary totals of the information provided in the table. Differences in these totals to a summation of the provided data are attributed to adding with additional significant figures and then rounding.

II. **Background**

A. Federal Requirements

The U.S. EPA adopted exhaust emission standards for spark-ignition marine engines in 1996[2]. These combined HC and oxides of nitrogen (NOx) standards are a function of rated power as described in Equation 1.

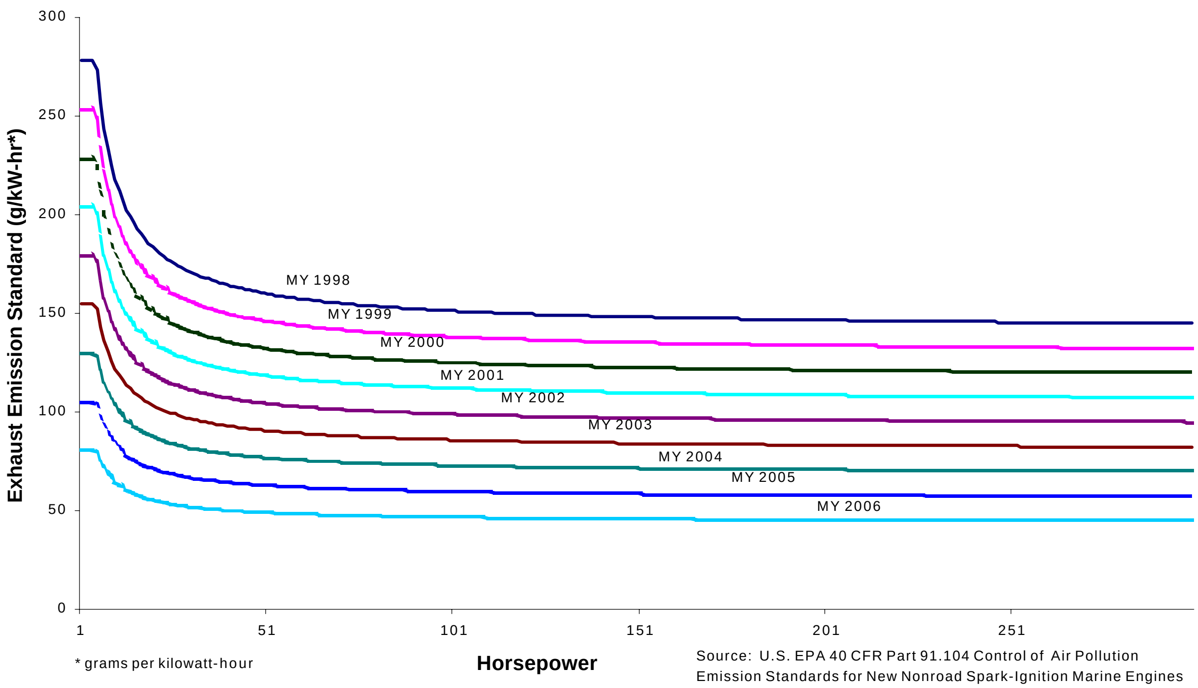
Equation (1)

$$HC + NOx = A * (151 + \frac{557}{P^{0.9}}) + B$$

where HC + NOx is in units of grams per kilowatt-hour (g/kW-hr), A and B are coefficients that decrease each year of the implementation, and p is the rated power of the engine.

Figure 2 shows how the U.S. EPA standards decrease between initial implementation in 1998 and model year 2006. The U.S. EPA standard is based upon a curve, as expressed in equation 1, because typically it is more difficult to control emissions from small horsepower engines than from larger horsepower engines.

Figure 2
U.S. EPA Model Year 1998 to 2006
Exhaust Emissions Standards Curves



B. <u>Affected Engine Categories</u>

The proposed regulation would apply to all outboard marine engines and personal watercraft including jet boats. At this time, the ARB is not pursuing exhaust emission standards for inboard and sterndrive marine engines because these engines are based on automobile engines that have lower emissions. Development of exhaust emission standards for inboard and sterndrive marine engines will require additional research.

1. Outboard Engines

Spark-ignition outboard engines are available in power ratings from 2 to 300 horsepower. They are used in a wide variety of applications including fishing, water skiing and water-borne transportation. The total population of gasoline powered outboard engines in California was 373,200 in 1990[3]. New outboard engines are typically produced and provided to boat manufacturers and sold as part of a package comprising boat and engine. These packages are then sold through dealerships. Outboard engines are also available separately and can be purchased as replacement, or auxiliary engines for existing boats. Examples of typical two-stroke and four-stroke outboard engines are shown in Figure 3.

Figure 3
Typical Two-Stroke and Four-Stroke Outboard Engines

Two-Stroke Engines
2 to 300 hp

Four-Stroke Engines
2 to 130 hp

Spark-ignition outboard engines include carbureted, fuel injected and direct-injected two-stroke, and carbureted and fuel injected four-stroke configurations. The market is currently dominated by carbureted two-stroke engines that are available in horsepower ratings between 2 and 300. Four-stroke engines are available with ratings between 2 and 130 horsepower and are a growing segment of the market. Direct fuel injection two-stroke engines are recent introductions in the higher horsepower range, including 90, 115, 135, 150, 175, 200 and 225 horsepower. Direct fuel injection is also being considered by manufacturers for much lower horsepower engines because of its improved fuel economy and lower emissions.

Aggregate sales of outboard engines totaled approximately 302,000 nationally in 1997[4]. California sales account for approximately 10 percent of the United States market. The average cost of an outboard engine in 1997 was $6,600[5], with a range of $600 to $20,000 across the diverse horsepower ranges.

2. Personal Watercraft

Personal watercraft are defined by U.S. EPA as marine vessels that are not outboards, inboards, or sterndrive, but they can more accurately be defined as small craft on which the rider sits or stands during operation. This encompasses Jet Skis, Wave Runners, Sea Doos, etc. The one exception to this definition is the jet boat which is in a class of inboard style vessels but uses propulsion units derived from those used in traditional personal watercraft. Personal watercraft are primarily used for recreation, including touring, and water skiing. They are also used in emergency response applications. Typical examples of personal watercraft and jet boats are pictured in Figure 4.

Figure 4

Typical Personal Watercraft and Jet Boat

Typical Personal watercraft 80 - 135 hp

Typical Jet Boat 80 - 270 hp

Personal watercraft utilize, almost exclusively, carbureted two-stroke engines and are propelled by a water “jet” produced by an engine-driven pump. In the 1999 model year it is anticipated that some engine manufacturers will introduce electronic fuel injection and direct fuel injection on some models of personal watercraft. California sales of personal watercraft accounted for 12 percent of the 176,000 units sold nationally in 1995.

3. Estimated Population of Outboard Engines and Personal Watercraft

Table 1 shows the estimated population of outboard and personal watercraft in 1997, 2010 and 2020. As shown in Table 1, the population of personal watercraft is projected to double by 2020 because of continued growth and popularity of this category of marine engine. This will have a significant impact on the emissions inventory attributed to this category.

Table 1

Estimated Population of Outboard Engines and Personal Watercraft in 1997, 2010 and 2020 in California

	1997	2010	2020
Outboards	346,000	349,000	333,000
Personal Watercraft	162,000	293,000	354,000
Total	508,000	642,000	687,000

Source: Air Resources Board, Proposed Pleasurecraft Exhaust Emissions Inventory, July 7, 1998, Mail Out# MSC 98-14

C. Water Quality Concerns

Engine exhaust from marine engines is generally routed to below the waterline for cooling, silencing and to minimize exposure to exhaust. Thus since the exhaust is emitted through water, the ARB has asked the State Water Resources Control Board to evaluate the proposed regulation in the context of water quality.

In recent months, water quality and distribution agencies have voiced concerns about detected levels of gasoline constituents in water supplies. These constituents include, but are not limited to methyl-tertiary-butyl-ether (MTBE), poly-aromatic hydrocarbons (PAHs), xylenes, ethyl benzene, toluene and benzene. Agencies such as the East Bay Municipal Utility District (EBMUD), the Tahoe Regional Planning Agency (TRPA), and the Santa Clara Valley Water District have determined that one way to mitigate the levels of gasoline constituents found in water supplies is to restrict or ban the use of marine engines. Other agencies within and outside California are also considering restrictions on marine engine activity due to environmental concerns. The following actions have been undertaken by these water agencies[6].

1. TRPA

On June 25, 1997, TRPA adopted an ordinance amending Chapter 81 of its Code of Ordinances. This section prohibits the discharge of unburned fuel and oil from carbureted two-stroke engines commencing June 1, 1999 into Lake Tahoe, other Tahoe Region waterways, or the Truckee River within the Tahoe Region. TRPA has indicated that they will consider modifying this section to align its restrictions with the exhaust emission standards established by this proposed regulation.

2. EBMUD

On March 10, 1998, EBMUD adopted Resolution Number 33088-98 amending Section 5 of the Watershed Rules and Regulations prohibiting the use of high emission motor engines at San Pablo Reservoir effective January 1, 2000. The resolution added a new subsection Z to Section 5.01 of the District Watershed and Recreation Rules and Regulations. Section 510 (Z) allows the use of only zero-emission marine engines, inboard gasoline powered engines, and four-stroke gasoline outboard engines or equivalent. Additionally, starting January 1, 2002, San Pablo Reservoir will be restricted to marine engines with zero emissions into the water.

3. Santa Clara Valley Water District

On April 21, 1998 Santa Clara Valley Water District adopted a proposal to restrict, but not entirely ban, boating on Anderson, Calero, and Coyote reservoirs due to water quality concerns. These restrictions took effect during the summer of 1998. Boaters must secure reservations in order to launch on these waterways, thus allowing a restriction on the number of gasoline-powered marine engines during peak periods between May and October. Exceptions to these restrictions may be allowed for marine engines not using gasoline with MTBE, or for marine engines that are proven to have high efficiency engines. Calero will be restricted to use by personal watercraft only, and Anderson will be reserved for motorized boats (i.e. with the exclusion of personal watercraft). Coyote will be open to both personal watercraft and motorized boats.

Santa Clara Valley Water District’s program of restrictions and reservations is structured to allow shifts in the requirements to respond to changes in measured levels of MTBE. For example, in late August 1998, MTBE levels in Coyote Reservoir increased beyond acceptable levels due to increased use by personal watercraft. Santa Clara Valley Water District responded by shifting the reservation requirements and activity restrictions between the Calero and Coyote to lower MTBE levels in Coyote through the end of October.

III. <u>Need for Control</u>

A. <u>Ozone</u>

Ozone, which is created by the photochemical reaction of NOx and ROG, causes harmful respiratory effects, including chest pain, coughing, and shortness of breath, affecting people with compromised respiratory systems and children most severely. In addition, NOx itself can directly harm human health. Beyond their human health effects, other negative environmental effects are also associated with ozone and NOx. For example, ozone injures plants and materials. NOx contributes to the secondary formation of particulate matter (PM) in the form of nitrates, acid deposition, and excessive growth of algae in coastal estuaries.

California has made significant progress in controlling ozone. Statewide exposure to unhealthful ozone concentrations has been cut in half since 1980. The frequency and severity of pollution episodes is declining, and emissions are on a downward trend. More needs to be done however to reach state and federal health-based air quality standards for ozone and particulate matter. Nearly all Californians breathe air that violates one or more of these standards.

The 1994 Ozone State Implementation Plan (SIP) is California's plan for attaining the federal one-hour ozone standard. The SIP calls for new measures to reduce emissions of ozone precursors from mobile sources to half of what emissions would have been under regulations existing in 1994.

While the U.S. EPA has adopted the standards described in SIP measure M16, and those standards will result in hydrocarbon emission reductions of 75 percent, that level of reduction will not be reached until the year 2025. The 1994 SIP relied on the U.S. EPA regulation to reduce emissions in the South Coast Air Basin by 12 tons per day in ROG+NOx 2010, from a baseline of 32 tons per day ROG+NOx (if the source were uncontrolled in 2010) leaving an inventory controlled to 20 tons per day ROG+NOx in 2010.

Since development of the 1994 SIP, the emissions inventory has been further refined, taking into account the changes in the marine engine industry, including a substantial increase in the population of personal watercraft.

Emissions from outboard and personal watercraft in California in 1997 totaled 129[7] tons of ROG+NOx per day. Table 2 lists the emission inventory for pleasurecraft and the subcategories of outboard engines and personal watercraft in 1997, with estimated values for 2010 under the implementation of the U.S. EPA program.

Table 2

Statewide Emissions Inventory from Pleasurecraft in 1997 and Estimated for 2010 Under U.S. EPA Program

Year	Category	ROG	NOx	ROG+NOx
1997	Personal Watercraft	66	0.5	66.5
	Outboard Engines	63	1	64
	Total	129	1.5	130.5
2010	Personal Watercraft	45	8	53
	Outboard Engines	38	2	40
	Total	83	10	93

Source: OFF-ROAD Inventory Computer Model, October 1998[7]

The emissions levels listed in Table 2 are in tons per day averaged over 365 days. The emissions inventory attributed to marine engine use on a typical summer weekend day when their emissions are of greatest concern, was 777 tons per day of ROG+NOx statewide in 1997 (Six times greater than the annual average). In the South Coast Air Basin these typical summer weekend emissions were 168 tons per day of ROG+NOx[8].

In addition to providing needed emission reductions in the South Coast Air Basin, the proposed marine engine regulations will also help achieve and maintain: the federal 1-hour ozone standard in regions such as the San Joaquin Valley and the Sacramento area, the federal 8-hour ozone and particulate matter standards in a number of areas, and the State ozone and particulate matter standards throughout California.

B. Water

The impacts of outboard and personal watercraft two-stroke engine operation on California water bodies have not been quantified because the extensive use of personal watercraft has occurred recently. Ongoing studies such as the Lake Tahoe Watercraft Study are not completed but will provide more definitive information on the aquatic environment. Although the actual impact has yet to be determined, a threat to water quality certainly exists. The threat can be qualitatively assessed by reviewing ARB statistics regarding watercraft operation on California water bodies. A qualitative threat of this magnitude is a sufficient basis for regulatory actions by state agencies other than the State Water Resources Control Board (SWRCB), provided that such actions do not infringe on SWRCB's primary role in reducing such threats.

The number of two-stroke engine powered personal watercraft has increased by 240 percent since 1990 and is expected to double again by 2010. Current estimates show 162,000 personal watercraft are being used on an average of 41 hours per craft per year on California's lakes and rivers. Fuel consumption is estimated at 5 to 10 gallons per hour. Unlike automobile emissions, which are exhausted to air, all marine engines exhaust directly into the water. All exhaust pollutants, therefore, are brought into intimate contact with the water body thereby enhancing pollutant transfer. In addition, ARB information indicates that two-stroke carbureted engines discharge an unburned fuel/oil mixture at levels approaching 20 to 30 percent of the fuel/oil mixture consumed. Such unburned fuel includes oil required for lubricating all two-stroke engines.

Based on current and future outboard usage and the expanding use of personal watercraft and the potential per vessel discharge of unburned fuel from both marine engine types, millions of gallons of gasoline could be discharged to water bodies of the State. This unregulated discharge of fuel and oil threatens degradation of high quality waters and pollution affecting the beneficial uses of the State's waters. The proposal to control emissions from spark-ignition marine engines is of considerable interest to the SWRCB since implementation of these regulations will effect significant reductions in the discharge of gasoline and oil.

The discharge of gasoline to waters of the State is generally addressed by State and federal law and adopted Policy as outlined below:

1. Federal and State Mandates for the Protection of Water Quality

The Porter-Cologne Water Quality Control Act (Porter-Cologne) is the principal law governing water quality regulation in California. The SWRCB and nine Regional Water Quality Control Boards (RWQCBs) are charged with implementing its provisions. Porter-Cologne establishes a comprehensive program for the protection of water quality and the beneficial uses of water.

The U.S. EPA has approved California's Water Quality Control Program authorized by Porter-Cologne as a satisfactory way to ensure implementation of the Federal Clean Water Act in California. The SWRCB and RWQCBs are specifically required to implement the Clean Water Act provisions through their planning and regulatory actions (Section 13370 of the California Water Code [CWC]).

It is the policy of the State of California, as set forth by the Legislature in Porter-Cologne (Section 13000 of the CWC) that the quality of all the waters of the State shall be protected, that all activities and factors affecting the quality of water shall be regulated to attain the highest water quality within reason, and that the State must be prepared to exercise its full power and jurisdiction to protect the quality of water in the State from degradation. In fact, State agencies in carrying out activities that affect water quality are required to comply with State policy for water quality control as promulgated by the SWRCB (Sections 13146 and 13247, CWC).

The SWRCB is mandated by federal and State requirements to protect and enhance water quality. Important to this issue is the Federal Antidegradation Policy (40 CFR 131.12) and the SWRCB's adoption of that policy in SWRCB Resolution No. 68-16, a component of the State's policy for water quality.

The current Federal Antidegradation Policy states that existing stream water uses and the water quality necessary to protect them must be maintained. In addition, where high quality waters constitute an outstanding national resource, such as waters of national and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected. In California, Lake Tahoe and Mono Lake have been designated as Outstanding National Resource Waters.

The SWRCB policy enunciated in Resolution No. 68-16 is broader than the federal policy because it covers both surface and ground water and protects potential as well as actual uses. The SWRCB has interpreted Resolution No. 68-16 to incorporate federal policy where applicable. In addition to the preservation of existing water quality, Resolution No. 68-16 also states that discharges to existing high quality waters will be controlled as necessary to assure that pollution or a nuisance will not occur, and that the highest water quality consistent with maximum benefit will be maintained.

Porter-Cologne requires adoption of Water Quality Plans which contain the guiding policies of water pollution management in California. There are a number of statewide water quality control plans adopted by the SWRCB. Regional water quality control plans, commonly referred to as Basin Plans, have also been adopted by each of the RWQCBs.

All water quality control plans identify the existing and potential beneficial uses of waters of the State and establish water quality objectives to protect these uses. For example, most surface and ground waters of the State are presumed to be suitable for beneficial use as drinking water. (SWRCB Resolution 88-63.) The water quality control plans also contain an implementation, surveillance, and monitoring plan. Water Quality Control Plans include enforceable prohibitions against certain types of discharges.

Statewide plans and all nine RWQCBs also have narrative and numeric objectives in their Basin Plans to protect water quality, including numeric objectives for gasoline components. The latter are based on the Department of Health Services' primary and secondary Maximum Contaminate Levels for drinking water. Other numeric objectives are intended to protect beneficial uses (fish and wildlife habitat, recreational uses, etc.). Narrative objectives are used where the data needed to establish numeric objectives are unavailable. Examples of the narrative objectives for the San Diego RWQCB Basin Plan are described below. This narrative language is typical of, if not identical to, that found in Basin Plans of the other eight RWQCBs.

<u>Water Quality Objective for Oils, Grease, Waxes, or other Materials:</u>

> Waters shall not contain oils, greases, waxes, or other materials in concentrations which result in a visible film or coating on the surface of the water or on objects in the water or which cause nuisance or which otherwise adversely affect beneficial uses.

<u>Water Quality Objectives for Taste and Odor:</u>

> Waters shall not contain taste or odor producing substances at concentrations which cause a nuisance or adversely affect beneficial uses.

The natural taste and odor of fish, shellfish, or other regional water resources used for human consumption shall not be impaired in inland surface waters and bays and estuaries.

Water Quality Objectives for Toxicity:

All waters shall be maintained free of toxic substances in concentrations that are toxic to or that produce detrimental physiological responses in human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analysis of species diversity, population density, growth anomalies, bioassays of appropriate duration, or other appropriate methods as specified by the RWQCB.

The ARB’s proposed regulations of marine engines and equipment could affect water quality of the State and are therefore required to promote attainment of water quality objectives (Sections 13146 and 13247, CWC).

As mentioned above, the numerical objectives based on Maximum Contaminant Levels are intended to protect public health. Additional numeric objectives are being developed for this purpose. Presently, however, little is known of the environmental fate of many exhaust, gasoline, and lubricating oil components. An analysis of the impacts of marine engine exhaust, including unburned gasoline, on the aquatic environment is difficult due to the highly variable physical and chemical natures of the exhaust components and the variety of gasoline formulations and additives. Evaporation, deposition, and degradation rates of each of these components, as well as other environmental conditions, all would influence each compound’s fate, transport and toxicity. Both in-situ and in-tank studies have been conducted on marine engine exhausts while the degree of impact on the aquatic environment is still under investigation.

However, public health and other beneficial uses (e.g. aquatic) are also protected by narrative standards with respect to pollutants for which numeric objectives have not been developed. There is no doubt that the chemicals being discussed are detrimental to the water quality needed to sustain beneficial uses of water and that occurrence of these chemicals is expected to increase dramatically absent adequate controls. With few exceptions, surface and ground waters of the State are considered to be suitable, or potentially suitable, for beneficial use as a municipal or domestic water supply (SWRCB Resolution No. 88-63, as implemented by RWQCBs). Marine engines are now discharging significant quantities of pollutants into such waters with further significant increases anticipated. ARB's proposed regulations will significantly reduce the discharge of pollutants to waters of the State.

Discharges to water from marine engines and equipment are therefore threatening to pollute or otherwise adversely affect water quality for one or more beneficial uses and are threatening to violate State and regional water quality narrative objectives for Oils, Grease, Waxes or other Materials. Such discharges are also threatening to pollute waters or otherwise adversely affect water quality for one or more beneficial uses and are threatening to violate State and regional water quality narrative objectives for Tastes and Odors. Such discharges are also threatening to violate State and regional Toxicity narrative objectives because such waters may not be maintained free of toxic substances in concentrations producing detrimental physiological responses in human, plant, animal, or aquatic life. Finally, such discharges are threatening to adversely impact water quality for one or more beneficial uses of Lake Tahoe, an outstanding National resource water, in violation of SWRCB Resolution 68-16.

Given the adverse effects of the constituents in question on water quality, the best approach is to limit, as best as possible, the total amount of material exhausted. This is especially true of the unburned gasoline and lubricating oil component generated by two-stroke engines.

IV. Summary of Proposal

A. Introduction

The proposed spark-ignition marine engine regulations consist of exhaust emission standards, certification test procedures, compliance provisions, and consumer provisions such as environmental labeling and warranty requirements for new spark-ignition marine engines. Where possible the proposal follows the framework of the U.S. EPA regulations for spark-ignition marine engines. To allow California-specific compliance assurance, several of the provisions are written to give authority to ARB to implement independent enforcement programs that demonstrate compliance with the California standards and requirements.

The ARB staff has met with various stakeholders to discuss the regulatory proposal. The staff held individual meetings during the months of April and May 1998, and a general public workshop was held on July 9, 1998. Staff met again with manufacturers and other stakeholders individually during August and September of 1998. Staff also held a series of working group meetings to discuss the specific issue of environmental labeling with industry representatives, water agencies and environmental groups. To the extent possible, this proposal incorporates the comments and suggestions of all interested parties.

The following is a discussion of each element of the regulatory proposal including a description of the provisions, an explanation of the intent, and where appropriate, a comparison of the provisions to the U.S. EPA regulation. The text of the proposed regulation is contained in Attachment A, and the emissions test procedures are contained in Attachment B.

B. Applicability

The proposed regulations apply to new spark-ignition outboard engines and personal watercraft produced in model year 2001 and later. These are the same classifications of marine engines regulated by the U.S. EPA 1996 Spark-Ignition Marine Engine regulations. As in the U.S. EPA's regulation, this proposal does not address inboard and sterndrive engines or compression-ignition engines. It is anticipated that ARB will pursue exhaust emission standards for these engines at a later date.

C. Definitions

The definitions included in the proposal are consistent with those listed in the federal marine engine rulemaking, with additional definitions added for program elements specific to California. Outboard engines are defined as marine engines that, when properly mounted on a marine vessel in the position to operate, house the engine and drive unit external to the hull of the marine vessel. Personal watercraft engines are defined as marine engines that do not meet the definition of outboard engines, inboard engines, or sterndrive engines.

D. Emission Standards and Test Procedures

1. Exhaust Emission Standards

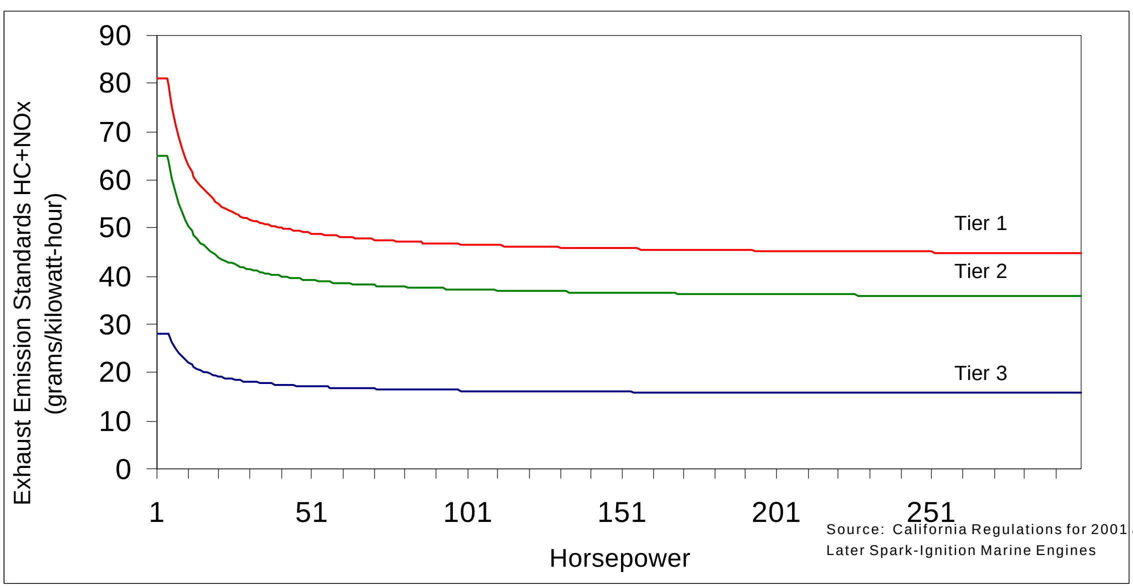
A major goal, throughout the development of the proposal, was to harmonize as much as possible with the U.S. EPA regulation. Consequently, the proposed exhaust emission standards are based on a percentage of the U.S. EPA 2006 emission standards curve which varies with engine power. The proposal consists of a three tiered implementation schedule using this approach. The proposed standards are outlined in Table 3. The three tiers are further illustrated in Figure 5.

Table 3 Corporate Average HC + NOx Emission Standards			
	Tier 1	**Tier 2**	**Tier 3**
Implementation in Model Year	2001	2004	2008
Percent of U.S. EPA 2006	100 %	80 %	35 %
Equation Used to Determine Exhaust Emission Standards[1] for Engines Greater than 4.3 kW (6 hp)	$0.25*(151+\frac{557}{P^{0.9}})+6.00$	$0.20*(151+\frac{557}{P^{0.9}})+4.80$	$0.0875*(151+\frac{557}{P^{0.9}})+2.10$
Standard for Engines less than 4.3 kW (6 hp)	81 g/kW-hr	65 g/kW-hr	30 g/kW-hr
Maximum Family Emission Level (FEL)[2]	134 g/kW-hr	80 g/kW-hr[2]	44 g/kW-hr

1. Where p is the sales-weighted power of the engine family in kilowatts. The standard is in units of grams per kilowatt-hour (g/kW-hr).
2. For each engine family, the manufacturer family emission level used for corporate averaging may not exceed the value given in this row.

Source: Air Resources Board, Proposed Gasoline Spark-Ignition Marine Regulations, Mail Out #MSC 98-08, June 8, 1998,

Figure 5
Exhaust Emission Standards Curves



2. Family Emission Level (FEL)

The FEL is the designated emission level to which the manufacturer certifies the engine. This level may be higher or lower than the standard required by the exhaust emission standards curve as described in the next section - Corporate Averaging. Engines may not exceed their applicable FELs during their useful life. As such, manufacturers include deterioration factors to account for changes in emission performance through use, and compliance margins to account for test and production variability.

3. Corporate Averaging

The standards being proposed are corporate average exhaust emission standards. On a sales and horsepower weighted basis, manufacturers' engine production must on average comply with values set by the curve. This means manufacturers may produce engines with emissions above the curve as long as other engines are produced with emissions sufficiently below the curve to offset the excess emissions on a sales and horsepower weighted basis. This approach provides a manufacturer flexibility and reduces the cost of compliance. Equation 2 is used to calculate positive and negative credits for determining corporate average compliance.

EQUATION (2)

$$\frac{\sum_{j=1}^{n} (PRODjx)(FELjx)(P)}{\sum_{j=1}^{n} (PRODjx)(P)} = STDca$$

where:

n	=	the total number of engine families (by category)
PRODjx	=	the number of units of each engine family j produced for sale in California in model year x
FELjx	=	the Family Emission Level for engine family j in model year x
P	=	the average power (sales-weighted) of engine family j produced for sale in California in model year x
STDca	=	an engine manufacturer's corporate average HC + NOx exhaust emissions from those California spark-ignition marine engines subject to the California corporate average HC + NOx exhaust emission standard.

This equation uses sales volume and horsepower to average mass emissions for the engine being certified and, thereby allows offsetting of higher emitting engines with lower emitting engines. There would, however, be an upper bound limit on the higher emitting engines. This FEL cap is shown in Table 3 above and is necessary to encourage manufacturers to abandon conventional high-emitting carbureted two-stroke technology, thereby reducing individual or point exposure to extremely high polluting engines.

The proposal also prohibits the averaging of personal watercraft with outboard engines. The U.S. EPA program is similar in not allowing cross trading between outboard engines and personal watercraft in the early years of the program. The proposal is consistent with this element of the U.S. EPA program, which cites the concern that allowing trading may delay application of clean technologies to both categories of marine engines. In addition, by allowing unrestricted trading between the categories, manufacturers that do not manufacture both personal watercraft and outboard engines would be penalized. These manufacturers, for example, would not be allowed to use corporate averaging credits generated by their existing low emission four-stroke outboard engine fleet. Although consistent, the proposal does differ from the U.S. EPA program (which allows trading between personal watercraft and outboard engines after 2001) by prohibiting cross-category trading throughout the program.

4. In-Use Standard

The exhaust emission standards proposed are in-use standards. Consequently, the manufacturer certifies that the engine will not emit more than the certification level over the useful life of the engine. Useful life, applied here, is the period of time when 50 percent of the model year fleet is no longer in use. The useful life is 16 years for outboard engines and nine years for personal watercraft. An in-use standard requires that manufacturers to include appropriate deterioration factors in the calculation of the FEL. The use of an in-use standard is consistent with the U.S. EPA regulation.

5. Test Procedures

The certification test procedures proposed by staff are identical to the U.S. EPA test procedures. The proposal incorporates the test procedures by reference to the “California Exhaust Emission Standards and Test Procedures for 2001 and Later Model Year Spark-Ignition Marine Engines” document which contains the U.S. EPA procedures in their entirety. Certification results and documentation are required to be processed by the ARB to obtain an Executive Order to allow sales of engines in

California. It is the intent of the proposal to require no unnecessary additional burden to engine manufacturers for certification of engines for the California program.

E. Certification Labeling Requirements

In order to clearly identify all California-certified, spark-ignited marine engines, staff proposes that each be affixed with a permanent engine label. The certification label would be located on the engine, inside the cowling or engine compartment. The label would indicate that the subject engine complies with the California regulations and also serves as an effective tool for in-use testing and other enforcement programs. As such, the label would be required to display various emission-related information, including the manufacturer designated HC + NOx standard which reflects certification on a corporate average basis. The label provisions also allow engine manufacturers to include other information or statements that demonstrate compliance with the requirements of other agencies. Engine certification labels are currently required as part of California's on- and off-road mobile source regulations. The requirements for the certification label are not substantially different from the U.S. EPA requirements and will require minimal modification by engine manufacturers.

Since it is common for engine manufacturers to sell their certified engines to equipment or vessel manufacturers, the proposal allows for some flexibility in the labeling provisions. For example, instead of the engine manufacturer's name on the certification label, the engine manufacturer is permitted to indicate the corporate name and trademark of an equipment manufacturer, or third-party distributor. This will facilitate marketing decisions in which the secondary parties wish to be identified as the sole manufacturer of their equipment or vessel, including the engine itself. This action will not impact the certifying manufacturer since its unique identification code is integrated into the engine family name. Also, staff proposes that these secondary parties be held responsible for the proper content and application of supplemental labels, where applicable. This includes being subjected to any potential remedies associated with supplemental label noncompliance.

F. Environmental Labeling Programs

1. Purpose

The proposal includes requirements for engine manufacturers to apply a standardized permanent environmental label to the exterior of the engine cowling or personal watercraft hull. The purpose of this requirement is two-fold. Its primary purpose is to inform consumers of the relative emissions level of new engines, and to educate the public on the benefits of clean engine technologies. Staff anticipates that this increased consumer awareness of these engines may establish a market trend towards popularity of clean technologies, thereby accelerating the benefits of the program by encouraging the acquisition of engines that comply with more advanced emission standards than required at the time of purchase.

A second purpose of the environmental label is to provide water agencies with a mechanism to clearly identify clean engine technologies in order to control access and activity on sensitive waterways. As discussed in Section II (Background), water authorities such as TRPA, EBMUD, and Santa Clara Metropolitan Water District are restricting access to Lake Tahoe, San Pablo Reservoir, and Calero, Coyote, and Anderson Reservoirs, respectively, to engine technologies with demonstrated lower emission levels. These agencies have identified the need for a standardized, permanent, and easily visible environmental label system in order to effectively enforce these restrictions. For that reason, ARB is proposing a label program that meets both of these goals; consumer awareness of relative emission benefits and standardized, permanent labels that can be used by water agencies to implement activity restriction programs that protect water quality.

2. Requirements

Staff proposes a three tier label program, following the structure of the proposed exhaust emission standards. The three tiers are described in Table 4.

Table 4 Summary of Environmental Labels			
	Label Name	**Emission Level**	**Color**
Tier 1	Low Emission Engine	100 % of U.S. EPA 2006	Red
Tier 2	Very Low Emission Engine	80% of U.S. EPA 2006	Green
Tier 3	Ultra-Low Emission Engine	35% of U.S. EPA 2006	Blue

Source: Air Resources Board, Proposed Gasoline Spark-Ignition Marine Engine Regulations, Mail Out # MSC 98-08, July 8, 1998.

All of the described labels are required to have the following characteristics:

- Round in Shape
- 4 inches in diameter
- Permanent and/or destructed upon removal
- Reflective

Figure 6 shows a sample of the proposed labels. In order to protect against fraudulent placement on non-eligible engines, this proposal also requires that labels be non-transferable between engines and not available as a replacement part. The regulation requires that the labels be applied on new engines (or vessels in the case of personal watercraft) by the manufacturer. It would also be required that engine manufacturers provide consumers with an explanation of the environmental label language. Example language is included in the text of the regulation. This explanation of the labeling program would be included in the manufacturer's literature attached to new engines (hang tag), and in the owner's manual.

Figure 6

Proposed Environmental Labels

Through the development process, staff and the water agencies recognized the need to incorporate existing clean technology engines in the environmental label program. To exclude existing four-stroke and direct-injection two-stroke engines in the labeling program in some manner would adversely impact marine engine owners that have purchased environmentally friendly marine engine technologies in the absence of a regulation.

Staff is proposing the inclusion of a fourth label in the environmental label program to accommodate these existing engines. This fourth label, pictured in Figure 7, would be yellow in color and will be denoted by “Clean Engine Technology” (CET). The CET label will be required to include the manufacturer’s name and an unique serial number as part of its design. In all other respects the label will follow the requirements as established for the Tier 1 through 3 Environmental Labels as discussed above.

Figure 7

Proposed Clean Engine Technology Label

Owners of pre-2001 model year four-stroke or direct-injection two-stroke engines that do not have an environmental label attached at the time of purchase will be able to have the CET label installed on their marine vessel by equipment manufacturers, distributors or dealerships. The engine manufacturer is ultimately responsible for ensuring that the CET label is administered properly (i.e., labels are placed only on eligible engines or vessels).

The environmental label provision is unique to the California proposal and is not required by the U.S. EPA program.

The environmental label program was designed with the help of a working group comprised of National Marine Manufacturers Association (NMMA) members, the Association of California Water Agency members, the Bluewater Network, the APEX Group, marine engine dealers associations, and TRPA. A discussion of the labeling alternatives evaluated through this process is located in Section VIII (Outstanding Issues).

G. In-Use Compliance Program

Certification with the marine engine regulations requires manufacturers to demonstrate that the engines will comply with the emission standards during the useful life of the engine. It is the intent of staff's proposal to make use of data obtained through the U.S. EPA in-use testing program to determine compliance with ARB's exhaust emission standards. The proposal also includes the authority for ARB to conduct California specific in-use testing. California specific programs will follow the same process used by the U.S. EPA to implement testing. This includes appropriately timed notification to the engine manufacturer for the need to test an engine family, sample size, test engine selection, emission testing protocol, and data reporting requirements.

If an engine family exceeds the applicable HC + NOx standard on average, the subject engine family would be subject to remedial action designed to mitigate the increased emissions caused by the noncompliance. These programs may include a combination of the following:

- Payment of a mitigation fee to be used for off-road emission reduction or verification programs.
- Adjustment of the corporate average standard for following model years.
- Accelerated turn-over program to retire older technology engines, carried out by the manufacturer.
- Demonstration of advanced innovative, emission-reducing technology on future production engines.

Under this program, manufacturers would not be permitted to utilize federal in-use credits to offset noncompliance. The compliance plan used to mitigate increased emissions from non-compliance with the in-use emission standards will be determined through a consultative process with the ARB and approved by the Executive Officer. If a combination of these programs is found to be ineffective at mitigating the increased emissions resulting from noncompliance, the manufacturer will be subject to an engine recall order.

H. Defects Warranty Provisions and Emission Control Warranty Statement

Staff is proposing that engine manufacturers ensure that the engines they build will have emission-related components that are reliable, durable and capable of complying with the applicable emission standards. However, since subjecting each component to separate durability tests is costly and time-consuming, it is believed that an adequate defects warranty would act as an incentive for both engine manufacturers and part suppliers alike to produce an overall, high-quality product. Currently, most engine manufacturers provide standard warranties of between one and three years. Staff's proposed emissions defects warranty would provide a coverage period of four years or 250 hours, whichever occurs first, for outboard and personal watercraft engines. The yearly periods represent approximately 25 and 44 percent of the outboard and personal watercraft engines' average useful life, respectively. A greater percentage of the useful life of personal watercraft is warrantied because of the higher emissions that would result from improperly functioning personal watercraft engines. Staff believes that these warranty periods are appropriate given the cost and duty cycles of the engines. Requirement of an extended emission warranty is consistent with other ARB mobile source regulations and appropriate given the level of emissions and purchase price associated with marine engines. In addition, this provision offers a recognizable benefit of the regulation to consumers.

The addition of an hourly limitation ensures that marine engines that encounter very heavy usage (e.g., commercial applications) do not exceed their designed life prior to the yearly warranty period. Determination of hourly use and warranty coverage thereof will encourage engine manufacturers to include hour meters on engines.

The proposed warranty requirements apply to engine components that affect emissions performance. The warranty requirements do not cover routine and scheduled maintenance, and do not warranty parts past their designed replacement interval.

The U.S. EPA regulations also require lengthened warranty provisions. Table 5 lists the U.S. EPA warranty requirements as they are phased in over the implementation period and compares them to the proposed ARB requirements.

Table 5

Comparison of Federal and California Emissions Related Parts Warranty Requirements

	U.S. EPA Requirements		**ARB Proposal**	
Model Year of Implementation	***Parts Covered***	***Warranty Period***	***Parts Covered***	***Warranty Period***
1998-2000	All Emission Related Parts	1 Year	N/A	N/A
2001-2003	Emission Related parts	1 Year	All Emission Related Parts	4 Years or 250 hours
	Major Emission Related Parts[1]	3 Years or 200 Hours		
2004 and Beyond	Emission Related Parts	2 Years or 200 Hours		
	Major Emission Related Parts[1]	3 Years or 200 Hours		

1. Major emission related parts are limited to catalysts, exhaust gas recirculation systems, air injection and other parts added only for the direct control of emissions.

Source: U. S. EPA, Control of Air Pollution; Final Rule for New Gasoline Spark-Ignition Marine Engines; Exemptions for New Nonroad Compression-Ignition Engines at or Above 37 Kilowatts and New Nonroad Spark Ignition Engines at or Below 19 Kilowatts, Title 40, Code of Federal Regulations Parts 89, 90 and 91, October 4, 1996; and ARB, Proposed Gasoline Spark-Ignition Marine Engine Regulations, Mail Out # MSC 98-08, July 8, 1998.

For each new marine engine sold in California, engine manufacturers would be required to include an explanation of their emissions defect warranty, the warranty responsibilities of the owner, and proper maintenance instructions in the owner's manual.

I. Production-Line Testing

Staff proposes a production line testing requirement to ensure that manufacturers are building their engines as designed. This program will follow the procedure used for the U.S. EPA’s Cumulative Sum procedure. This procedure replicates the statistical foundation of a federal compliance program known as a “Selective Enforcement Audit,” while providing greater opportunity for a quick decision of compliance. Therefore, the Cumulative Sum procedure would reduce the manufacturer’s testing burden, especially for those engine families consistently below the emission standard by a wide margin. The minimum number of tests required is only two and the maximum is thirty.

The existing federal Cumulative Sum procedure is proposed to be modified to ensure year-round sampling; this will provide some assurance that engines meeting the standard in the first or second quarters of production do not encounter compliance problems in later quarters. Additionally, the use of federal FELs and emission credits will not be applicable.

J. Selective Enforcement Audit (SEA) Program

In addition to the other enforcement programs proposed, the proposal would implement an SEA program to discourage inappropriate production line testing and/or reporting of data. This program is procedurally identical to that finalized by the U.S. EPA and, as the name implies, would be used when the Executive Officer determines that a manufacturer's production test data are questionable or not representative of the engine family. Since the possibility of an SEA can be imposed at any time under short notice, manufacturers are more likely to ensure that their production engines are built exactly as certified rather than risk the assessment of potential noncompliance penalties.

V. <u>Technological Feasibility</u>

A. Overview

The marine engine industry is currently in a transition period in response to a changing marketplace and because of the need to develop products which comply with the U.S. EPA's national emission standards. Figure 8 shows the certification levels of all 1998 outboard engines. The taller bars represent traditional outboard engines of the carbureted two-stroke configuration which have high emissions, relatively poor fuel economy and rudimentary oil injection systems which cause exhaust smoke under many operating conditions. These engines are incapable of meeting the emission standards proposed by staff, unless the averaging provisions of the proposal are used to offset their high emissions and they are controlled to the capping standard.

Over the last decade, four-stroke engines have enjoyed increasing market share in low and mid-horsepower outboard engines (under about 130 horsepower). Figure 9 shows that most of these engines are currently capable, with a 30 percent compliance margin, of meeting staff's first (2001) and second (2004) tier proposed emission standards, and the lower-emitting versions meet the third (2008) tier as well. While the four-stroke engines typically cost more to purchase, they are quieter, have less vibration, and use about 30 percent less fuel compared to carbureted two-stroke engines. They also do not produce the objectionable smoke or odor associated with carbureted two-strokes. These advantages have caused continued growth in the four-stroke market segment.

Despite the advantages of four-stroke outboards, a market continues to exist for two-strokes in applications requiring lower initial cost (low horsepower engines) or high horsepower with minimum weight (high horsepower engines). This has caused the development and marketing of lower-emission two-stroke engines using special fuel injection systems. These "direct-injection" engines are currently being marketed as premium high-horsepower engines. The direct-injection engines shown in Figure 9 are primarily those engines over 130 horsepower (the 90 and 120 horsepower OMC engines are also direct injection). Manufacturers have product introductions planned for lower horsepower applications in the future. The current versions of these engines enjoy fuel economy approaching four-stroke engines, reduced smoke and odor, and good performance. They do not currently match the emissions capability of optimized four-stroke engines; most direct-injection engines are capable of meeting the first and second tier standards proposed by staff, but will have difficulty meeting the third tier standards without exhaust aftertreatment.

Figure 8
All U.S. EPA 1998-1999 Certified Marine Engine Families Including Two-Stroke Carbureted, Two-Stroke Direct-Injection, and Four-Stroke Technologies

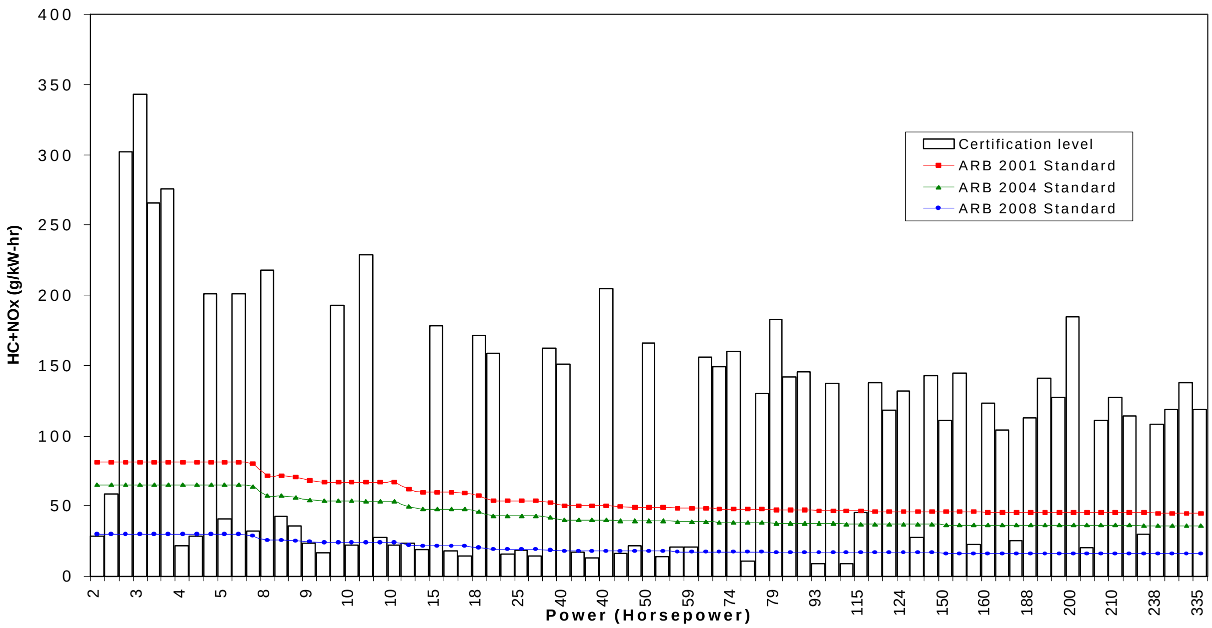
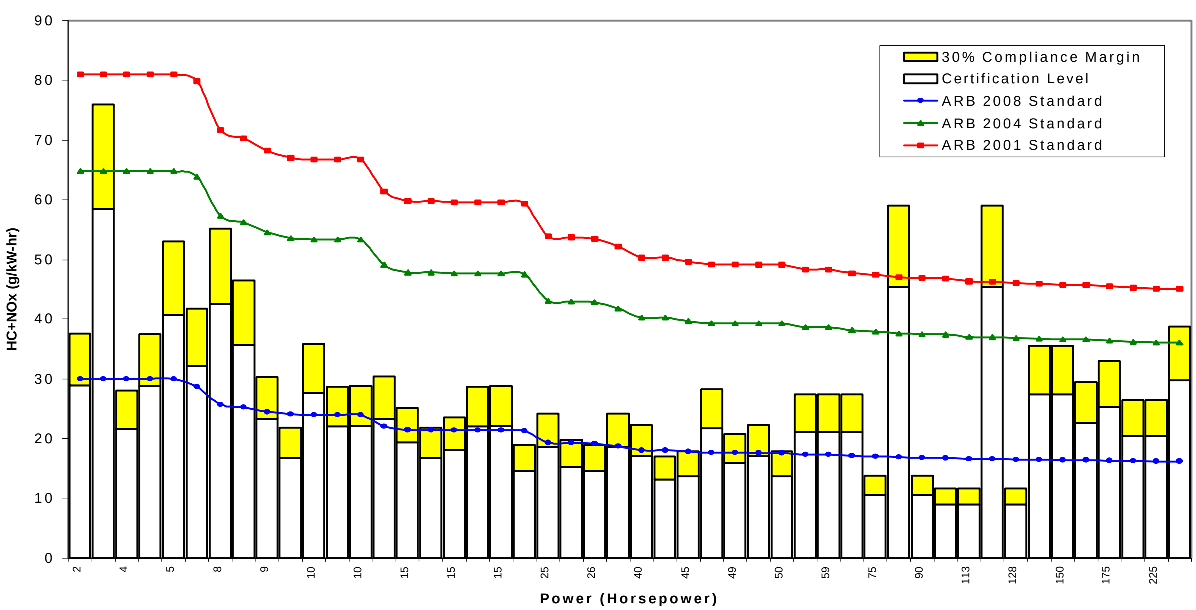


Figure 9

U.S. EPA Certified Four-Stroke and Direct-Injection Two-Stroke Outboard Marine Engine Models with a 30 Percent Compliance Margin



The marine engine manufacturers are transitioning their two-stroke product lines to include numerous direct-injection models to comply with the national emission standards. The standards allow the use of corporate averaging to offer a full mix of conventional two-strokes, direct-injection two-strokes, and four-strokes. Staff's proposed emission standards reflect three concerns regarding the national program. First, the explosive growth of the personal watercraft population has created a much larger emissions impact from marine two-stroke engines than was envisioned when the national standards were adopted. Second, the national standards are implemented too slowly to achieve the short-term emission reductions which California needs, and third, the ultimate long-term goals of the national program do not achieve sufficient reductions for California.

The staff's proposal accelerates the implementation of the federal standards, then establishes long term goals which will require additional efforts by industry and produce greater emission reductions. In the following sections, the major technical options which the marine engine manufacturers have for compliance with the proposed standards will be discussed.

B. Technical Options

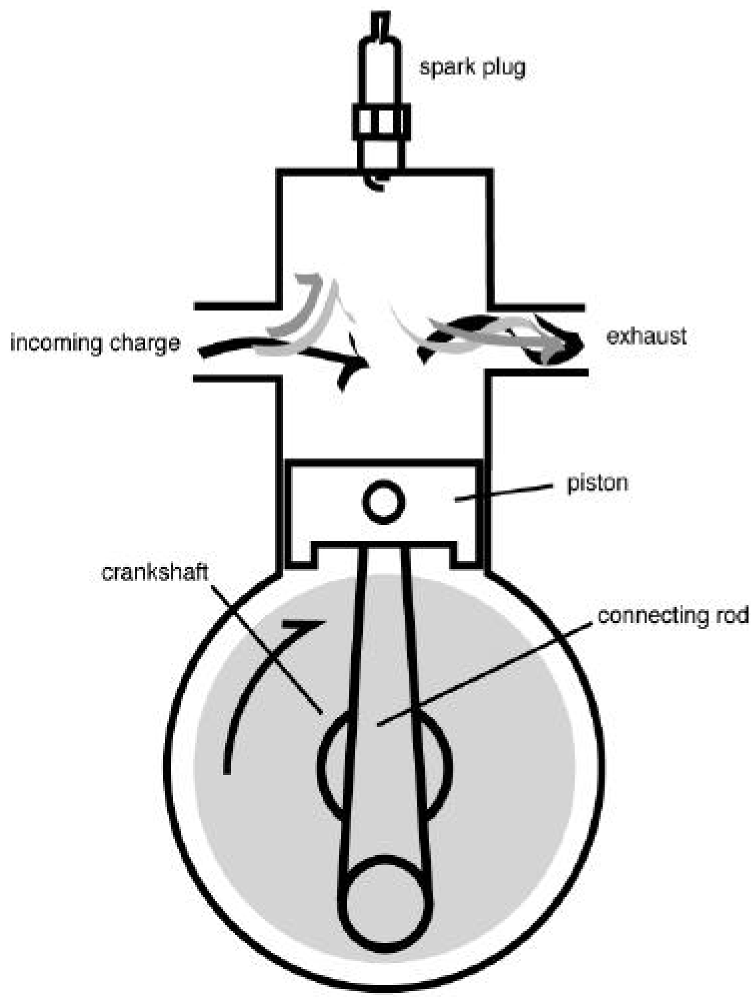
1. Conventional Two-Stroke Engines

All internal combustion piston engines, whether they be used in lawnmowers, automobiles, or watercraft, produce power by burning a fuel which heats the gases in the engine's cylinder causing them to "push" on the piston in the cylinder. This linear motion of the moving piston is converted to rotary motion through a connecting rod and crankshaft, just as any hand-operated crank converts reciprocating motion of a person's arm to rotational motion. The major variations in basic engine design relate to the process used to get a combustible mixture into the cylinder in the first place, igniting it, and expelling the products of combustion to make room for the next charge of combustible mixture. These processes are described as engine cycles. For example, a two-stroke cycle engine is one which completes the processes of charging, combusting fuel, and exhausting waste products in one upward and one downward piston stroke (one rotation of the crankshaft). By the same logic, a four-stroke cycle engine requires two upward and two downward strokes (twp rotations of the crankshaft) to do the same process.

Figure 10 provides a cutaway rendition of a two-stroke engine. The piston is located at its lowermost position, where the process of exhausting spent combustion products and inducting fresh fuel and air happen simultaneously through openings in the cylinder called ports. One can further visualize that as the crankshaft rotates, the piston will move upwards, the ports will be sealed, and the fresh fuel/air mixture compressed. When the piston reaches the top, a spark plug ignites the mixture, creating the pressure in the cylinder which forces the piston down, creating power. As the piston approaches the bottom of the cylinder, the ports are again uncovered, and cycle starts over.

Figure 10

Two-Stroke Engine Diagram



Source: Air Resources Board, J. Swanton, October 1998.

The advantages of conventional two-stroke engines are simplicity, light weight, and good power. The disadvantages are poor efficiency (resulting in high fuel consumption), high emissions, and the need to use an oiling system where lubricating oil is used once, then expelled as part of the exhaust. The low efficiency and high emissions result from the charging and exhausting processes occurring simultaneously. As Figure 10 shows, some of the fresh fuel and air coming into the cylinder is able to escape with the exhaust. In typical carbureted two-stroke engines, up to one third of the fuel being delivered to the engine goes straight through the engine without being burned. This unburned fuel represents very high HC emissions.

One method of capturing more of the fuel/air in a carbureted two-stroke engine is by using a special exhaust system (called an expansion chamber) which reflects a pressure pulse caused by the exhaust port opening back to the port at the precise time when fuel is starting to escape. This pressure pulse bounces the fuel/air back into the engine, increasing horsepower and efficiency. This type of system typically works well in a fairly narrow speed range where the returning pulse arrives at exactly the right time, but efforts to broaden the speed range typically reduce the power gains.

2. Direct-Injection Two-Stroke Engines

The basic problem which causes the short circuiting of fuel through a conventional two-stroke engine is that the fuel and air are premixed into a combustible mixture outside of the engine in a carburetor. If fuel introduction could be delayed until after the piston moves up to cover the ports, all of the fuel would be available for combustion in the engine. This could be done by inducting air instead of fuel/air mixture, then injecting the fuel later. Two-stroke direct-injection engines are configured like the engine shown in Figure 10, except that a fuel injector is placed next to the spark plug.

Several manufacturers are using direct-injection two-stroke technology for their more powerful outboards to lower exhaust emissions and improve fuel economy. Also, conversion to direct fuel injection is relatively straight forward for existing two-stroke engine designs, involving a new cylinder head for the injectors, removal of the carburetors, providing a high pressure fuel pump, and providing a computer to manage the fuel system. Currently there are two major manufacturers of direct fuel injection systems, Ficht by OMC and Orbital by Mercury Marine. Both systems inject fuel at very high pressures at rates of up to 100 to 150 times per second. This is done in different ways for each system. The Orbital system uses compressed air, whereas the Ficht system uses an electromechanically controlled piston.

This technology is generally considered new to the marine industry. Data from federally certified engines show that emissions are about 85 percent lower than carbureted two-stroke outboard engines.

Through precise delivery of oil as needed, oil consumption during idle and low throttle operation is very low. At higher throttle operation, oil consumption of a two-stroke direct-injection engine is much closer to that of carbureted two-strokes, resulting in emissions associated with oil consumption. Overall, however, two-stroke direct-injection engines consume approximately 50 percent less oil during operation compared to carbureted two-stroke engines.

Although the number of model introductions with direct fuel injection has been limited thus far (only two marine engine manufacturers produce them -- see Table 6), other engine manufacturers have plans to introduce additional models using direct fuel injection in 1999. Industry has stated that more than $500 million has already been invested in application of direct fuel injection technology to outboards and personal watercraft[9].

Table 6

1998 and 1999 Model Two-Stroke Direct-Injected Outboard Engines

	0-100 hp	101-150 hp	151-200 hp	>200 hp
Mercury		115, 135, 150	200	225
OMC	90	115, 150	175	200, 225

1. Mercury Engines Uses Orbital Direct-Injection Systems
2. OMC Engines Uses Ficht Direct-Injection Systems

3. Four-Stroke Engines

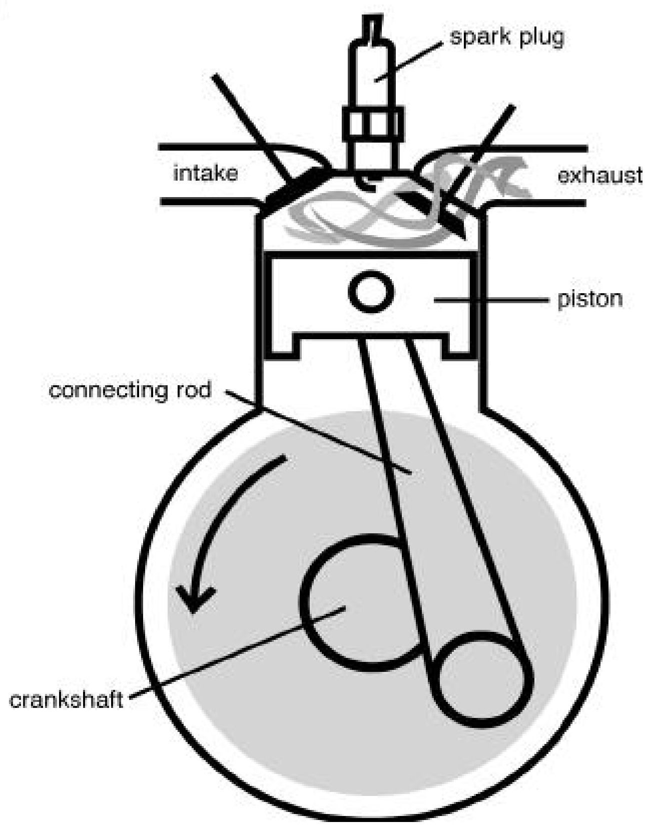
While the direct-injection two-stroke engine represents a large improvement in emissions performance compared to conventional two-stroke engines, the four-stroke engine is typically even cleaner. This is because the process of exhausting and charging the direct-injection two-stroke is very time constrained, since it must occur while the piston passes through the lower part of the cylinder. Efficient exhausting and charging would suggest that the ports should be large and high to provide time for these processes to occur, but high ports would cause the power stroke to be shorter, wasting energy which could instead be put to work pushing the piston. These tradeoffs are major design constraints.

The four-stroke engine devotes separate complete strokes to the exhaust and charging functions. As shown in Figure 11, the charging and exhaust functions are controlled by mechanically activated valves at the top of the cylinder. The timing of the opening and closing of these valves can be optimized for proper charging and exhausting (exhaust stroke shown in Figure 11) and the intake and exhaust valves do not need to be open at the same time preventing short circuiting.

Because of the good mixture control provided by four-stroke engines, they typically produce lower emissions than direct-injection two-stroke engines. Compared to conventional carbureted two-stroke engines, the emissions difference is dramatic, typically 75 to 90 percent lower.

Figure 11

Four-Stroke Engine Diagram



Source: Air Resources Board, J. Swanton, October 1998

Additionally, four-stroke engines do not consume oil as part of the combustion cycle, thus reducing introduction of combusted and unburned oil products to the air and water. Although most outboard engine manufacturers do not manufacture their product lines exclusively with four-stroke technology, there has been an increase in its application since the U.S. EPA implemented the national regulation in 1998. Emissions data collected by the U.S. EPA have shown that existing four-stroke engines can easily comply with the proposed California Tier 1, and Tier 2 standards and many currently comply with the proposed Tier 3 standards. The cleanest four-stroke outboard engines, the Honda 115 and 130 hp, are almost 95 percent cleaner than a comparably rated carbureted two-stroke engine. These outboard engines are based on one of Honda's popular automobile engines and use advanced multi-port fuel injection. Other manufacturers including Suzuki are also utilizing engines from their automotive applications. Table 6 shows the broad range of currently available outboard engines that utilize four-stroke technology.

Table 7

1998 and 1999 Model Four-Stroke Outboard Marine Engines

Manufacturer	0-20 hp	21-40 hp	41-60 hp	61-80 hp	>80 hp
Honda	2,5,9.9,15	25,30,40	50	75	90,115*,130*
Mercury	4,5,9.9,13,15	25,30	40,45,50	75	90
OMC	5,6,8,9.9,15	40	50*	70*	
Suzuki	9.9,15	40	50*,60*	70*	
Yamaha	4,9.9,15	25	40,50	80	100

* Engines equipped with electronic fuel injection.

Engine manufacturers have expressed concern about four-stroke engines, including their larger size, heavier weight, and increased cost. However, this has not been found to be the case for most outboard engines with power output less than or equal to 75 kilowatts (100 horsepower). Most engines in this class require little equipment repackaging, offer similar power-to-weight ratios, and consume less fuel and oil, thereby offsetting increased purchase costs. Manufacturers have indicated that they plan to introduce more four-stroke models in the under 100 horsepower range. It should be noted that certification data from four-stroke engines indicate greater challenges with controlling emissions from smaller engines, (see Figure 9) although emission levels even at small horsepowers are considerably lower than carbureted two-stroke engines.

Currently no four-stroke outboard engines are produced for sale above 130 horsepower. Trade journals have stated that at least one manufacturer is currently working on a 200+ horsepower four-stroke outboard and that it appears likely that other engine manufacturers will eventually focus on this power range, perhaps incorporating more advanced automotive engines. Note that sterndrive inboard engines are available at power levels exceeding 400 horsepower that utilize automotive type four-stroke technology, so high horsepower outboards are not the only means of attaining high horsepower pleasurecraft.

4. Exhaust Aftertreatment

One of the largest breakthroughs in automotive emission control was the introduction of catalytic converters in 1975. These devices are simply a porous ceramic or metal substrate coated with precious metals which cause the chemicals in exhaust to react. They have no moving parts and (automotive catalysts) range in size from a small pet food can to larger than a large coffee can. Catalysts in automobiles are used to reduce NOx and combust HC and CO simultaneously eliminating these emissions at efficiencies exceeding 90 percent. Catalysts were such a significant development because they freed engine designers to focus on performance and efficiency while depending on the catalyst to perform much of the emission control. Modern automotive catalysts reduce emissions by orders of magnitude compared to what was possible by controlling emissions in the engine itself.

The marine engine control levels proposed by staff for 2001 and 2004 are attainable through engine modification or substitution as described in the sections above. For the third tier of control proposed for 2008, catalysts are a control option which will be considered by outboard engine manufacturers. For example, staff projects that moderate efficiency (50 percent) catalysts could be used to reduce emissions from direct-injection two-strokes to complying levels.

The application of catalysts to outboard engines is different from automotive applications for several reasons. First, two-stroke engine exhaust contains oil which could contaminate the catalyst reducing efficiency. Second, water could damage a catalyst by causing a thermal shock which would mechanically damage the substrate and third, catalysts only perform properly at elevated temperatures (this is a concern because marine engines typically cool the exhaust as much as possible for safety reasons and because the direct-injection two-strokes have relatively low exhaust temperatures).

Despite these potential problems, U.S. EPA in its analysis supporting the national emissions standards, cited catalysts as a potential control technology for two-stroke marine engines in their Regulatory Impact Analysis report. It should be noted that catalysts are being used on other production and demonstration two-stroke engine applications with success as shown in Table 8.

Table 8

Catalyst Equipped Two-Stroke Applications

Type of Application	Typical Efficiency
Utility Engines(Husqvarna)[1]	64%
Mopeds (Taiwan)[2]	40% to 60%
Personal Watercraft[3]	21% to 74%

1. ARB Certification Data, 1996, 1997.
2. Asia Technical Department, L. Chan, C. Weaver, Motorcycle Emission Standards and Emission Control Technology, September 1994.
3. H. Fujimoto, A. Isogawa, and N. Matsumoto, “Catalytic Converter Applications for Two-Stroke, Spark-Ignited Marine Engines,” SAE Paper 951814.

In addition to these production applications, staff believes that catalysts are indeed feasible for marine two-stroke engines. Isolating the catalyst from water contaminants would be accomplished by mounting the catalyst(s) close to the engine above the waterline which would also maximize the operating temperatures or by placing a one-way valve in the exhaust stream to prevent water from entering. Note that engine damage can occur if water enters the engine itself, so the same approaches used to protect engines would need to be applied to the catalyst. Catalyst temperatures would need to be controlled through insulation and/or water cooling to maintain a proper operating environment for good conversion efficiency. Thermal management is required for all catalyst systems, so methods of managing temperatures are already well known.

Outboard engine manufacturers cite excessively low (below 400^{o} C) exhaust temperatures as a potential problem for catalysts applied to direct-injection two-stroke engines. However, this problem is not insurmountable. Catalysts are available with operating temperatures extending down to 175^{o} to 250^{o} C, and some intake air throttling could be used at light load conditions to maintain catalyst operation. If throttling were used, efficiency and engine-out emissions would suffer, but used judiciously, this could be available to maintain catalyst activity. At intermediate to high loads the unthrottled operation of direct-injection two-stroke engines is ideal for catalyst use, since the air needed for conversion is already in the exhaust.

With respect to oil contamination, the successful use of catalysts on other types of two-stroke engines has shown that this problem can be managed through an approach called open washcoat structure which prevents the ash produced from oil combustion from interfering with catalyst activity.

In summary, staff recognizes that there are potential challenges with catalyst application to two-stroke outboards, but the existence of potential technical solutions suggests that catalysts can be applied, given the nine-year leadtime for the Tier 3 standards.

In addition, staff is also recommending a technology review for a 2006 timeframe to assess industry's progress in achieving the proposed 2008 standards. Although there are engines currently on the market which meet the proposed Tier 3 standards, staff wants to insure that there is sufficient product availability and that the above technical issues are resolved in a cost-effective manner.

5. Technology Summary

Table 8 summarizes the discussion of available technology. At the bottom of the Table, "typical" emissions required by the staff proposal are cited for each tier. For comparison, baseline carbureted two-stroke engines are shown. A 50 percent efficient catalyst applied to an uncontrolled two-stroke engine could reduce these emissions by half, but the emissions would still exceed all 3 tiers of the staff proposal. Higher catalyst efficiencies are feasible, but the concerns regarding contamination and thermal management become more severe as efficiency is increased. The direct-injection two-stroke is capable of meeting the first and second tiers of the proposed standards, but compliance with the third tier would likely require addition of a catalysts. Since carbureted four-stroke engines can meet all 3 tiers of the proposal. Some of the current four-strokes use fuel injection which further lowers emissions. Most current fuel injected four-stroke engines would comply with all three tiers of standards. Finally, if a 50% efficient catalyst was used on the cleanest four-strokes, emissions would drop well below Tier 3 standards. While all of the options shown are feasible and may be used because of the flexibility provided by the averaging provisions of the proposed regulations, staff expects manufacturers to focus on direct-injection two-strokes, direct-injection two-strokes with catalysts, and four-strokes.

Table 9

Summary of Technology

Technology	Typical Emissions g/kW-hr*	Complexity/level of Development
Carbureted two-stroke	100 - 600	Simple/low cost/developed
Carbureted two-stroke with Catalyst	50 - 100	Modest/not yet on the market
Direct-injection 2-st	24 - 45	Modest/Developed - current introduction
Direct-injection 2-st with Catalyst	10 - 13	Modest/Not developed yet
Carbureted 4-st	15 - 35	On the market/Developed
Fuel Injected 4-st	8 - 25	On the market/Developed
Fuel Injected 4-st with catalyst	4 - 12	Developed for other applications

* Average Emission Level for Tier 1 - 48 g/kW-hr
Tier 2 - 38 g/kW-hr
Tier 3 - 17 g/kW-hr

It is also noteworthy that outboard engines are not the only choice for marine propulsion. In particular, sterndrives are very popular. They combine an automotive engine, with emission capabilities of the four-stroke engines shown in Table 9, with the bottom portion of an outboard. Thus, the engine is mounted inside the boat, and power is transmitted through a shaft and gears to outside the hull to an outboard drive unit which mounts to the propeller. Sterndrives are more fuel efficient than carbureted two-stroke outboards, and are available at power levels exceeding the most powerful outboard. Both Mercury and OMC are major sterndrive manufacturers. Sterndrives are also potentially less expensive than high-horsepower direct-injection outboards, as shown in Table 10.

Table 10

Outboard Vs. Sterndrive Costs[1]

HP	Outboard	DI Outboard	Sterndrive
90	$6,200	$7,000	
150	$9,000	$10,300	
200	$9,600	$12,200	$10,200[1]

1. 190 horsepower engine and drive unit.
Source: Literature survey, Dealer phone survey, October 1998.

C. Compliance Capability

The following sections review the industry's compliance capabilities for each of the emissions standards proposed. Because of differences in technical readiness and engineering constraints outboards and personal watercraft are discussed separate.

1. Outboard Engines

a. Tier 1

Complying engines are already on the market at all the popular horsepower levels. Thus the industry can meet the 2001 Tier 1 standards in that it can provide complying product. The concerns raised by outboard engine manufactures relate to production capacity and model availability.

Table 11 provides staff's estimate of the number of controlled engines for California that manufacturers would have to provide by horsepower under the national and proposed Tier 1 standards in 2001. The table was generated assuming that each horsepower group must comply on average. Since all horsepower groups can average with each other, the balance among the horsepower categories could be shifted by producing more controlled engines in one category and less in another.

Table 11 shows that two to eight times more complying engines would be needed in California under the staff proposal for each horsepower grouping. On the other hand, since California sales are only 10 percent of the national sales, the worst case would be a doubling of production of complying engines, and a more typical case would be a more modest increase. Given these results, staff believes that industry can provide enough product in 2001.

Table 11

Estimated Number of Controlled Engines to Meet ARB Tier 1 Standards

HP Range	% of Pop.[1]	Average HP	Annual CA Sales	Average U.S. EPA Emissions Std.[2] (g/kW-hr)	Average CA Emissions Std.[2] (g/kW-hr)	Emissions from Carb 2-st.[3]	Emissions from Carb 2-st. DI[4]	Emissions from 4-st.[5]	Federal # of Controlled Engines	CA # of Controlled Engines	Number of Engines to Meet CA Std.[2]
0-2	0.93	2	202	204	81	302	0	57	20	182	162
3-15	51.73	6	11159	201	80	319	0	34	4626	9354	4729
16-25	14.06	20	3032	137	56	165	0	22	584	2309	1726
51-120	13.72	37	2960	123	51	171	0	21	941	2370	1429
51-120	12.07	79	2603	114	47	146	59	0	958	2954	1996
51-120	12.07	79	2603	114	47	146	0	18	653	2013	1360
51-120	12.07	79	2603	114	47	146	25		690	2126	1437
121-175	5.57	145	1202	110	46	126	33	0	208	1033	825
176-250	1.60	196	345	109	45	127	33	0	68	299	231
251-500	0.32	247	70	108	45	129	0	0	70[6]	70[6]	0

1. Pop. means population
2. Std. means Standard
3. Carb 2-st. means carbureted two-stroke
4. DI means direct-injection
5. 4-st. means four-stroke
6. All engines in the 251-500 horsepower range are all conventional two-stroke engines that exceed both the U.S. EPA and ARB standards.

The second issue is product availability, which concerns both dealers and manufacturers. The tables in the previous section showed that the major manufacturers have complying products covering the range of power levels required by the market, although it may be necessary for consumers to upsize or downsize slightly, where it would previously have been possible to select from more horsepower “steps.” As manufacturers continue to introduce complying products, selection will improve.

b. Tier 2

The Tier 2, 2004 standards are set at 80 percent of the U.S. EPA 2006 standards curve. This level and implementation date was proposed by NMMA as an achievable level above and beyond the U.S. EPA 2006 curve. Staff anticipates that engine manufacturers will meet these requirements with a combination of two-stroke direct fuel injection and four-stroke technologies. The levels at which engine manufacturers are currently certifying direct-injection two-stroke engines are close to the levels required by this tier. Since the commercial introduction of direct fuel injection technologies is fairly recent, it is anticipated that refinements in the emission levels of the direct fuel injection technology will also be seen in the coming years. Such refinements have occurred with other ARB regulated industries including on-road passenger cars. The Tier 2 standard will likely result in less credit generation and coupled with a lower upper limit on certification levels will mean very few if any carbureted two-stroke engines will be certified under this tier. Staff anticipates that fewer credit generating engine lines will be necessary by 2004 because of projected new product introductions. Further, NMMA’s support of this portion of the staff proposal suggests that manufacturers are confident of product availability in 2004 to support a full line of low-emission engine models.

c. Tier 3

As was shown in Table 9, the only currently known technologies capable of meeting the 2008 Tier 3 standards are direct-injection two-strokes with catalysts, and the range of four-strokes. Since the four-stroke engines are available and almost capable of meeting the proposed 2008 standards today, the proposed nine-year lead time is provided for further optimization of the direct-injection two-stroke engines and developing durable catalyst installations. While this lead time may seem long, recall that the first six years (through 2004) will be devoted to conversion of existing models to four-stroke or direct-injection two-stroke configurations to meet the Tier 2 standards. During that time, staff anticipates that manufacturers will continue to develop catalyst systems to prepare for compliance with the 2008 levels. In addition, four-stroke models will be introduced with the 2008 standards in mind.

Table 12 suggests a possible 2008 complying outboard engine model mix.

Table 12

Example 2008 Outboard Engine Complying Model Mix

hp	Carbureted 4-Stroke	Fuel Injected 4-Stroke	Direct-Injected 2-Stroke	
				with catalyst
0 - 10	100%			
11 - 20	100%			
21 - 30	95%			5%
31 - 50	60%	10%	15%	15%
51 - 75	20%	30%	25%	25%
76 - 100	20%	40%	15%	25%
101 - 125	35%	25%	25%	20%
126 - 150	5%	15%	40%	40%
151 - 200		5%	40%	55%
>200			40%	60%

In 2008, carbureted four-strokes will likely be used exclusively below about 30 horsepower because the cost of adding direct-injection will likely be higher than using existing four-stroke technology. In the mid-horsepower range (30 to 100 horsepower) both direct-injection two-strokes with catalysts and four-strokes will compete with each other at roughly comparable cost. Staff currently projects that the high-horsepower market (over 100 horsepower) will continue to be dominated by two-strokes, which will be equipped with direct fuel injection and catalysts.

However, based upon Honda’s introduction of 115 and 130 horsepower outboards which use fuel injected four-stroke automotive engine designs, staff projects that these types of engines could enjoy growing popularity in the 100-150 horsepower range. In fact, staff may be underestimating the potential for automotive based engines because automotive engines are produced in much greater quantities than marine two-stroke outboards, so production economies of scale could make these engines cost-competitive with the marine engines, despite their complexity. For example, a 115 horsepower Honda automobile engine without accessories, currently retails for approximately $2,500 at the dealership. An OMC 115 horsepower two-stroke direct-injection replacement engine similarly equipped retails for $7,800. Given that the two-stroke engines would still require catalysts, one can see the potential for over 100 horsepower auto-derived four-stroke outboards.

2. Personal Watercraft

Personal watercraft differ from outboards in a number of key areas. First, personal watercraft have the engine and drive unit inside of the hull. Outboards are specifically designed to be mounted outside of the hull as a single unit which includes the engine, transmission, and drive (propeller). The whole engine is turned to maneuver the boat for outboards, while personal watercraft are maneuvered by changing the direction of the nozzle which ejects water to provide thrust. Outboards provide thrust to move a boat through a propeller which turns freely in the water, while personal watercraft suck water from under the hull and pump it through a nozzle to provide thrust. The power unit for a personal watercraft is an engine connected directly to a water pump. This type of jet propulsion has been used for decades in larger boats equipped with automotive engines as a low-cost drive system which is safe because no moving parts are outside of the boat hull. Jet drive units, whether they are used in full sized boats or personal watercraft, typically have poor fuel economy because of water friction inside the drive and because pulling water from under the hull tends to “suck” it into more firm contact with the water, which increases hull drag. When these drive unit characteristics are combined with a carbureted two-stroke engine which wastes up to 30 percent of its fuel, fuel economy is very poor and HC and oil emissions are very high.

The two-stroke engines used in personal watercraft are typically purpose-designed and were derived primarily from early snowmobile engines. Their basic design is similar to two-stroke outboards, but they are optimized for the power absorption characteristics of the jet pump rather than a propeller. Propellers require a broad power band for acceptable low- and mid-speed performance while the power absorption of a jet drive is very low at low and mid-engine speeds, then becomes very high near maximum speed. This allows for personal watercraft engine designs to use larger/higher ports which increase peak power at the expense of low- and mid-range power, and highly-tuned expansion chamber exhausts.

The major personal watercraft manufacturers are developing direct-injection two-stroke engines for this application. Polaris and Tigershark have both announced 1999 models using OMC's Ficht direct-injection two-stroke technology (See Figure 12 Below). Initial emission test results have shown that just installing direct fuel injection on personal watercraft engines may not produce the same emission reductions expected for outboards. Some of this may be because the personal watercraft manufacturers are purchasing this technology and are hence about a year behind in its application. Staff believes that the engine port timing and expansion chamber exhaust used for personal watercraft engines is further limiting the early test results.

Figure 12
Direct-Injection Personal Watercraft

Polaris **Tigershark**

A potential solution to this problem is to use the port timing and exhaust design currently being applied to outboards and to adjust the engine size to provide the requisite horsepower. In some cases this could possibly be done with existing engine blocks, in others, a new block could be required. Because personal watercraft have the engines inside the hull, they do not suffer from packaging constraints as severe as with outboards which have a tight-fitting streamlined cover. Thus, changing engine size or design is less problematic for personal watercraft.

a. Tier 1

Staff believes that the major personal watercraft manufacturers have models with direct-injection two-stroke engines slated for introduction in 1999, so there will be complying product available in California. However, because they are lagging behind the outboard engine manufacturers, the full range of products will not likely be available in 2001.

Based upon the relatively narrow horsepower range of personal watercraft (about 70 to 130 horsepower), a personal watercraft manufacturer should be able to cover the entire range of hulls with two basic engines; one for 70-100 horsepower applications and another for over 100 horsepower applications. The practice of producing engines in multiple sizes/ratings is normal to the outboard engine industry and is transferable to the personal watercraft industry.

Staff expects that developing two basic engines by 2001 is feasible for personal watercraft manufacturers, given that the first ones will be introduced in 1999. The problem will be that adapting the new engines into existing and planned hull configurations may require more than the two years provided, which will result in some product availability limitations in 2001.

b. Tier 2

Given that the personal watercraft manufacturers supported NMMA’s proposal of meeting standards 20 percent below the national standards in 2004, which is the second tier of the staff proposal, we expect a full line of complying products to be available before 2004.

c. Tier 3

For 2008 third tier standards compliance, staff expects the personal watercraft manufacturers to collaborate with outboard engine manufacturers in the development of catalyst systems and to achieve similar levels of control. A technology review will be provided in 2006 to assess progress in catalyst development and other technical options. Finally, it is noteworthy that several of the personal watercraft manufacturers are also motorcycle manufacturers which produce high-horsepower four-stroke motorcycle engines. These manufacturers will likely consider using these engines in personal watercraft because of the economies of scale resulting from multiple applications for these engines. (They are already emission controlled to low levels for compliance with the on-road motorcycle standards.) It may turn out that high-performance four-stroke engines will become the preferred option for future personal watercraft. In addition, staff is also aware of two separate companies who are in the prototype stages of development of a four-stroke or rotary engine which could be used in this market.

VI. Cost of Compliance/Cost Benefit

A. Cost Methodology

The first step taken by the staff in assessing costs was to define the systems and technologies that would likely be used by manufacturers to meet the required emission levels. Based on ARB's experience with automotive emission controls, other categories of off-road engines, and discussions with industry engineers and component suppliers, the most likely emission control technologies needed to meet the proposed requirements were identified in the Technological Feasibility section. For near term goals, the cost to the manufacturers for most individual components in each of the systems currently under development are fairly well established and retail prices of complete complying engines are available. For more distant goals, projections are required. From historic discussions, it appears that manufacturers tend to overestimate the level of technology and amount of hardware needed, and therefore the costs to meet distant development goals.

Once emission systems have been defined and hardware costs determined, ARB's assessment of further costs to manufacturers for research, development, warranty, shipping, and dealer flooring are needed, and they may vary significantly within the industry. Further, manufacturers did not provide the necessary level of detail in their submissions to support a detailed analysis of these costs. As will be discussed, staff has evaluated these costs for other industries and will apply the result to this analysis.

The cost effectiveness numbers presented herein are to be compared with $5 per pound of HC + NOx, which is a typical value for recent emission control activities in California, and to $11 per pound which is considered an upper threshold.

B. Costs of Tier 1 and 2 Standards for Outboards

Engines which meet the proposed Tier 1 and Tier 2 emission standards are currently on the market, along with higher-emitting carbureted two-strokes. Emission certification data are available for these engines. The actual prices being charged for the various engines are also available. Assuming that the entire price difference between engines which do not meet the Tier 1 and 2 emission standards and those which meet the standards are due to the production costs of those engines, the following cost-effectiveness analyses are performed. This assumption is very conservative because at least part of the price difference may be due to higher demand for low-polluting engines.

To perform the analysis, a spreadsheet was used which contains entries by horsepower rating, annual engine sales, emission control requirements under the National and California standards, carbureted two-stroke and controlled engine emission levels, incremental engine prices, and fuel economy improvements and associated savings. This allowed staff to calculate, by horsepower, the number of additional controlled engines which would have to be sold, the associated retail prices, and lifetime emission benefits. The results of the calculation are summarized in Table 11 for Tier 1 and Table 12 for Tier 2.

The cost benefit of Tier 1 standards for outboards by engine size (Table 13) ranges from $0.33 per pound of HC + NOx emissions reduced to $1.52. The overall cost effectiveness, derived as a sales weighted average from Table 13, is $0.97 which compares favorably with other control measures. While the table shows that the cost effectiveness estimates of controlling the lower horsepower outboards are high, this is offset by the very low cost effectiveness for the higher horsepower engines. Further, in the low horsepower applications, complying products already exist, so the proposed regulation would cause the market to select the cleaner products at average price increases of $900 per engine/vessel, which is about 14 percent of the average engine purchase price.

Table 13
Cost Benefit of Tier 1 - Outboards

HP Range	CA Sales[1]	Price Difference per Engine (dollars)	Total Cost Difference[2] (dollars)	Emission Benefit per Engine (pounds HC+NOx)	Total Emission Benefit (pounds HC+NOx)	Cost Effective-ness (dollars per pound)
0-2	162	150	24,300	99	16,038	$1.52
3-15	4,729	250	1,182,250	293	1,385,597	$0.85
16-25	1,726	900	1,553,400	654	1,128,804	$1.38
26-50	1,429	1,350	1,929,150	1,081	1,544,749	$1.25
51-120	1,437	1,900	2,730,300	2,124	3,052,188	$0.89
121-175	825	2,100	1,732,500	3,752	3,095,400	$0.56
176-250	231	2,300	531,300	5,008	1,156,848	$0.46
251-500	34	2,300	78,200	6,925	235,450	$0.33
Total			9,761,400		11,615,074	$0.97[3]

1. Of complying engines needed.
2. Does not include savings due to improved fuel economy.
3. Sales weighted average.

Table 14 **Cost Benefit of Tier 2 - Outboards**						
HP Range	CA Sales[1]	Price Difference per Engine (dollars)	Total Cost Difference[2] (dollars)	Emission Benefit per Engine (pounds HC+NOx)	Total Emission Benefit (pounds HC+NOx)	Cost Effective-ness (dollars per pound)
0-2	54	150	8,100	53	2,862	$2.83
3-15	251	250	629,500	156	392,808	$1.60
16-25	929	900	836,100	352	327,008	$2.56
26-50	773	1,350	1,043,550	585	452,205	$2.31
51-120	708	1,900	1,345,200	1,152	851,616	$1.65
121-175	429	2,100	900,900	2,038	874,302	$1.03
176-250	132	2,300	303,600	2,722	359,304	$0.84
251-500	20	2,300	46,000	3,766	75,320	$0.61
Total			5,112,950		3,335,425	$1.81 [3]

1. Of complying engines needed.
2. Does not include savings due to improved fuel economy.
3. Sales weighted average.

Overall, the cost effectiveness of Tier 2 standards for outboards by engine size (Table 14) ranges from $0.61 per pound of HC + NOx emissions reduced to $2.83. The overall cost effectiveness, derived from a sales weighted average from Table 14, is $1.81. All these values compare favorably with the cost effectiveness of other control measures.

C. Cost of Tier 3 Standards for Outboards

Since outboard engines are not currently manufactured with catalysts, the cost methodology outlined above cannot be applied based upon the retail prices of actual controlled/uncontrolled engines in the marketplace. Instead, it was necessary to estimate the cost of control based upon the additional hardware which would be required for compliance. This is shown in Table 15 for a mid-horsepower engine which would be typical of “average” compliance costs. The catalyst price shown is based upon a catalyst volume of 1.0 liter on a 3 liter engine, which the catalyst suppliers believe would be required for this level of control. The price for engine reconfiguration to package the catalyst is an estimate because no data were provided on this by the industry. The nine year leadtime provided prior to implementation of the Tier 3 standard will allow manufacturers to include revisions to the engine package and catalyst as part of routine product introduction and updates, so the cost will range from zero to substantially higher than the staff estimate, depending on the timing and technical difficulty of the specific catalyst installation.

Table 15

Catalyst Component Costs for a 100 Horsepower Engine

Component	Manufacturer's Costs	Consumer Costs
Catalyst	70	154
Catalyst Packaging	10	22
Revisions to Engine	170	374
Total	250	550

The staff accounted for assembly shipping, warranty, support costs, investment recovery, and dealer costs through a multiplicative factor of 2.2 which is based upon a more detailed analysis performed for on-road motorcycles[10] which considered all these factors for an industry of comparable size and number of different products. The on-road motorcycle analysis considered three cases shown in Table 16, with resulting values ranging between 1.20 and 2.2, and category averages of 1.77 and 1.47. The 2.2 multiplier was selected as a very conservative estimate to include consideration of increased investment cost recovery for research and development to introduce new complying products.

Table 16

Consumer Price Factors from Motorcycle Analysis

	Small Engine	Large Engine
Lax Standard	2.20	1.65
Stringent Standard	1.35	1.20
Average	1.77	1.47

As shown in Table 15, the estimated incremental retail price increase for a catalyst installation on a mid-size (100 horsepower) outboard engine is $550. This value will track engine size, so a first approximation of a catalyst installation on a 200 horsepower outboard would be $1,100. These estimates were used for the high horsepower direct injection two-strokes in Table 17 which shows that the cost benefit of Tier 3 standards for outboards by engine size ranges from $0.32 per pound of HC + NOx emissions reduced to $3.57.

Table 17

Cost Benefit of Tier 3 - Outboards

HP Range	CA Sales[1]	Price Difference per Engine (dollars)	Total Cost Difference[2] (dollars)	Emission Benefit per Engine (pounds HC+NOx)	Total Emission Benefit (pounds HC+NOx)	Cost Effective-ness (dollars per pound)
0-2	60	150	9,000	42	2,520	$3.57
3-15	3,923	250	980,750	126	494,298	$1.98
16-25	1,465	900	1,318,500	293	429,245	$3.07
26-50	1,223	1,350	1,651,050	492	601,716	$2.74
51-120	1,253	1,900	2,380,700	979	1,226,687	$1.94
121-175	717	550	415,860	1,741	1,248,297	$0.32
176-250	258	825	206,400	2,328	600,624	$0.36
251-500	70	1,100	76,720	3,225	225,750	$0.34
Total			7,038,980		4,829,137	$2.08 [3]

1. Of complying engines needed.
2. Does not include savings due to improved fuel economy.
3. Sales weighted average.

D. Costs of Tier 1 and Tier 2 Standards for Personal Watercraft

There are currently no personal watercraft on the market which use two-stroke direct fuel injection engines, so it was necessary for staff to estimate those costs in a manner similar to the catalyst estimates just discussed. Table 18 shows the staff’s retail price increase estimate to be $1,070.

Table 18 **Incremental Cost Estimate for Direct-Injection Two-Stroke Personal Watercraft**		
Component	Manufacturer's Costs	Consumer Costs
Revised Cylinder Head	35	77
Fuel Injectors	90	198
Electronic Fuel Pump + Pumping	45	94
Throttle Body + Air Cleaner	35	77
Oil injection Improvements	45	99
Larger Alternator	30	66
Computer + Harness + Sensors	250	550
Removal of Carburetors (2)	-60	-96
Total	**$470.00**	**$1,070**

The resulting estimate compares well with the average retail price difference between direct fuel injection two-stroke and conventional two-stroke outboards shown in Tables 13 and 14 as ranging between $1,900 and $2,300. Staff expects outboard price differences to be higher because of packaging issues and because they are typically four cylinder engines (compared to two cylinders for personal watercraft). The lifetime emissions benefit reduction for controlling a personal watercraft to Tier 2 levels is 2,843 pounds of HC+NOx. This produces a cost effectiveness of $0.38 per pound. The personal watercraft manufacturers supported the NMMA proposal which is the Tier 2 staff proposal.

E. Costs of Tier 3 Standards for Personal Watercraft

Because the primary estimate of catalyst cost for outboards was performed for a 100 horsepower engine, the catalyst portion of the cost estimate will not change for personal watercraft which are typically above 100 horsepower. The packaging constraints on a personal watercraft are less severe than for an outboard, but the level of exhaust tuning is also higher, which will complicate catalyst installation. Because of these offsetting issues, the $550 outboard estimate is reasonable for personal watercraft, the lifetime benefit of controlling a Tier 2 compliant personal watercraft to Tier 3 levels is 509 pounds of

HC + NOx giving cost/benefit of $1.08 per pound. The cost effectiveness for all three tiers of standards for personal watercraft compare favorably to the cost effectiveness of other recently adopted emission control measures.

VII. Air Quality, Environmental and Economic Impacts

A. Introduction

This section addresses the overall emission reductions that will be achieved by implementing these regulations. It also covers impacts to the environment, including water quality. Finally, analyses are included on the economic impacts of the regulation.

The primary emissions impact estimates provided herein are for summer weekend days because the use of outboard marine engines and personal watercraft are highly seasonal and highest on weekends. This approach is appropriate because emissions occurring on summer weekends contribute to the highest ozone exceedences of the year. Annual average impacts are also provided for comparison with other control measures, but they are less relevant.

The ARB's regulations implementing its California Environmental Quality Act (CEQA) obligations require Staff Reports to assess significant beneficial as well as adverse impacts. (Title 17 California Code of Regulations, Section 60005(b).) This section describes the potential impacts of the proposed regulations. Since both the proposed regulation and all alternatives considered would reduce amounts of both exhaust emissions to air and raw fuel entering waters of the state, only beneficial impacts are discussed. The proposal would not have any significant adverse effects on the environment and therefore no alternatives or mitigation measures are proposed to avoid or reduce any significant effects on the environment.

B. Air Quality Impacts

The emissions from outboard marine engines and personal watercraft are significant. Table 19 shows the 2010 statewide summer weekend day inventory for passenger cars compared to outboard marine engines and personal watercraft controlled to the U.S. EPA standards. Note particularly that projected ROG emissions from outboard and personal watercraft engines nearly equal emissions from passenger cars.

Table 19

Comparison of Pleasurecraft Emissions to Passenger Car Emissions in 2010

	ROG	NOx	ROG+NOx

Table 19 Comparison of Pleasurecraft Emissions to Passenger Car Emissions in 2010			
Outboards and Personal Watercraft[1]	304	38	342
Passenger Cars (2010 On-road Fleet)	333	519	852

1. Reflects effect of U.S. EPA emission standards.

1. Statewide Air Quality Impacts

The proposal is designed to achieve emission reductions earlier and significantly greater than the U.S. EPA standards. Tables 20 and 21 list the expected emission reductions of ROG and NOx for personal watercraft and outboards for 2010 and 2020 respectively. The reductions are above and beyond those that will result from the U.S. EPA program.

Table 20

2010 Statewide Emission Reductions Over U.S. EPA Program (Weekend Summer Day) (Tons per Day)

	ROG	NOx	ROG+NOx
Outboard Engines	26	0.5	27
Personal Watercraft	81	2	83
Total	107	3	110

Source: OFF-ROAD Inventory Computer Model, October 1998.

Table 21

2020 Statewide Emission Reductions Over U.S. EPA Program (Weekend Summer Day) (Tons per Day)

	ROG	NOx	ROG+NOx
Outboard Engines	32	6	38
Personal Watercraft	96	27	123
Total	128	33	161

Source: OFF-ROAD Inventory Computer Model, October 1998.

Table 20 shows that combined weekend summer day emissions from outboard engines and personal watercraft of ozone forming pollutants ROG+NOx will be reduced by 110 tons per day in 2010 statewide from the U.S. EPA 2010 baseline levels. In 2020 emissions of HC + NOx will be reduced by 161 tons per day from the U.S. EPA 2020 baseline as shown in Table 21. Greater reductions are projected for 2020 because by 2020 most outboard marine engines and personal watercraft in use will comply with the proposed standards.

2. South Coast Air Basin 2010 Impacts

Table 22 provides the summer weekend day emissions for the South Coast Air Basin. These emissions are of significant concern and illustrate the need for the additional controls proposed by staff.

Table 22

2010 Pleasurecraft Inventory in the South Coast Air Basin (Weekend Summer Day) (Tons Per Day)

	ROG	NOx	ROG+NOx
Uncontrolled Emission Inventory	284	37	321
Emission Reductions From U.S. EPA Standards	140	-9	131
Additional Emission Reductions from Staff Proposal	30	1	31

Source: OFF-ROAD Inventory Computer Model, October 1998.

3. Impacts on the 1994 State Implementation Plan for Ozone

In 1994, ARB approved a revision to the SIP which contains clean air strategies needed to meet the health-based, one-hour federal ozone standard in the six areas with the most serious smog problem. The 1994 SIP includes measures to reduce emissions from mobile sources under state control (including passenger cars, heavy-duty trucks, and off-road equipment) as well as assignments to U.S. EPA to control emissions from sources under exclusive or practical federal control (such as planes, marine vessels and locomotives). The responsibility to adopt national emission standards for marine pleasurecraft was assigned to U.S. EPA in SIP measure M16.

In addition to the specific measures defined in the 1994 SIP, the South Coast Air Basin needs approximately 75 tons per day of ROG plus NOx emission reductions from mobile sources to attain the one-hour federal ozone standard. These additional emission reductions are often referred to as the ARB's mobile source "Black Box."

a. Emission Inventory Comparison

At the time the 1994 SIP was adopted, we believed that marine pleasurecraft produced far fewer emissions than we know they do today. Unlike the weekend summer day emissions previously presented elsewhere in the report, the emissions and reduction estimates in this section are based on an average summer day, consistent with 1994 SIP. As seen in Table 23, in the 1994 SIP, the uncontrolled inventory projection for pleasurecraft in the South Coast in 2010 was 32 tons per day of ROG plus NOx emissions, with 12 tons per day of emission reductions expected to result from implementation of M16. Since 1994, we have improved the emissions inventory for pleasurecraft, with revised emission factors, activity data, and growth factors. These changes reflect a significant increase in the use and horsepower of personal watercraft. As a result, the current, uncontrolled inventory projection for the South Coast in 2010 is 144 tons per day of ROG plus NOx emissions on an average summer day, more than four times higher than expected in the 1994 SIP. Although ARB did not specifically commit in the SIP to reduce pleasurecraft emissions beyond U.S. EPA's national standards, staff now believes that further emission reductions are necessary, feasible, and cost-effective.

b. SIP Impacts of the Staff Proposal

Tables 23 and 24 compare the uncontrolled emissions, the reductions expected from state and federal standards, and the controlled emissions estimated for the South Coast in 2010 under the 1994 SIP (14 vs. 12), with the corresponding numbers using current inventory estimates and the staff's proposal. With the current inventory, the staff proposal would remove more tons of pollutants from the air than expected in the 1994 SIP (63 vs. 20). The staff proposal would also provide greater overall control, expressed as the percent reduction in combined ROG plus NOx emissions -- a 51 percent reduction versus a 38 percent reduction in the SIP. Although the level of controlled emissions would remain higher than anticipated in the 1994 SIP, the more effective control achievable with the staff proposal would help to offset the increased inventory, cover shortfalls in defined ARB measures, and make progress toward the Black Box.

Table 23

1994 SIP Emissions Estimate of 2010 Pleasurecraft Inventory in the South Coast Air Basin (Typical Summer Day) Tons Per Day

	ROG	NOx	ROG+NOx
Uncontrolled Emissions	29	3	32
Emission Reduction Commitment for Measure M16	12	--	12
Controlled Emissions	17	3	20

Source: OFF-ROAD Inventory Computer Model, October 1998.

Table 24
Current Inventory Emissions Estimate of 2010 Pleasurecraft Inventory in the South Coast Air Basin (Typical Summer Day) (Tons Per Day)

	ROG	NOx	ROG+NOx
Uncontrolled Emissions	127	17	144
Emission Reductions from U.S. EPA Standards	63	-4	59
Additional Emission Reductions from Staff Proposal	14	0	14
Controlled Emissions	50	21	71

Source: OFF-ROAD Inventory Computer Model, October 1998.

c. 1994 SIP Currency Analysis

Since the staff proposal goes beyond the defined measures in the SIP, we believe that the prior paragraph provides the most relevant and appropriate analyses to evaluate the impact on the 1994 SIP (see Table 24). However, for measures developed to fulfill ARB’s SIP commitments, the staff reports generally include an analysis of the impact of each proposal in the “currency” of the 1994 SIP. For pleasurecraft, the SIP currency analysis would involve applying the standards in the staff proposal to the controlled emissions in the 1994 SIP. As a result, the emissions that would hypothetically be available for further control are 20 tons per day, yielding less than five tons per day of emission reductions from the staff proposal in 1994 SIP currency. Although this analysis provides an “apples to apples” comparison to the 1994 SIP, it does not fully reflect the need for the staff proposal or the potential air quality benefits.

d. Statewide Need for Staff Proposal

Although the South Coast is the only area of the State with a Black Box, due to the magnitude of its smog problem, the emission reductions from the staff proposal are needed statewide. Beginning in 2001, the proposed pleasurecraft regulations will help achieve and maintain: the federal one-hour ozone standard in regions such as the San Joaquin Valley and the Sacramento area, the federal eight-hour ozone and particulate matter standards in a number of areas, and the State ozone and particulate matter standards throughout California.

3. Other Statewide Air Quality Benefits

Current carbureted two-stroke technology use results in the discharge of enormous quantities of gasoline into the environment. As much as 25 to 30 percent of fuel consumed by carbureted two-strokes is not burned in the combustion cycle. Considering this, as much as 50 to 60 gallons of fuel per year is discharged into the environment from one average personal watercraft operated for 41 hours per year. Conversion to technologies that do not cause this release of unburned fuel would have obvious HC (ozone precursor) reduction benefits, as well as other significant benefits as discussed below.

A positive benefit from the implementation of this regulation is reduced exposure to toxic air contaminants found in gasoline and gasoline-powered engine exhaust. This is the result of improved technologies being implemented with increased fuel efficiency, and although not quantified for this proposal, it is estimated to be significant to users of marine engines who are directly exposed to exhaust during marine engine operation.

Resulting from use of more oil efficient technologies, staff anticipates that emissions from combusted and unburned lubricating oil will be reduced. Four-stroke technology typically generates very few emissions associated with oil consumption because oil is not mixed with the fuel in the combustion cycle. Two-stroke direct-injection engines consume approximately 50 percent less oil during operation compared to carbureted two-stroke engines. Use of each of these technologies (four-stroke and two-stroke direct-injection) will result in improved emissions related to oil consumption.

C. Water Quality Impacts

Because the proposed regulations on marine engines and equipment will qualitatively reduce discharges of pollutants to waters of the State of California, such qualitative reductions will promote attainment of or reduce the threat of violation of narrative objectives regarding “Oils, Grease, Waxes or other Materials,” “Tastes and Odors,” and “Toxicity,” and federal and State narrative antidegradation and policies described in section [III.B] above. The pollutant reductions potentially achieved from the proposed regulations will assist individual dischargers and water management agencies in maintaining water quality objectives and beneficial uses of waters of the State.

The SWRCB therefore fully endorses staff’s proposal to control emissions from new spark-ignition marine engines. This action is in concert with agency coordination prescribed in Porter-Cologne (CWC 13163). In addition, the source control accomplished by the proposed regulation is an initial and fundamental principle of water quality regulation [as embodied in Sections 13325a and 13225b, CWC).

Considering the substantial quantities of gasoline and oil currently estimated to be discharged into the aquatic environment, continued evaluation and monitoring will be necessary to assess the effectiveness of the proposed regulation in reducing water quality impacts. If impacts are not minimized, additional actions may be necessary to eliminate potential water quality impairments.

D. Economic Impacts

Overall, The proposed regulations are not expected to impose a significant cost burden on marine engine manufacturers. These manufacturers tend to be large and are mostly located outside California. Annual costs of the proposed regulations are estimated to be around $33 million in 2001, $20 million in 2004 and $21 million in 2008. These costs are expected to be passed on by manufacturers to marine engine buyers, resulting in an increase of about 14 percent in average retail prices of a marine engine. NMMA has indicated that marine engine sales decrease by 2.3 percent for every one percent increase in price of the product. Though likely demonstrated in the past, this price elasticity may be overcome with the implementation of the proposed regulations as the products being introduced to the market offer additional value to consumers including improved fuel and oil economy, reduced smoke and in some cases, improved performance. The price increase is not expected to dampen the demand for marine engines significantly. As a result, and as explained in further detail below, staff expects the proposed regulations to impose no significant adverse impacts on California competitiveness, employment, and business status.

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 regulation. The assessment must include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

Also, State agencies are required 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 must include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

2. Businesses Affected

Any business which involves manufacturing outboard marine, personal watercraft, and jet boat engines would potentially be affected by the proposed regulations[c]. Also potentially affected are businesses which manufacture boats, supply parts to these manufacturers, and distribute and service marine engines.

The marine engine industry consists of about 40 manufacturers worldwide, which produce over 1,200 distinct engines and market them through numerous distribution channels[11]. The ten largest manufacturers control over 90 percent of the market[12]. None of major engine manufacturers are located in California although some of their operations are within the state. Table 25 provides a list of the 14 largest companies in the marine engine industry.

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[c] These manufacturers fall into the industry identified by SIC 3519.

Table 25

Major Companies in the Marine Engine Industry

Outboard	Personal Watercraft	Jet Boats
Outboard Marine Corp. Mercury Marine Yamaha Suzuki Tohatsu Honda Nissan	Yamaha Kawasaki Arctic Cat Products Bombardier Polaris	Bombardier Yamaha Mercury Marine

Source: U.S. EPA, Regulatory Impact Analysis, Control of Air Pollution Emission Standards for New Nonroad Spark-Ignition Marine Engines, June 1996.

3. Potential Impact on Engine Manufacturers

Engine manufacturers currently have numerous options to meet the requirements of the proposed regulations, including converting current two-stroke engine technology to four-stroke, direct-injection two-stroke, or equipping engines with catalytic converters in some applications. These technologies are not new to engine manufacturers and have been used for some marine applications. For example, four-stroke engine technology has been used in production of inboard vessels since their inception and in the production of outboard motors since 1972. The direct-injection two-stroke technology is being used in production of personal watercraft by some manufacturers in model year 1999.

Based on the application of a combination of these technologies, staff estimates that the proposed regulations will increase average annualized costs of manufacturing marine engines by about $33 million in 2001, $20 million in 2004 and $21 million in 2008[13]. A small number of well-diversified manufacturers will incur the bulk of the cost increase. Low-volume manufacturers are unlikely to spend much of their own resources on this effort; they are more likely to rely on their suppliers. There are a large number of low-volume producers in the industry that tend to fill special market niches. These manufacturers tend to compete in the market based on non-price factors such as unique features of their products and superior service. These manufacturers are usually able to pass on the cost increase because their customers are less sensitive to price changes in the market. Large manufacturers are also likely to pass on the cost increase to consumers in the long run if they are unable to lower their production costs. Thus, the proposed regulations are not expected to have a noticeable adverse impact on affected manufacturers.

Industry representatives, however, have indicated that boat buyers are usually very sensitive to any price changes. They cite an industry study which estimated a long-term price elasticity of 2.3 for boats, implying that boat sales will fall by 2.3 percent for every one percent increase in boat prices. Although the initial boat price is a major factor in a buyer decision, it is not the crucial factor according to an industry study. The purchase of boat is a major decision for most boat buyers and usually it usually takes a boat buyer about six months of research before making a decision to purchase. Most boat buyers are concerned about the overall affordability of purchasing a boat. Many factors affect affordability including personal income, boat financing, the initial price and maintenance routines. As a matter of fact, the industry's own study shows that maintenance routines are more important to a prospective buyer than the actual cost of a boat. The study also indicates that most buyers would like to negotiate price because they believe that they can gain more specific product information during the negotiation process that justifies the purchase. Thus, it is most likely that boat buyers are willing to pay higher prices for new boats which are more fuel efficient ant require less maintenance. Most manufacturers, therefore, should have no difficulty passing on the cost increase to consumers in the long run if they are unable to lower their production costs. As a result, the proposed regulations are not expected to have a noticeable adverse impact on affected manufacturers.

4. Potential Impact on Distributors and Dealers

Most engine and vessel manufacturers sell their products through distributors and dealers, of which some are owned by manufacturers and some are independent. Some low-volume manufacturers also deal directly with their customers. These distributors and dealers are not directly affected by the proposed regulations. However, the regulations may affect them indirectly in two ways. First, because of consumer sensitivity to price changes, an increase in prices of marine engines could potentially reduce sales volume, thereby resulting in a reduction of revenues for these dealers and distributors. Second, some dealers have indicated that adequate supplies of new engines across the product line may not be available in a timely manner, resulting in a loss of sales. Staff's survey of personal watercraft dealerships showed that they generally do not rely on a single manufacturer for inventory and that many personal watercraft dealerships also sell other recreational equipment and vehicles. These data indicate that temporary fluctuations in the availability of full personal watercraft product lines would not have a significant impact on their ability to remain viable. Outboard engine manufacturers have indicated that given their product plans to introduce clean technology engines, there will be few gaps in product lines. Also, compliance with the proposal may result in a reduction in the diversification of model selection as manufacturers reduce the total number of models sold.

On the other hand, the development of low-emission marine engines may stimulate sales of marine engines. This is because some distributors and dealers have recently experienced a significant fall in their sales of high-polluting marine engines due to uncertainty created by the considerations of imposing bans or restrictions by the National Park Services and some local agencies on the use of high-polluting marine engines in water reservoirs and lakes. At the same time, distributors and dealers are experiencing a surge in demand for low-polluting marine engines. In fact, one manufacturer has recently raised its retail prices for direct-injection two-stroke engines by 15 percent in response to increased demand for their premium engines. Any combination of potential bans or restrictions statewide is likely to accelerate the shift from high-polluting to low-polluting marine engines despite higher prices for low-polluting marine engines.

5. Potential Impact on Consumers

The potential impact of the proposed regulations on the retail prices of marine engines hinges on the ability of manufacturers to pass on the cost increases to marine engine customers. Assuming that manufacturers are able to pass on the entire costs of compliance to marine engine customers, staff estimates the average price of a marine engine would increase by about $150 to $2,300 for California customers. This represents an average increase of about 14 percent in the price of a marine engine. The price increase is well within the range of California personal income gains in recent years. During 1990 to 1997, California personal income rose about 2.2 to 8.2 percent annually[14].

The price increase may actually be offset partially by the cost savings that would result from improved performance of new marine engines (fuel and oil efficiencies). Improved engine durability would potentially reduce the need for parts and services, resulting in cost savings to consumers. Thus, the estimated price increase is not expected to have a significant impact on the marine engine demand in California.

6. Potential Impact on Business Competitiveness

The proposed regulations would have no significant impact on the ability of California marine engine manufacturers to compete with manufacturers of similar products in other states. This is because all manufacturers that produce marine engines for sale in California are subject to the proposed regulations regardless of their location. None of major manufacturers of marine engines have manufacturing facilities located in California although they have some presence here.

7. Potential Impact on Employment

California accounts only for small share of manufacturing employment in marine engine production. According to the U.S. Department of Commerce, California employment in the internal combustion engines (not elsewhere classified) industry which includes manufacturers of marine engines was less than 2,500 in 1995 or about 0.1 percent of total manufacturing jobs in California. These employees work in 23 establishments across the state. One establishment had over 500 employees, one had between 100 to 500 employees and the rest had less than 100 employees. There were also 131 retail outlets in California in 1995, which were primarily involved in the retail sale of new and used motorboats and other marine engines, marine supplies, and outboard motors. These retail outlets employed an estimated 2,000 employees with an annual payroll of approximately $48 million. These employees are not expected to be affected adversely because a small price increase is unlikely to dampen the demand for personal watercraft in California substantially, and the retail outlets also market products other than marine engines. Thus, the proposed regulations are not expected to cause a noticeable adverse impact on the California employment.

The bans or restrictions on the use of high-polluting marine engines being implemented by some water agencies, however, may stimulate demand for new less-polluting engines, resulting in creation of some jobs. On the other hand, some jobs may be lost in businesses supplying parts and providing services for marine vessels. This is because new engine technologies are expected to be more durable, reducing the need for parts and services as old technologies are phased out.

8. Potential Impact on Business Creation, Elimination, or Expansion

The proposed regulations would have no noticeable impact on the status of California marine engine manufacturers. As stated above, the regulations would potentially increase retail prices of marine engines by an average of about 14 percent. The increase in prices is unlikely to dampen demand for regulated products significantly because the impact of a price increase is expected to be offset by a faster rise in California personal income.

The regulations may actually induce sales of marine engines by requiring the industry to accelerate the introduction of less-polluting marine engines. Recent concern about water pollution has prompted some water districts to ban or restrict the use of high emission marine engines on waterways and other waterways may consider such bans or restrictions in the future. As discussed under "Potential Impact on Distributors and Dealers," the uncertainty created by these considerations has already caused a reduction in demand for some marine engines. An actual ban or restriction will further reduce the demand for marine engines unless less-polluting marine engines become available in the market. An accelerated development of less-polluting marine engines may lead to an absolute increase in sales of marine engines for some California dealers and distributors, or at least an increase in sales over likely sales in the absence of the regulations. Several water agencies have indicated a preference to replace bans with restrictions allowing operation of only low-emission vessels.

9. Potential Impact to State, Local or Federal Agencies

Some state agencies now receive, and may continue to receive, funding based on marine engine fuel taxes. Because cleaner-burning marine engines may yield improved fuel efficiency, the regulation could indirectly reduce the amount of fuel sold and could therefore reduce the amount of tax revenue received. However, the predicted marine engine inventory shows that the population is expected to increase with the introduction of the cleaner-burning technology. Therefore, staff believes that there will be no significant impact on fuel tax revenues.

VIII. Alternatives

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

- Rely on the U.S. EPA program for emission reductions, as planned in the SIP.
- NMMA's proposed implementation of U.S. EPA's 2006 standards with a 20 percent reduction in 2004.
- Staff's initial July 9, 1998 Workshop proposal (Mail Out #MSC 98-08, June 8, 1998).
- Staff's intermediate proposal (100, 80, 50 percent of U.S. EPA)

A. U.S. EPA Regulations

The first option evaluated was allowing the U.S. EPA regulation to achieve the emission reductions from marine engines needed to meet our air quality goals. This proposal would have had no impact on manufacturers selling marine engines in California. However, as demonstrated in earlier sections of this report, this option would have fallen significantly short of meeting California's air quality goals.

B. National Marine Manufacturers Association's Proposal

The second proposal evaluated was the NMMA's proposal. Recognizing California's need for further emission reductions from marine engines beyond the U.S. EPA program, NMMA proposed implementation of the 2006 standards in 2004 with a 20 percent reduction. This represents a two year acceleration of the U.S. EPA program with a reduction of 20 percent beyond the U.S. EPA standards. NMMA identified this option as the limit to feasible reductions beyond the U.S. EPA program given their substantial investment and technology development work to meet the U.S. EPA's program over the next seven years.

The NMMA proposal would yield insufficient emission benefits to meet California's air quality goals. This is primarily because of the date of implementation, which is key to achieving substantial emission benefits by 2010. It also lacks a stringent third tier which will guarantee continued reductions beyond 2010. However, the NMMA's proposal has been incorporated into the current staff proposal as the middle tier of the implementation schedule.

C. Staff's Initial Workshop Proposal

Staff's initial Draft Workshop Proposal presented at the July 9, 1998 Public Workshop proposed the standards listed in Table 26.

Table 26

Exhaust Emission Standards as Proposed in the July 9, 1998 Workshop Package g/kW-hr

	Tier 1	**Tier 2**	**Tier 3**
Model Year Implementation	2001	2004	2007
Outboards Less than 100 hp	20	17	13
Outboards Greater than 100 hp	40	27	13
Personal Watercraft	40	27	13

Source: Air Resources Board, Proposed Gasoline Spark-Ignition Marine Engine Regulations, Mail Out # MSC 98-08, July 8, 1998.

This proposal would bring the emissions inventory statewide down to 52 tons per day ROG+NOx for outboard engines and personal watercraft in 2010 if all three tiers were implemented as proposed. This is 12 tons per day lower than the current proposal. The emissions inventory in the South Coast Air Basin in 2010 from these categories under this proposal would be 15 tons per day ROG+NOx.

While this proposal provides additional emission reductions that are needed to achieve air quality goals, representatives of the marine engine manufacturers raised concerns regarding significant technical and economic challenges that may be created with the adoption of this alternative. The following major issues contributed to the staff's decision to modify the initial workshop proposal:

- Lack of a "curve" to set the emission standard. Industry representatives demonstrated, through submittal of certification emission test results, the challenges associated with reducing emissions from smaller horsepower engines. The curve shape developed by the U.S. EPA is preferable because it takes into account these engine power/emissions characteristics.

- Tier 3, 13 g/kW-hr Emission Standard. While some engines have demonstrated emission levels as low as 13 g/kW-hr, and though the average emission level for currently certified four-stroke engines is 14 g/kW-hr, it became apparent that meeting a 13 g/kW-hr standard across the entire product line would be extremely difficult for very small engines, especially given the need to include a margin between the certification level and the family emission level for compliance assurance. The proposed standards range from 28 g/kW-hr for the smallest engines to approximately 16 g/kW-hr for the largest engines in Tier 3.

- Product Availability. Tier 2 and 3 posed significant concerns about product availability across a significant portion of manufacturers' product lines. Staff revised the proposal to include a Tier 2 that was suggested by NMMA and a Tier 3 that includes a curve to accommodate smaller horsepower engines. Staff will conduct a product availability review prior to the implementation of Tier 3.

D. Staff's Intermediate Proposal

The intermediate proposal considered by staff during the development of the current proposal was a strategy based on exhaust emission standards listed in Table 27.

Table 27

Intermediate Staff Proposal HC + NOx Exhaust Emission Standards (grams/kilowatt-hour)

	Tier 1	**Tier 2**	**Tier 3**
Implementation Date	2001	2004	2007
Percent of U.S. EPA 2006 Standard	100%	80%	50%

Source: Air Resources Board, Letter Regarding: "Proposed Spark-Ignition Watercraft Regulations," Mail Out #MSC 98-22, September 8, 1998.

As can be seen in Table 27, the only differences between the intermediate staff proposal and the presented proposal are the Tier 3 implementation date and emission level. The projected ROG+NOx emissions inventory in 2010 and 2020 for this alternative was 130 and 101 tons per day ROG+NOx, respectively. This alternative was rejected by staff simply because further emission reductions are economically and technically possible.

In order to provide additional time for compliance and to achieve greater emission reductions in the long term, staff modified this intermediate proposal, pushing back the Tier 3 implementation date to 2008 and lowering the standard to 35 percent of the U.S. EPA 2006 standard.

E. Summary of Considered Proposals

Table 28 summarizes the various proposals evaluated by staff during the regulatory development process. It should be noted that the numbers presented in this comparison are in annual average tons per day. For planning purposes, the higher weekend summer day average tons per day inventory numbers are used throughout the report.

Table 28

Summary of Proposals Evaluated

	Summary of Proposal	**Statewide 2010 HC+NOx Emissions[1]**	**Statewide 2020 HC+NOx Emissions[1]**	**SCAB 2010 HC+NOx Emissions[1]**	**Concerns**
U.S. EPA	No California Specific Regulations	94	75	27	Inadequate air quality benefit
NMMA	80% of U.S. EPA 2006 in 2004	82	61	23	Inadequate air quality benefit
Initial Staff Workshop Proposal	Straight line standards from 40 to 13 g/kW-hr	52	24	15	Economic concerns
Intermediate Staff Proposal	100%, 80% and 50% of U.S. EPA	65	40	18	Further reductions are possible
Current Proposal	**100%, 80%, and 35% of U.S. EPA 2006**	**64**	**31**	**18**	**Proposed for Adoption**

1. Annual Tons per day ROG+NOx from outboard and personal watercraft engines
Source: OFF-ROAD Inventory Computer Model, October 1998.

IX. Outstanding Issues

A. Introduction

Staff presented the concepts for the proposed regulations through a workshop and numerous individual meetings with stakeholders. Marine engine manufacturers supported most areas of the proposed regulations as reasonable, especially where harmonization with the U.S. EPA was achieved. However, issues did arise as to the feasibility of reasonable compliance with the Tier 3 exhaust emission standards, warranty requirements, lead time for 2001, and the establishment of a multiple tiered environmental label program. The following discussion briefly summarizes the outstanding issues pertaining to the proposal as of submittal for publication.

B. Product Availability in 2001

Personal watercraft manufacturers have indicated that full product lines will not be available in 2001 that meet the Tier 1 exhaust emission standards. Manufacturers claim that they will have converted only 20 to 50 percent of their product lines to cleaner technologies by 2001. Because of the desirability of complying craft, staff does not expect this to translate fully into lost sales. As discussed in Section V (Technological Feasibility), personal watercraft manufacturers can cover a broad range of product with two complying engines, so this projection may also reflect less popular lines not being converted and eventually being dropped. Staff has evaluated the possible impact to California dealerships if a limited range of personal watercraft was available. From this analysis staff found that most dealerships carry lines from more than one manufacturer, sell additional recreational equipment and vehicles, and often have carryover from previous model years. Dealerships indicated that most of their income is derived from aftermarket parts and service. Given this information, staff projects that there will be minimal impact to dealerships, suggesting that this level of product unavailability will be acceptable.

C. Product Availability in 2004

Marine engine manufacturers have expressed similar concerns about meeting the Tier 2 standards as they have expressed about the Tier 1 standard, namely that while the standard may be technologically feasible, conversion of a significant amount of their product line in time for implementation of Tier 2 in 2004 may be challenging. While there may be some unavailable products in 2004, NMMA's proposal of the Tier 2 standards contained in the staff proposal indicates that member companies believe they will be able to provide sufficient complying product.

D. Product Availability in 2008

The exhaust emission standard proposed for Tier 3 in 2008 is 35 percent of the U.S. EPA 2006 emission curve. As discussed in Section V (Technological Feasibility), staff anticipates that manufacturers will employ a combination of four-stroke engines and two-stroke direct-injection engines with aftertreatment. Engine manufacturers have expressed concern that these standards, if achievable technologically, would be difficult to fulfill across their product lines. Staff will conduct a review of product availability which complies with the Tier 3 standard prior to its implementation. However, given the long lead time provided in the implementation schedule, compliance with the standard across a significant portion of the product line is achievable.

E. Warranty Requirements

The proposal establishes a four year or 250 hour emission related parts defect warranty requirement. Manufacturers have expressed concern about requiring such extended warranty periods, citing difficulties with determining appropriate warranty claims. Staff believes emissions related parts warranty periods provide an added assurance that emissions performance will be maintained throughout a significant portion of the engine's life. This requirement is consistent with other mobile source regulations.

F. Multiple Tier Environmental Label Program

Through the working group process, several alternative proposals were suggested and evaluated. However, consensus was not reached within the working group on the number of labels, the design of the labels, or the emission levels at which labels should be required. The proposals included:

NMMA Proposal: A single label set at the 2004 standard of 20 percent lower than the U.S. EPA's 2006 standard. This suggestion proported to offer simplicity while avoiding potential confusion for consumers. Most clean technology engines would be eligible for the label. The proposal was modeled after the U.S. EPA's Energy Star Program, with the features of easy recognition and understandability.

ARB staff proposed the a multi-tier label program in order to establish a mechanism to identify relative levels of emission performance. The multi-tier label program would be similar to a smog index rating or the on-road's "low-emission vehicle" program's "transitional", "low", "ultra" and "super-ultra low" emission vehicle designations, which promote consumer purchase of the cleanest technology.

Bluewater Network's Proposal: A three label system with the highest emitting level set at an emission standards curve similar to the U.S. EPA 2006 standard and the lowest label level using a curve that approaches 8 g/kW-hr. This approach establishes multiple tiers that water agencies can choose from for setting activity restrictions while setting at least one of the curves at a level beyond today's available technology as a goal for future improvements.

The water agencies expressed support for a multi-tiered program following Bluewater's framework. In fact, East Bay Municipal Utility District expressed support for a further fourth or fifth level indicating even lower levels including zero-emission levels.

NMMA opposed this proposal for the reasons cited in their single label proposal, and because it provides water agencies with the ability to distinguish between the various levels of emission controlled engines. NMMA believes that the water agencies would use this labeling system to allow only the cleanest engines to operate on their waterways.

Proposed Environmental Label Provisions: The label provisions proposed incorporate a three label structure similar to that proposed by Bluewater Network. However, rather than adopt the levels proposed by Bluewater, the proposal establishes the exhaust emission standards for 2001, 2004 and 2008 as the criteria for the three labels.

X. **Conclusions**

Staff's goal in developing this regulation was to propose marine engine regulations that achieved the greatest possible emission reductions in a technologically feasible and cost effective manner.

Staff recommends adoption of the proposed regulation which will achieve an annual average 30 ton per day reduction over the U.S. EPA program by 2010, a 32 percent improvement. By 2020 the regulation will achieve, on an annual average basis 59 percent greater reductions over the U.S. EPA program or 44 tons per day. On a weekend summer day basis, the proposed regulations will achieve a 110 tons per day reduction over the U.S. EPA program by 2010.

The proposed Tier 1 and 2 exhaust emission standards are technologically achievable with a mix of clean technologies currently being used, or recently introduced including four-stroke engine technology and direct fuel injection two-stroke technology. Tier 3 exhaust emission standards are achievable with four-stroke engines and with direct-injection two-stroke engines coupled with aftertreatment.

The proposed regulations are necessary to meet air quality emission reduction goal and are supported by the State Water Resources Control Board as being beneficial to water quality.

No alternative considered by the agency would be more effective in carrying out the purpose for which the regulation is proposed or would be as effective or less burdensome to affected private persons than the proposed regulation.

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