SUMMARY OF BOARD ITEM

ITEM NO. 01-6-2: PUBLIC MEETING TO CONSIDER APPROVAL OF EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2003 AND LATER SPARK-IGNITION INBOARD AND STERNDRIVE MARINE ENGINES

STAFF RECOMMENDATION: The staff recommends the Board amend the following sections of title 13, California Code of Regulations, chapter 9 Off-Road Vehicles and Engine Pollution Control Devices, article 4.7 Spark-ignition Marine Engines; sections 2440 through 2447, and the incorporated California Exhaust Emission Standards and Test Procedures for 2001 Model-year and Later Spark-ignition Marine Engines.

DISCUSSION: In 1994, the Air Resources Board (ARB) approved a State Implementation Plan (SIP) for ozone. Among its provisions, the ozone SIP includes measures to reduce emissions from mobile sources including cars, heavy-duty trucks, and off-road equipment and vehicles. In 1996 the United States Environmental Protection Agency (U.S. EPA) adopted regulations for implementation beginning in 2006 which are aimed at reducing hydrocarbon (HC) and oxides of nitrogen (NOx) emissions from spark-ignition marine engines. These federal regulations, which affect outboard engines and personal watercraft, are estimated to reduce emissions from this category by approximately 75 percent once the entire fleet has been converted to the new standard (estimated to be 2025). In 1998, the ARB adopted emission standards for outboards and personal watercraft that are more stringent and are phased-in ahead of the U.S. EPA requirement (2001 through 2008). The ARB regulations will reduce HC+NOx emissions from this category by an additional 67 percent after the complete turnover of the fleet has occurred (estimated to be 2030).

This proposed regulation is aimed at reducing emissions from inboard-engine boats using gasoline engines similar to those found in on-road vehicles. The common types of boats affected by this regulation are sterndrives (inboard/outboards), straight-propeller inboards, vee-drive inboards, and jet-drives. At full implementation of the standards and full fleet turnover, these regulations will reduce ozone precursor emissions from inboard boat engines by approximately 67 percent below current uncontrolled levels. These regulations propose to use the same test procedures and test cycle as the existing ARB and U.S. EPA outboard/personal watercraft regulations.

Implementation of the proposed emission standards would begin in 2003 with combined HC+NOx standards capped at present uncontrolled levels of 15 grams per kilowatt-hour. The second tier of standards, set at 67 percent below the 2003 standards, would be required on a percentage of sales in 2007 and 2008, and on all new engines in 2009. Additionally, beginning in 2007, on-board diagnostic systems would be required on engines complying with the proposed standards to ensure the continued proper performance of emission control devices (*e.g.*, catalytic converters) over time.

The proposed regulations supplement the environmental labeling program for outboards and personal watercraft. These regulations would allow a "four-star" environmental-label level beyond the "three-star" 2008 level mandated for outboard engines.

SUMMARY AND IMPACTS: The estimated statewide benefits of the regulation are 56 tons per weekend summer day of HC+NOx in 2020.

Overall, the regulations are not expected to impose a significant cost burden on marine engine manufacturers. The cost-effectiveness of the regulation ranges from $2.10 to $3.40 per pound. This translates to average price increases of $750 to $1200 for an engine, or less than a 4-percent increase in the price of an average inboard boat.

TITLE 13. CALIFORNIA AIR RESOURCES BOARD

NOTICE OF PUBLIC HEARING TO CONSIDER ADOPTION OF EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2003 AND LATER SPARK-IGNITION INBOARD AND STERNDRIVE MARINE ENGINES.

The Air Resources Board (the Board or ARB) will conduct a public hearing at the time and place noted below to consider amendments to the California regulations for new spark-ignition inboard and sterndrive marine engines.

DATE:	July 26, 2001
TIME:	9:00 a.m.
PLACE:	Ramada Plaza Hotel Whitcomb Ballroom 1231 Market Street San Francisco, California 94103

This item will be considered at a two-day meeting of the Board, which will commence at 9:00 a.m., July 26, 2001, and may continue at 8:30 a.m., July 27, 2001. This item may not be considered until July 27, 2001. Please consult the agenda for the meeting, which will be available at least 10 days before July 26, 2001, to determine the day on which this item will be considered.

This facility is accessible to persons with disabilities. If accommodation is needed, please contact the Clerk of the Board by July 12, 2001, at (916) 322-5594 or TDD (916) 324-9531 or (800) 700-8326 for TDD calls from outside the Sacramento area to ensure accommodation.

INFORMATIVE DIGEST OF PROPOSED ACTION/POLICY STATEMENT OVERVIEW

Sections Affected: Amendment to the following sections of title 13, California Code of Regulations and the documents incorporated by reference therein: chapter 2, Enforcement of Vehicle Emission Standards and Surveillance Testing; article 2.1, Procedures for In-Use Vehicle Voluntary and Influenced Recalls; sections 2111 and 2112; chapter 2, Enforcement of Vehicle Emission Standards and Surveillance Testing; article 2.3, In-Use Vehicle Enforcement Test Procedures; section 2139 and 2140; chapter 2, Enforcement of Vehicle Emission Standards and Surveillance Testing; article 2.4, Procedures for Reporting

Failures of Emission-Related Components; section 2147; chapter 9, Off-Road Vehicles and Engines Pollution Control Devices; article 4.7, Spark-Ignition Marine Engines; sections 2440-2446; and the incorporated "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines;" and the adoption of chapter 9, Off-Road Vehicles and Engines Pollution Control Devices; article 4.7, Spark-Ignition Marine Engines; section 2444.2.

The California Clean Air Act, as codified in the Health and Safety Code sections 43013 and 43018, specifically mandated ARB to regulate off-road mobile sources of emissions. Included are marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. In 1998, the Board approved regulations to control emissions from spark-ignition personal watercraft and outboard marine engines. For these types of engines, the regulations became effective with the 2001 model year. The amendments proposed herein seek to reduce hydrocarbon (HC) emissions and oxides of nitrogen (NO_x) emissions from spark-ignition inboard and sterndrive marine engines, effective with the 2003 model year.

In crafting the proposal, ARB staff met with engine manufacturers and other interested parties in numerous individual and group meetings, including trips to marine engine manufacturing facilities, as well as conference calls. The staff also held a public workshop on September 19, 2000.

STAFF PROPOSAL

The proposal applies to spark-ignition inboard and sterndrive marine engines. Specifically, California's spark-ignition marine engine regulations would be amended to include inboard and sterndrive engines. Thus, these engines would be subject to exhaust emission standards, certification test procedures, on-board diagnostic systems, compliance provisions, consumer provisions such as environmental labeling, and warranty requirements.

The proposed exhaust emission standards are shown below in Table 1. The standards commence with the 2003 model year, followed by more stringent levels that are phased-in beginning in 2007.

Table 1.

Inboard and Sterndrive Exhaust Emission Standards	
Model Year	$HC+NO_x$ (grams/kilowatt-hour)
2003	15.0[1]
2007[2]	5.0

(1) Sales-weighted corporate average, through 2008 model year.

(2) Phased-in standard, reaching 100% compliance with 2009 model year.

Beginning with the 2003 model year, inboard and sterndrive marine engines must show compliance with the 15.0 grams per kilowatt-hour $HC+NO_x$ standard. This standard will keep inboard and sterndrive marine engine exhaust emissions at or below existing levels. This standard, based on a corporate average methodology for demonstrating compliance, provides manufacturers flexibility to comply with the regulations. Additionally, crankcase emissions will no longer be vented into the ambient atmosphere.

With the 2007 model year, manufacturers must comply with the catalyst-based 5 grams per kilowatt-hour $HC+NO_x$ standard. These standards are expected to require three-way catalyst, closed-loop technology to comply with the more stringent $HC+NO_x$ standards. Specifically, for each engine manufacturer's California production, at least 10 percent of the engines in 2007, 50 percent in 2008, and 100 percent in 2009 and beyond would comply with the 5 grams per kilowatt-hour $HC+NO_x$ standard. A phase-in provides industry with flexibility to develop these engines over a period of years.

Small volume manufacturers will have the option to delay compliance until 2009. Inboard and sterndrive engines rated over 373 kilowatts (500 horsepower) will also be exempted from the standards until 2009. Thus by 2009, all new engines produced for sale in California and not manufactured exclusively for competition would be subject to the more stringent exhaust emission standards.

The 2007 and later model year engines complying with the catalyst-based 5 grams per kilowatt-hour $HC+NO_x$ standard will be required to incorporate a computer-controlled on-board diagnostic system. This type of system monitors the engine, identifies emission-related malfunctions, and stores retrievable data related to the malfunction (in the form of a diagnostic trouble code(s)) in the computer's memory so that the malfunctions can be corrected. In the event of a malfunction, the system will emit either an audio or visual alert.

Initially, the 2003-2008 model year inboard and sterndrive engines would be required to provide a two-year emissions defects warranty to the ultimate purchaser. By 2009, the engines would be warranted for three years. This warranty ensures that emission-related parts are free of defects.

Compliance of production engines subject to this rulemaking would be determined using selective enforcement audit (SEA) testing. Procedurally, this program is identical to that used by the United States Environmental Protection Agency (U.S. EPA) and, as the name implies, would be used when the Executive Officer has reason to believe that the emissions of the engines being produced during the production run may exceed the standards.

To ensure that 2009 and later model year engines are meeting the emission standards throughout their 480-hour/10-year compliance period; staff also proposes ARB's traditional in-use testing program. For any engine family selected for testing under this program, exhaust emission testing would be performed on an appropriate sample of in-use engines. If an engine family exceeds the applicable $HC+NO_x$ standard on average, the manufacturer would be subject to recall provisions to remedy the noncompliance.

Staff is also proposing that inboard and sterndrive engines participate in the engine and environmental labeling programs for marine engines. The engine label identifies the engine as compliant with California regulations and may be used for enforcement purposes. The environmental labeling program denotes the relative level of emissions emitted by the engine. Currently, for personal watercraft and outboard marine engines, there are three tiers that represent graduated levels of reduced emissions. The proposal adds a fourth tier, which is appropriate for inboard and sterndrive engines certified to 2007 catalyst-based exhaust emission standards. Upon demonstration of compliance to the applicable emission standard, 2003 and later model year inboards and sterndrives shall display the corresponding emission label.

RELATED FEDERAL ACTIONS

In 1996, U.S. EPA adopted exhaust emission standards for personal watercraft and outboard marine engines. Although U.S. EPA has recently issued an Advance Notice of Proposed Rulemaking that seeks to include inboard and sterndrive marine engines, there currently are no federal regulations for these classes of engines.

BENEFITS OF THE PROPOSAL

The staff analysis indicates that by 2020, the proposal will reduce HC by 11 tons and NO_x by 45 tons per summer weekend day. The combined 56 tons per day reduction is equivalent to removing 1.6 million cars from the road in 2020. The combined $HC+NO_x$ reductions would cost less than $3.50 per pound reduced, which is within the range of cost-effectiveness of other ARB and district emission reduction programs.

AVAILABILITY OF DOCUMENTS AND AGENCY CONTACT PERSONS

The ARB staff has prepared a Staff Report: Initial Statement of Reasons (ISOR) for the proposed regulatory action, which includes a summary of the environmental and economic impacts of the proposal. The Staff Report is entitled, "PUBLIC HEARING TO CONSIDER ADOPTION OF EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2003 AND LATER SPARK-IGNITION INBOARD AND STERNDRIVE MARINE INBOARD ENGINES."

Copies of the Staff Report and the full text of the proposed regulatory language, in underline and strike-out format to allow for comparison with the existing regulations, may be obtained from the Public Information Office, Air Resources Board, 1001 "I" Street, Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990 at least 45 days prior to the scheduled hearing (July 26, 2001).

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

Inquiries concerning the proposed administrative action or substance of the proposed regulations may be directed to the designated agency contact persons, Ms. Jackie Lourenco, Manager, Off-Road Controls Section of the Air Resources Board's Mobile Source Control Division at (626) 575-6676.

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

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

This notice, the ISOR and all subsequent regulatory documents, including the FSOR, when completed, are available on the ARB Internet site for this rulemaking at http://www.arb.ca.gov/regact/marine01/marine01.htm.

COSTS TO PUBLIC AGENCIES AND TO BUSINESSES AND PERSONS AFFECTED

The determinations of the Board's Executive Officer concerning the costs or savings necessarily incurred in reasonable compliance with the proposed regulations are presented below.

The Executive Officer has determined that the proposed regulatory action will not create costs or savings, as defined in Government Code section 11346.5(a)(6), to any state agency or in federal funding to the state, costs or mandate to any local agency or school district whether or not reimbursable by the state pursuant to part 7 (commencing with section 17500), division 4, title 2 of the Government Code, or other nondiscretionary costs or savings to local agencies. However, the Air Resources Board may incur additional implementation or enforcement costs at some future time.

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

The Executive Officer has also determined that there will be no, or an insignificant cost impact on representative private persons or businesses resulting from the proposed action.

Furthermore, the Executive Officer has initially assessed that the proposed regulatory action will not affect the creation or elimination of jobs within the State of California, the creation of new businesses or elimination of existing businesses within California, or the expansion of businesses currently doing business within California. An assessment of the economic impacts of the proposed regulatory action can be found in the Staff Report.

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

Finally, the Executive Officer has also determined that the proposed regulatory action may affect small businesses.

SUBMITTAL OF COMMENTS

The public may present comments relating to this matter orally or in writing at the hearing, and in writing or by e-mail before the hearing. To be considered by the Board, written submissions not physically submitted at the hearing must be received **no later than 12:00 noon, July 25, 2001**, and addressed to the following:

Postal mail is to be sent to:

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

Electronic mail is to be sent to marine01@listserv.arb.ca.gov, facsimiles are to be sent to (916) 322-3928 and received at the ARB **no later than 12:00 noon, July 25, 2001**.

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

STATUTORY AUTHORITY

This regulatory action is proposed under that authority granted in Health and Safety Code sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104. This action is proposed to implement, interpret and make specific Health and Safety Code sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43145, 43205.5 and 43210-43212.

HEARING PROCEDURES

The public hearing will be conducted in accordance with the California Administrative Procedure Act, title 2, division 3, part 1, chapter 3.5 (commencing with section 11340) of the Government Code.

Following the public hearing, the Board may adopt the regulatory language as originally proposed, or with nonsubstantial or grammatical modifications. The Board may also adopt the proposed regulatory language with other modifications if the text, as modified, is sufficiently related to the originally proposed text that the public was adequately placed on notice that the regulatory language, as modified, could result from the proposed regulatory action. In that event the full regulatory text, with the modifications clearly indicated, will be made available to the public, for written comment, at least 15 days before it is adopted. The public may request a copy of the modified regulatory text from the Board's Public Information Office, 1001 "I" Street, Environmental Services Center, 1st Floor, Sacramento, CA 95814, (916) 322-2990.

CALIFORNIA AIR RESOURCES BOARD

Michael H. Scheible

for Michael P. Kenny
Executive Officer

Date: May 29, 2001

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

State of California
AIR RESOURCES BOARD

STAFF REPORT

PUBLIC HEARING TO CONSIDER ADOPTION OF EMISSION STANDARDS AND TEST PROCEDURES FOR NEW 2003 AND LATER SPARK-IGNITION INBOARD AND STERNDRIVE MARINE ENGINES

Date of Release: June 8, 2001
Scheduled for Consideration: July 26, 2001
Agenda Item No.: 01-07-XX

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ATTACHMENT B: Test procedures

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EXECUTIVE SUMMARY

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 (ARB 1994b). 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 aircraft, marine vessels and locomotives). The responsibility to adopt emission standards for marine pleasure craft (measure M16) was assigned to the U.S. Environmental Protection Agency (U.S. EPA). The SIP's M16 emission reduction obligation was 12 tons per day hydrocarbon (HC) reductions in 2010 in the South Coast Air Basin (approximately 10 tons per day from two-stroke outboards and 2 tons per day from four-stroke inboard and sterndrive engines). The U.S. EPA rulemaking, starting with the 1998 model-year for outboards, combined with a subsequent California rulemaking for outboards starting with the 2001 model-year, accounted for the reductions expected from outboard engines. The proposed U.S. EPA rulemaking for spark-ignition (gasoline) inboard and sterndrive engines has not yet been adopted.

ARB staff proposes regulations to reduce HC emissions and oxides of nitrogen (NOx) emissions from new gasoline inboard and sterndrive marine engines sold in California. Development of this proposal was undertaken to address California's SIP commitment and the overall significant emissions impact from this category of engines.

Central to the proposal are exhaust emission standards that start in 2003 and become more stringent in 2007. Specifically, staff is proposing an HC+NOx emission standard capped at present-day levels beginning with the 2003 models. More significantly, the proposal includes a more stringent hydrocarbon plus nitrogen oxides (HC+NOx) standard of 5 g/kW-hr, a reduction of about 67% from today's engines, phased-in in 2007, with full implementation on all models in 2009. Additional features of the proposal include provisions for installation of on-board diagnostics, broadening of the existing consumer-labeling program for outboards to include a 4-star super ultra-low emissions label, establishment of emission warranty requirements and new and in-use engine compliance provisions.

If adopted, the regulation will reduce statewide HC+NOx emissions by 10 tons per day on a typical summer weekend in 2010. By 2020, when many inboard and sterndrive engines will be emission-controlled, the HC+NOx emission reduction will be 56 tons per day. Using assumptions consistent with the 1994 SIP for the South Coast Air Basin, the HC reduction on an annual average day will be 1 ton, which achieves one half of the SIP commitment. The staff was unable to identify a viable option which would achieve the full 2 tons per day HC commitment.

The cost-effectiveness of this proposal is \$2.08 to \$3.39 per pound of HC+NOx emissions reduced for the 2007 standards. This translates to average price increases for new engines of about \$750 to \$1200 for the 2007 standards to comply with this regulation. The range of estimates is due to differing assumptions regarding spreading of development costs for the emission control system over all U.S. sales *versus* over just California sales. For perspective, these costs represent 3 to 4 percent, respectively, of the average 2000-model year sterndrive boat price (\$28,600). The cost-effectiveness of the proposal is well within the range of other adopted mobile source measure costs.

To address the limited resources available to individual marine engine manufacturers, and increase confidence in the in-use operation and durability of catalyst systems installed in boats, the ARB, U.S. EPA and the National Marine Manufacturers' Association are cooperating in a program to test catalysts on marine engines, design optimum air-fuel control programs, minimize water exposure of catalysts and oxygen sensors, and demonstrate the catalyst systems for the full boat-design life. So far this effort has demonstrated a catalyst-controlled engine in the laboratory with a compact catalyst which achieves 67% reduction of HC+NOx emissions, and that water exposure of the exhaust components can be minimized by routing warm cooling water to the exhaust manifolds. The in-boat catalyst demonstration program is scheduled to begin in summer, 2002. The results of this program will be the basis of the proposed 2003 and 2005 technology reviews.

The staff recommends that the Board adopt the staff proposal.

I. INTRODUCTION

The California Clean Air Act, as codified in Health and Safety Code section 43013, directs the Air Resources Board (ARB) to regulate off-road mobile sources of emissions. Health and Safety Code section 43018 further mandates ARB "to achieve the maximum degree of emission reduction possible" from mobile sources of pollution in order to attain California's ambient air quality standards. These off-road mobile sources include, but are not limited to, marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. This regulation focuses on spark-ignition (gasoline) inboard and sterndrive marine engines, typically found in recreational boats such as ski boats or family fishing boats.

In 1998, ARB adopted emission control regulations for gasoline marine engines used in personal watercraft and outboard-engine boats. Inboard and sterndrive engines were not addressed in the rulemaking. At this juncture, staff proposes amending the gasoline marine regulations (Title 13, California Code of Regulations, section 2440 *et seq.*) to include inboard and sterndrive engines. Because these engines are automotive-derived, staff believes that emissions from these engines can be reduced significantly through the use of common automotive emission control technologies such as closed-loop fuel-control systems and three-way catalytic converters. The proposal described herein establishes exhaust emission standards and accompanying compliance procedures for new marine inboard and sterndrive engines.

II. BACKGROUND

In November 1994, ARB approved the State Implementation Plan (SIP) for ozone, which outlined the measures to be taken to bring the State's air quality into attainment with federal ambient air quality standards for ozone (ARB 1994b). During the SIP's development, it became clear that reducing emissions of hydrocarbons (HC) and oxides of nitrogen (NOx) from off-road engines and equipment operating within the state is imperative for cleaning California's air. The SIP identified several categories of off-road mobile sources in which significant emission reduction opportunities exist, including outboard marine engines, inboard marine engines, and commercial diesel marine engines.

The SIP includes various control measures to reduce ozone; the responsibilities for which were divided between ARB and U.S. EPA. SIP measures M9 and M13 focused on off-road compression-ignition (diesel) engines and large ocean-going marine vessels, respectively. Measure M16, entitled "Pleasure Craft," focused on recreational gasoline marine engines. At that time, implementation of measure M16 was determined to be the responsibility of U.S. EPA.

The U.S. EPA adopted regulations for outboard and personal watercraft marine engines in 1996 (40 CFR 91) and for commercial marine diesel engines in 1999 (40 CFR 94). However, when updated emission inventory assessments showed a significant increase in recreational marine emissions, the ARB adopted more stringent regulations for outboard and personal watercraft marine engines in 1998. No regulations have yet been adopted for gasoline inboard and sterndrive marine engines.

A. Description of Inboard and Sterndrive Engines

Before describing inboard and sterndrive engine types, a distinction between propulsion and auxiliary engines should be made. Marine propulsion engines act to move the boat by impeller (in the case of jet-drives) or propeller. Marine auxiliary engines are those used for power generation or deck winch operation. For sailboats, the term "auxiliary engine" also refers to a small propulsion engine, either inboard/propeller or sterndrive/propeller, which is meant for use in times of low wind. The greatest number of marine auxiliary engines are small diesels used on sailboats. Under California's land-based off-road engine regulations, the emissions of auxiliary and propulsion diesel marine engines below 50 horsepower (hp) are controlled. Likewise, non-propulsion gasoline marine engines are regulated under California's small (below 25 hp) off-road engine regulations, and large (25 hp and greater) off-road engine regulations. Thus auxiliary engines are subject to existing emission requirements, and are not addressed in this proposed regulation.

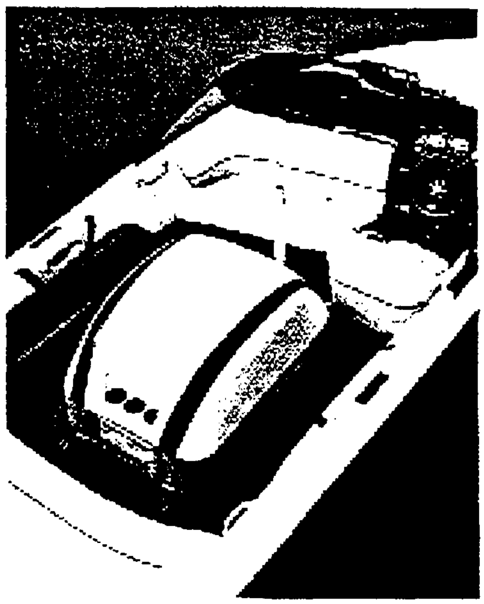
Propulsion engines can be mounted outboard, on the boat's rear transom wall, or inboard. Outboard engines are specially designed to be self-contained, and to have a high power-to-weight ratio. This means they are traditionally two-stroke combustion-cycle gasoline engines (although four-stroke outboards are becoming increasingly available). Inboard and sterndrive engines, on the other hand, are most commonly derived from V-8 or V-6 automotive gasoline engines. In the simplest inboard design, the engine drives a long, straight propeller shaft. This is the oldest historical design and it remains popular today. With sterndrive boats, the engine is situated inboard in the extreme rear-end of the boat, with the S-shaped transmission external to the boat. They are sometimes referred to as "inboard-outboards" for this reason.

The mode of propulsion of motor boats is mostly by propeller, although the use of water jet drive is also common. Personal watercraft use two-stroke modified outboard engines or marinized snowmobile engines to drive water jet-drive pumps. These are available up to 155 hp. Increasingly they are used in small boats, some with two such engines installed. Automotive-derived engines used in inboard boats can also drive jet-pumps.

Provided below are illustrations showing the different inboard boat drive types, that are subject to this regulation. Figure 1 shows the profile of an inboard propeller-drive ski boat. Figure 2 provides a "bird's-eye" view of engine compartment location at the center of the boat. The propeller is under the boat, so with the boat in the water no propeller would be visible. The engine is typically placed about half way between the bow and stern of the boat, near the balance point.

Figure 1
Profile of an Inboard-engine Propeller Boat

Figure 2
View of Inboard Engine Compartment



The left- and right-bank exhaust pipes are routed below the floor to the rear (transom), exiting just above water level. With this design, the propeller, shaft, gear box, and exhaust system are fitted by the boat builder. In contrast, for the sterndrive package, the entire assembly comes with the engine.

Figure 3 shows an x-ray view of an inboard vee-drive. It is referred to as a vee-drive because the engine is placed at the extreme rear end of the boat but faces backward with the shaft-end toward the front, forming the shape of a "vee." This placement allows more room in the boat unobstructed by an engine compartment. The exhaust in this configuration is also routed through the transom.

Figure 3
Schematic of an Inboard Vee-drive

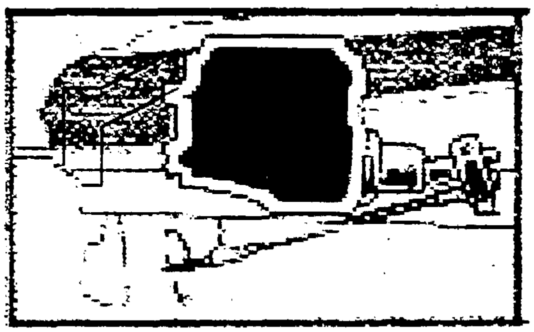


Figure 4 shows the side view of a sterndrive engine with drive attached. The engine is located at the extreme rear end of the boat. The slanted wall to the right of the black engine is the transom of the boat. The drive protrudes well below the bottom of the boat. The engine exhaust for most size engines flows out of the two manifolds (one on each side) through the exhaust riser, into the drive, and out through the propeller center hub. With this design, the engine and drive come as a package; the boat builder is not responsible for the design and fabrication of the exhaust system.

Figure 5 shows a jet-drive (without the engine attached). It would be installed at the rear of the boat where the shaft of a sterndrive would protrude. The drive is basically a water pump. The water inlet is at the bottom (lower left of figure) and is open through the bottom of the boat. The water jet comes out of the external end of the pump (right center in figure). In the figure, the nozzle is covered by a gate valve (lettered "Legend"). The valve is in the closed (covered) position, which provides reverse thrust. When it is open, the water jet moves the boat forward. The engine would be located in the extreme rear end of the boat, like a sterndrive, but the exhaust pipes would exit through (or above) the transom wall.

Figure 4
Side View of Sterndrive engine with Drive

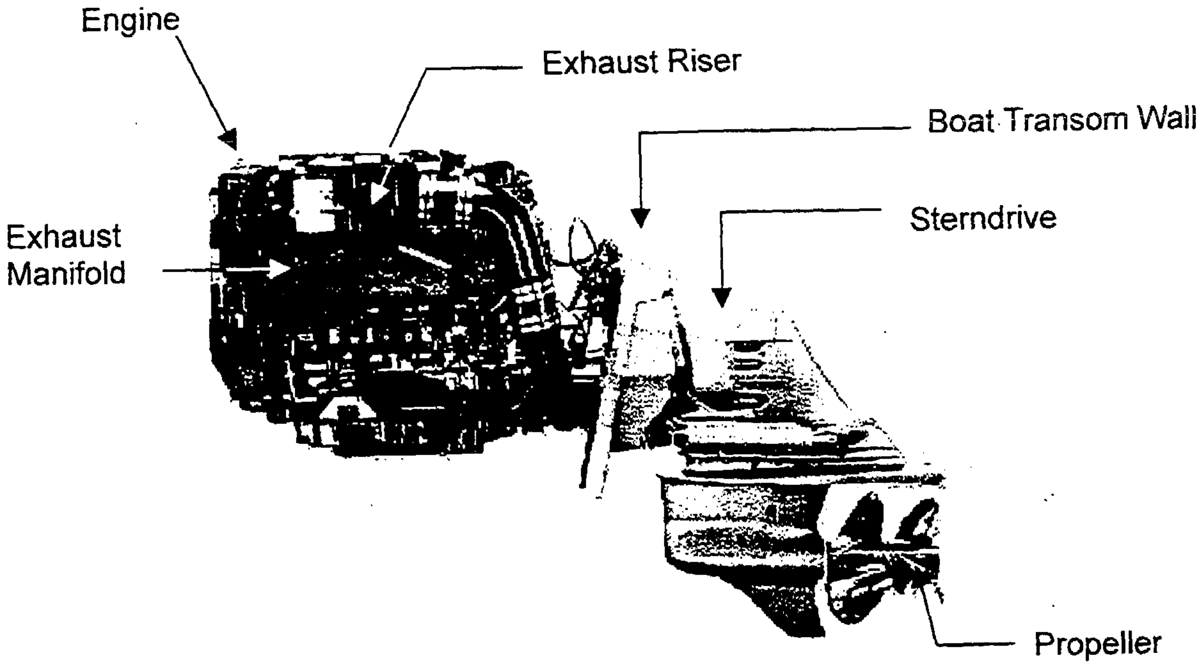
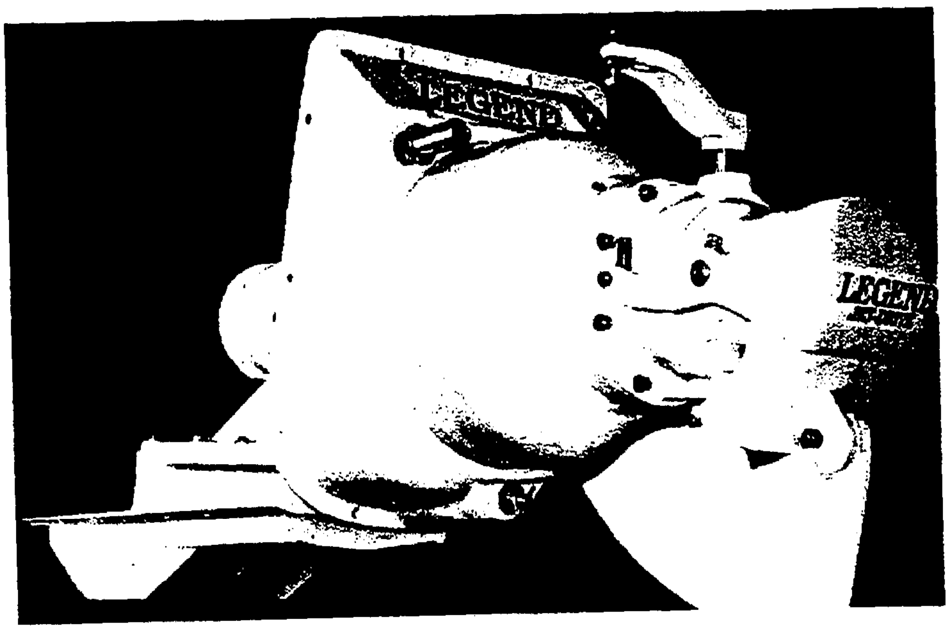


Figure 5
Jet-drive



B. Marinization

Gasoline inboard and sterndrive marine engines are automobile (or truck) engines adapted for use in boats. They are typically cast-iron four-stroke engines. The engine-out emissions characteristics of inboard and sterndrive marine engines are essentially the same as automobile engines (non-catalytic converter equipped). They have relatively high emissions.

In this report we refer to the engine marinizers as "engine manufacturers" because they are responsible for the final engine configuration which is installed in the boat. The marinizers receive the engines from a supplier, such as General Motors, and modify them for use in boats. A list of the major players in the different facets of the boat-building process is given in Table 1. The marinization process typically involves adding a raw-water cooling system, water-cooled and wetted exhaust system, leak-resistant fuel lines, corrosion-resistant and spark-resistant starter, alternator, and fuel pump. For carbureted and throttle-body fuel-injected engines, the engine manufacturers add an intake manifold and a carburetor or throttle-body. The engine manufacturers add an engine control module (on-board computer) to accommodate a marine air-fuel calibration. The marine versions of the automotive engines can also have a different camshaft and more corrosion-resistant head gaskets. A further description of the two main unique characteristics of a marinized engine, its exhaust system and its calibration/operating conditions, is provided below.

Table 1

Inboard/Sterndrive Powerboat Industry

Engine Suppliers	Engine Manufacturers or marinizers	Boat builders
General Motors Ford Motor Co Toyota	MerCruiser Volvo Penta Indmar Marine Power Pleasure Craft Marine	Bayliner Yachts Chris-Craft Larson Malibu Boats Sea-ray

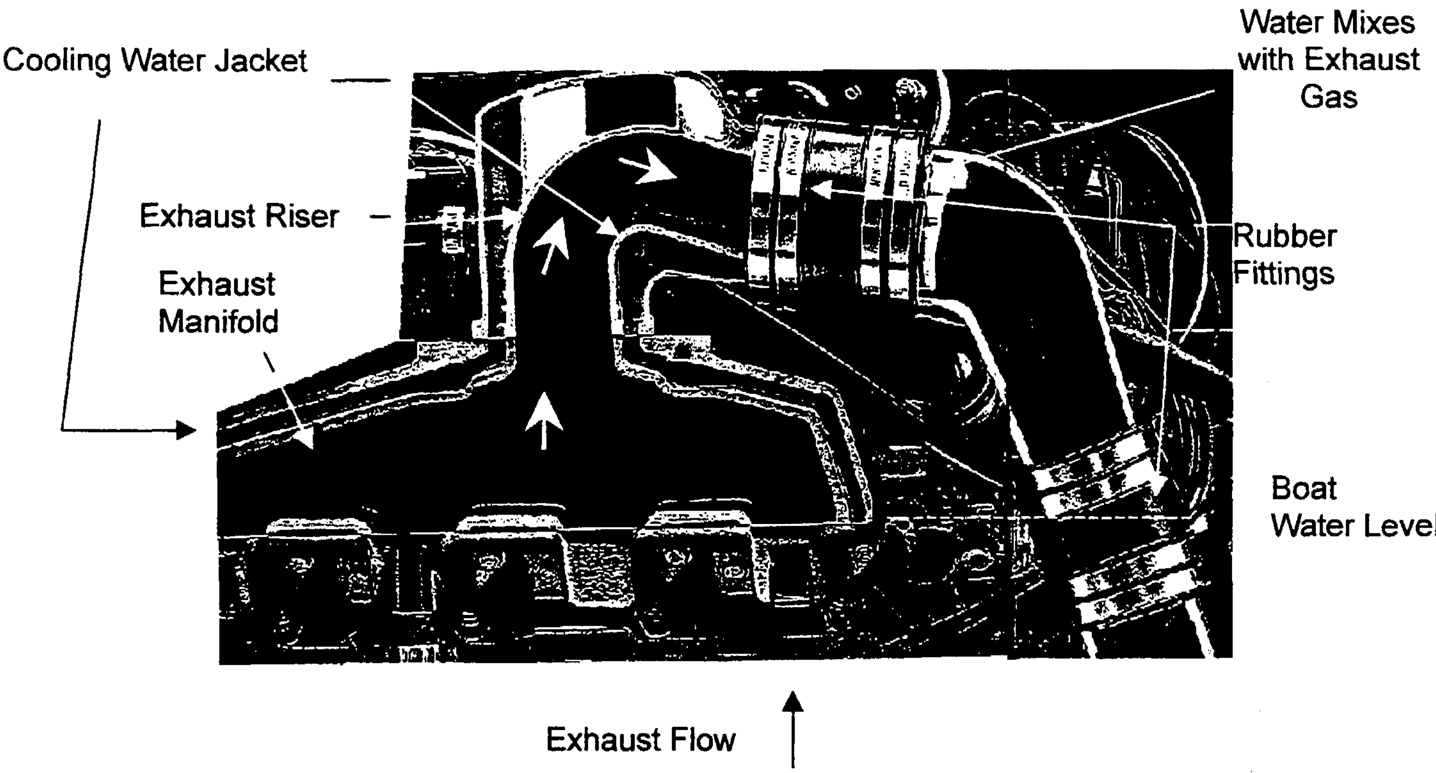
These lists are not all-inclusive.

1. Exhaust System

The engine exhaust in boats is treated differently than land-based engines. For the majority of inboards, the engine exhaust is ducted horizontally to the rear of the boat and passes through the transom, exiting just above the water line. In sterndrive and outboard engines, the engine exhaust is ducted through the lower propeller shaft and exits below water through the propeller hub. In all these drive-systems "used" cooling water is added to the exhaust gases inside the exhaust pipes, and exits with the exhaust gases as a spray. This is done primarily for safety reasons, to minimize heat generation from otherwise hot exhaust pipes within a confined engine compartment.

Figure 6 shows a cut-away view of a typical sterndrive exhaust system configuration. After exiting the exhaust manifold the exhaust gases are ducted up for a short distance through the exhaust riser before reversing direction and being ducted downward. The static water level in the boat is approximately even with the bottom of the exhaust manifold in the photo. This means that lake or sea water will fill the exhaust pipe when the engine is off up to approximately the middle of the rubber coupling on the right lower corner of the photo. Thus, the riser provides a labyrinth or seal which protects against the outside water traveling back up the exhaust pipe into the engine cylinders. The riser is typically water-jacketed. It is in the down leg or elbow that the water is directly mixed with the exhaust gases. After this point the exhaust gases are cool enough so that rubber pipes and joints can be used for the exhaust pipes.

Figure 6
Cut-away view of marine exhaust manifold



2 Calibration/Operating Conditions

Marine versions of automobile engines are usually operated at high speeds (wide-open throttle) for sustained periods of time. The basic automotive engine is designed for more low and medium-speed operation than for sustained, very high speeds. As an example of how an engine can differ depending on its application, a 350 cubic inch displacement engine used in a Chevrolet truck is rated at 255 hp at 4600 rpm. The industrial version of this engine used in forklifts is governed to 3000 rpm where it develops 201 hp. But the marine version is rated at 307 hp at 5000 rpm. Thus, marine engines are uniquely adapted and rated for the marine environment. In addition to unique camshaft designs, adequate cooling is critical. The air-fuel mixture is purposefully richened (using more fuel for the given rate of air) to limit oxidation of the carbon in the fuel, resulting in lower heat release and combustion temperatures, and large amounts of carbon monoxide (CO).

C. Emissions Inventory

Since the adoption of the 1994 SIP, the emissions inventory for marine engines has been updated. Table 2 below identifies the marine engine contribution to HC, CO, and NOx in California based on a typical summer weekend. Summer weekend values are shown because recreational boat usage is highly concentrated during these times, contemporaneous with the height of photochemical ozone production.

Table 2

Aggregate Marine Vessel Emissions

	Population, 2010	HC, TPD	NOx, TPD
Outboards	371,200	116	7
PWC	293,485	84	29
Inboards	124,200	30	40
Sterndrives	262,300	37	46
Recreational Diesels	12,200	4	11
Sail Auxiliary	11,400		
Commercial Diesels	*	10	109

Sources: (ARB 1998c), ARB OFFROAD model, ARB emission inventory website, this work. Summer weekend averages shown. The inboard and sterndrive entries do not include the effect of this proposal.
*7,200 berthed boats plus19,000 port visits per year (Booz Allen Hamilton, 1992).

As shown, the gasoline engines are much more numerous than the large commercial diesel engines (however they are not used nearly to the extent that the commercial diesel engines are). Also note that the two-stroke outboards and personal watercraft are the largest hydrocarbon sources. This is why they were targeted for control measures from U.S. EPA starting in 1998, and ARB starting in 2001. Additional reductions, beyond 2010, will occur when the regulations are fully implemented. The table also shows that the commercial diesels are the primary source of NOx emissions among the marine engines. This is why U.S. EPA targeted them for control starting in 2004. This leaves the recreational gasoline and diesel inboard and sterndrive categories as the next significant source of emissions. In particular, inboard and sterndrive engines, collectively, account for about 25% of the marine vessel HC inventory.

D. Outboard Engine Regulation

The 1994 SIP counted on U.S. EPA to adopt exhaust emission standards for outboards and personal watercraft (SIP measure M16). The standards, which phase-in between 1998 and 2006, ultimately require a 75% HC reduction for new engines. In 1998, ARB adopted regulations requiring outboard and personal watercraft engine manufacturers to meet the 2006 U.S. EPA standards five years earlier (*i.e.*, in 2001) and more stringent standards in 2008. Table 3 below compares the Federal and California phased-in exhaust emission standards for a 75-kilowatt (100 horsepower) outboard marine engine, the size of the typical personal watercraft engine.

Table 3

New Outboard Engine Emission Standards

	Federal $HC+NO_x$ g/kW-hr*	California $HC+NO_x$ g/kW-hr
1998	151	—
1999	138	—
2000	125	—
2001	113	47
2002	99	47
2003	86	47
2004	72	36
2005	60	36
2006	47	36
2007	47	36
2008	47	16

*grams per kilowatt-hour

E. Federal and International Regulations

1. Federal Standards

The U.S. EPA recently issued an Advanced Notice of Proposed Rulemaking for recreational marine diesel and inboard and sterndrive gasoline engine emissions (65 FR 76797). The recreational diesel requirements are similar to the commercial diesel requirements[1]. The proposed U.S. EPA inboard and sterndrive gasoline engine emission requirements are in the range of 9-10 g/kW-hr HC+NOx for engines near-term, and 5-7 g/kW-hr HC+NOx for engines with catalysts long-term. ARB and U.S. EPA are working together to set harmonized national emission requirements. It is anticipated that the U.S. EPA will promulgate standards similar to those proposed by staff. However, the U.S. EPA standards will probably lag the ARB-proposed implementation dates.

2. Swiss (BSO) Standards

A multi-country group (Switzerland, Germany, and Austria) regulates boat traffic on Lake Constance. The group is called the International Shipping Commission. They originally passed the *Bodensee Schiffahrts Ordnung* (BSO) in 1976. It dealt originally with traffic rules and boat equipment on Lake Constance. In 1992, boat-engine emission standards were added to the BSO.

Beginning in 1993, boat usage on the lake was contingent on the boat owner possessing certification from the boat/engine manufacturer stating that the engine(s) emit less than the "Stage 1" standards. Pre-1993 boats were exempted. The test cycle used to demonstrate compliance is the BSO steady-state 9-mode test cycle. The BSO test cycle is similar to ARB's proposed E4 test cycle (ISO 8178 E-4), to be discussed later in this report. The average power (weighted) on the BSO test cycle is 32%, as contrasted to 21% on the E4 test cycle. The E4 HC results are expected to be 8 to 10% higher than BSO hydrocarbon results.

The standards for 1993 (Stage 1) range from 4 to 5 g/kW-hr for HC (depending on engine power) and 15 g/kW-hr for NO_x. These apply to outboards and inboards, diesel or gasoline, commercial or recreational boats. In addition, all gasoline boats (and recreational diesels) have absolute mass emission rates (in grams per hour), which may not be exceeded. Diesel engines have a "smoke number" standard, whereby a white filter paper is measured for discoloration due to exposure to the exhaust.

Effective January 1996 on Lake Constance, the standards became so low as to preclude two-stroke outboards, and to require the use of catalysts on four-stroke

[1] The U.S. EPA-promulgated emission requirements for commercial diesel marine engines begin in 2004 (40 CFR Part 94). The regulations apply only to captive U.S.-flagged vessels with engines less than 30 liters per cylinder in displacement.

gasoline inboard and sterndrive engines. The standards vary according to the engine power rating, but a typical 120-kilowatt (165-horsepower) inboard or sterndrive engine is required to meet a 1.3 g/kW-hr standard for HC and a 3.7 g/kW-hr standard for NO_x. The standards for a very high-output inboard or sterndrive engine (300 kilowatts/400 horsepower) are 1.0 g/kW-hr for HC and 3.8 g/kW-hr for NO_x. No gasoline engines are available to meet these standards at this time, and the only boats operating on that lake are "grandfathered" pre-1993 boats.

3. European Standards

The European Community (EC) is now developing recreational marine engine emission standards. The latest information is that standards for two-stroke gasoline engines would be phased-in in 2003. For a 50-kilowatt two-stroke engine, combining the HC and NO_x emission standards yields a total of 31 g/kW-hr. This is more stringent than California's 2004 outboard standard of 38 g/kW-hr for a similar sized engine, but less stringent than California's 2008 standards (16 g/kW-hr). For inboard and sterndrive engines, however, the EC standards are not as stringent as the BSO standards or the staff's proposed standards. Again, combining EC standards for HC and NO_x, a 300-kilowatt inboard engine would be required to meet 21 g/kW-hr. Such an emission level is attainable by virtually all currently available engines.

F. Cooperative Test Program

The U.S. EPA and the ARB have been working together for the last year and half to

- demonstrate catalyst controlled emission levels on a marine engine in the laboratory and
- design and test an exhaust system on a boat which would minimize water ingestion/accumulation.

Members of the National Marine Manufacturers' Association (NMMA) donated engines, exhaust manifolds, engine control modules and air-fuel programs, closed cooling-systems, and replacement parts in support of the laboratory engine-testing effort. Members of the Manufacturers of Emission Controls Association (MECA) donated seven sets of candidate catalysts which were specially prepared, sized and fabricated for this program. In addition, NMMA members donated a boat, spare engine, and exhaust manifolds for the boat exhaust-testing project. This testing was performed at Southwest Research Institute in San Antonio, Texas.

The catalyst-testing program found that catalysts can achieve the approximately 70% reduction of HC+NOx proposed in these regulations with no or minimal engine performance degradation, and with no overheating or safety concerns.

The in-boat water ingestion project showed that condensation on cold exhaust manifolds was the main source of water accumulation, and that incorporating a thermostat on the cooling water to the exhaust manifolds eliminated the water accumulation.

As part of the industry meeting on March 15, 2001, ARB, U.S. EPA, NMMA and MECA agreed to participate in an in-boat catalyst-controlled engine test program. The NMMA members agreed to donate 6 boats. General Motors will donate the engines for the boats. MECA members agreed to donate candidate catalyst designs. The boats will be run through various typical and demanding procedures on both fresh water and salt water, will accumulate 480 hours of service, and will undergo emission tests at various time intervals. The goal of the project is to address issues of durability, operability, and safety.

III. NEED FOR CONTROL

ARB's efforts to control emissions from engines are, in large measure, in response to the need to control ground-level ozone exceedances in urban areas.

Ozone, created by the photochemical reaction of HC and NO_x, causes harmful respiratory effects, including chest pain, coughing, and shortness of breath, affecting people with compromised respiratory systems and children most severely. In addition, NO_x itself (specifically nitrogen dioxide) can directly harm human health. Beyond their human health effects, other negative environmental effects are also associated with NO_x and ozone. For example, ozone injures plants and building materials. NO_x contributes to the secondary formation of particulate matter (PM) in the form of aerosol nitrates, contributing to acid deposition, and exacerbating 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 with concentrations exceeding one or more of these standards.

The 1994 Ozone 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 about half of the rate allowed under regulations existing in 1994. Staff is developing a new "Clean Air Plan" to address all the State and federal air quality requirements including air toxics. Further emission reductions will likely be necessary to attain the goals of the new plan.

The SIP commitment to reduce emissions from gasoline inboard and sterndrive engines is 2 tons per day of ROG reductions in the South Coast Air Basin by 2010, to have been brought about by U.S. EPA adopting an emission regulation requiring 35% reduction of inboard and sterndrive engine emissions starting in 1996. U.S. EPA has not yet adopted this rule, concentrating first on the two-stroke outboard engines instead.

The ARB has been threatened with litigation over shortfalls of emission reductions promised in the SIP. ARB has entered into a settlement agreement as a result of the threatened suit. It calls for this proposed measure to be adopted in 2001 to result in 3 tons per day of HC reduction (in SIP currency, *i.e.* consistent with the inventory in place in 1994) in the South Coast Air Basin by 2010. Actual reductions will be larger as discussed later in this report, because emissions from inboard and sterndrive engines are known to be greater than thought in 1994, and because their use is concentrated on weekend days when the highest levels of ozone are experienced.

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.

IV. SUMMARY OF PROPOSAL

A. Introduction

Currently, California's gasoline marine engine regulations, which affect outboard engines and personal watercraft, consist of exhaust emission standards, certification test procedures, new-engine and in-use-engine compliance provisions, consumer provisions such as environmental labeling, and warranty requirements for engines used in personal watercraft and outboards. The proposed regulation described in this report would establish comparable requirements for gasoline inboard and sterndrive marine engine.

In crafting this proposal, ARB staff met with various stakeholders. Individual and group meetings took place from April 2000 through May 2001, including a general public workshop on September 19, 2000, and an industry meeting on March 15, 2001. The U.S. EPA participated in both the September and March meetings. During the development of this proposal, staff visited two engine manufacturing plants and one boat-builder. At the meeting in March, the manufacturers, catalyst vendors, Coast Guard, ARB and U.S. EPA worked out a cooperative in-boat testing program, and a two-phase set of emission standards. Staff met with the California State Department of Boating and Waterways and the Boating and Waterways Commission to discuss safety concerns of catalyst-equipped engines on boats. This proposal incorporates many of the comments and suggestions of all interested parties.

The following is a brief summary of each element of this regulatory proposal. A more detailed discussion, including a description of the provisions and an explanation of the intent, follows in Section V. The amended text of California's gasoline marine engine regulations is contained in Attachment A. Attachment B contains the amended text of the Test Procedures.

B. Applicability

The proposed regulation applies to new gasoline inboard and sterndrive marine engines produced for model-year 2003 and later, with exceptions provided for competition racing boats. With adoption of this proposal, all gasoline engines except for those in airplanes, snowmobiles, and on-road motorcycles with engine displacements less than 50 cubic centimeters will be subject to emission standards. Diesel engines used as recreational marine propulsion engines are excluded from these regulations. Marine diesel engines less than 50 horsepower are subject to existing off-road diesel engine standards. It is anticipated that federal regulations will be promulgated in 2002 to cover marine diesel engines over 50 horsepower.

C. Definitions

The definitions included in this proposal are consistent with both the California and the U.S. EPA gasoline marine engine rulemakings for personal watercraft and outboards. However, additional definitions have been added for program elements specific to the proposed on-board diagnostic system. "Small-volume manufacturer" and "competition" have also been defined in terms specific to this proposal.

D. Emission Standards and Test Procedures

1. Emission Standards

The staff proposes an HC+NO_x emission standard beginning in 2003. A more stringent HC+NO_x emission standard would be phased-in between 2007 and 2009. The standards are shown in Table 4.

The standards were selected to provide industry with flexibility regarding the choice of technology for compliance; however, staff anticipates that in order to meet the 2003 emission standards the manufacturers can either use present-day air-fuel ratio calibrations or the leaner air-fuel calibration designed to meet the European standards, and the 2007 standards will require the use of three-way catalysts with closed-loop air-fuel control.

Table 4
Inboard and Sterndrive Emission Standards

Model Year	HC+NOx Emission Standard g/kW-hr
2003	15.0*
2007**	5.0

* This standard applies to an engine manufacturer's engines, on a sales-weighted corporate average basis.

** 10% of California sales must comply with this standard in 2007. 50% of sales must comply in 2008. 100% of sales must comply in 2009.

The staff proposes to phase-in the more stringent, catalyst-based exhaust emission standards for inboard and sterndrive marine engines commencing in the 2007 model-year. Manufacturers will be required to introduce one engine family representing at least 10% of California sales in 2007. In 2008, the manufacturers will be required to produce 50% of their California sales as complying models. With the 2009 model year, all new engines produced for sale in California will be subject to the emission standards.

The proposed regulation allows no emissions to be emitted from the crankcase of these engines into the ambient atmosphere.

Small-volume manufacturers and engines over 500 horsepower would not have to comply with the standards until 2009.

2. Test Procedures

The ARB adopted the ISO 8178-4 E4 test cycle for recreational marine gasoline personal watercraft and outboard engines. Staff is proposing to use that test procedure for inboard and sterndrive engines also.

E. Certification and Environmental Labels

For new 2003 and later gasoline marine inboard and sterndrive engines sold in California, staff proposes the same labeling requirements as for outboards:

(1) an engine label, and
(2) an environmental label.

The engine label would be permanently affixed to the engine and would serve to denote a California-certified gasoline marine engine.

The environmental label, placed on the boat, would provide prospective engine owners, current engine owners, and enforcement personnel with information about the relative cleanliness of the engine, according to the Air Resources Board's standards. Staff is proposing to add a 4-star label to the regulations for inboard and sterndrive engines complying with the proposed 2007 standards.

F. Selective Enforcement Audit Testing

The proposal would implement selective enforcement audit (SEA) testing beginning in 2003. The proposed SEA testing is procedurally identical to the SEA program that is used by the U.S. EPA and, as that name implies, would be used when the Executive Officer has reason to believe that the emissions of the engines being produced may exceed the standards. Since SEA testing can be imposed on the engine manufacturer at any time and under short notice, manufacturers are more likely to ensure that their production engines are built exactly as certified, rather than risk the potential noncompliance.

G. In-Use Compliance Program

Compliance with the proposed regulations would require manufacturers to demonstrate that their post-2008 engines will comply with the emission standards throughout their certification life of 480 hours or ten years, whichever first occurs. To ensure that these certified engines are meeting the emission standards throughout their certification lives when properly maintained, staff proposes to incorporate California's existing in-use testing program for inboard and sterndrive engines. This testing program has a longstanding history with on-road mobile sources, and more recently has been incorporated into off-road rulemakings, such as those for off-road motorcycles and large off-road compression-ignition engines. Testing under this program is typically ordered and performed by ARB when there is evidence to indicate a possibility of noncompliance.

H. Defects Warranty Provisions and Emission Control Warranty Statement

Staff expects engine manufacturers to ensure the engines they build have emission-related components that are reliable, durable and capable of complying with the applicable emission standards for the useful life of the engine. It is believed that an adequate defects warranty acts as an incentive for both the engine manufacturers and the part suppliers alike to produce an overall high-quality product. Staff, therefore, proposes a two-year emissions defects warranty for inboard and sterndrive engines starting in 2003, increasing to three years in 2009. Currently, most inboard and sterndrive engines are warranted by the manufacturer for one to two years. For comparison, the emission warranty for a comparable car engine is three years, with higher cost parts warranted for seven years.

I. On-board Diagnostics

In order to keep the emission control system working at optimum levels of efficiency, staff is proposing that 2007 and later inboard and sterndrive marine engines meeting the 5.0 g/kW-hr HC+NOx emission standard be equipped with an on-board diagnostics marine (OBD-M) system. The OBD-M system will be responsible for monitoring the catalyst, oxygen sensor, fuel system, and comprehensive components (sensor and solenoids) for proper operation in-use. Staff is also proposing that misfire monitoring be required on 2009 and later engines. In case of malfunction, a light or other indicator would be illuminated or activated on 2009 and later engines.

V. DISCUSSION OF PROPOSAL

A. Applicability

The proposal would require compliance with applicable emission standards and other requirements for all gasoline inboard and sterndrive marine engines. All other gasoline marine engines, and diesel engines under 50 horsepower, are already subject to emission requirements.

B. Definitions

The definition "used solely for competition" is incorporated into the staff proposal and uses regulatory language that harmonizes with U.S. EPA's diesel commercial marine rule. Harmonization, where possible, is beneficial to industry because it establishes one set of requirements.

The ARB is precluded from regulating racing vehicles (Health & Safety Code §43001(a)). This statutory prohibition does not directly apply to competition boats. Staff believes that the intent of the statutory exemption is to be consistent for all mobile sources, vehicles, and mobile engines, and that the statutory language changes are lagging. Therefore staff is proposing to exempt competition engines so designated by the engine manufacturer. The criteria for this exemption are taken from U.S. EPA's 1999 final rulemaking for diesel marine engines (64 FR 73305), as extended to marine engine manufacturers. They are:

- Exhibiting features which make non-competition use unsafe, impractical, or unlikely; for example the presence of superchargers, or a highly reduced recommended rebuild interval.
- The vessel is registered with a nationally recognized organization that sanctions professional competitive events.

In order to offer flexibility, staff has also incorporated the definition of a "small-volume manufacturer" for purposes of identifying those manufacturers that would be eligible to delay certification and compliance requirements until 2009. A small-volume manufacturer is defined as an engine manufacturer with less than 2000 inboard and sterndrive engine sales per year nationwide. Thus, by 2009, the production of all California inboard and sterndrive engines would be emission-compliant.

Small-volume manufacturers will be required to "certify" on an annual basis. The process is expected to be very simple. The manufacturer would provide U.S. inboard and sterndrive sales from past and future years and descriptions of engines intended for sale into California to the Executive Officer.

C. Emission Standards and Test Procedures

Marine inboard and sterndrive gasoline engines are essentially automobile or truck engines adapted for use in boats. As derivatives of automobile engines, the engines are well suited for the use of automotive controls. There already exist compatible exhaust aftertreatment systems and electronic control systems. Staff relied on the emission reduction capability of this technology (closed-loop fuel control, three-way exhaust catalyst) as demonstrated on a laboratory test engine to develop the proposed 2007 emission standard of 5.0 g/kW-hr HC+NOx (3.7 g/hp-hr) for gasoline inboard and sterndrive engines. A summary of data used by staff is provided below.

1. Summary of Emissions Tests

ARB staff has gathered emission data using the E4 test cycle from the U.S. EPA (who performed in-house tests) and Mercury Marine. These data are shown in Attachment C to this staff report. The data show that carbureted uncontrolled (new) engines produce emissions of about 8 g/kW-hr HC and 6 g/kW-hr NOx, and rich-calibration (open-loop) electronically fuel-injected (EFI) engines produce emissions of about 5 g/kW-hr HC and 10 g/kW-hr NOx. Since about 1997, the engine makers have been phasing out production of carbureted engines. Currently, however, the existing fleet of gasoline inboard and sterndrive engines is still largely composed of carbureted engines. It is expected that all new marine engines will be electronic multi-point fuel-injected by 2005. Some manufacturers have been recalibrating their engines in response to the European standards which are proposed to take effect in 2002. Some manufacturers are expected to sell these recalibrated engines in the United States even though they are not yet required to meet the emission levels. The average of the emission results for these engines is 3.5 g/kW-hr HC and 13.0 g/kW-hr NOx on the E4 cycle. The population this was based on was not extensive, and the calibrations were not optimized.

2. Engine Test Program

The ARB and U.S. EPA have been testing and developing a catalyst-equipped, oxygen-feedback electronically fuel-controlled marine engine. The data and the experimental set-up are described and shown in Attachment C. GM Powertrain and Mercury Marine each donated 454 cubic-inch displacement engines and Southwest Research Institute installed, optimized, and evaluated the performance of the various control schemes. Engelhard and DCL International have developed and donated candidate catalysts.

Various combinations of stoichiometric air-fuel control (performed with exhaust oxygen sensing, and feedback to the electronic engine control module), exhaust gas recirculation, and three-way exhaust catalysts have been tested. The most successful combinations were a set of 1.7-liter space-unlimited catalysts placed horizontally downstream of the exhaust riser, and a set of compact 0.8-liter catalysts placed vertically in the exhaust riser. Both candidates had good HC+NOx conversion, were integrated with the engine's water cooling system, and did not unacceptably affect the engine's operating properties or size.

With twin 1.7-liter catalysts installed on the engine with oxygen-feedback stoichiometric air-fuel control, a composite emission rate of 3.2 g/kW-hr HC+NOx was achieved. The engine, in its baseline configuration (*i.e.*, without a catalyst or stoichiometric air-fuel control), produced emission levels of 12.9 g/kW-hr HC+NOx. Adding exhaust gas recirculation to the catalyst-controlled engine, 3.0 g/kW-hr HC+NOx was achieved. The large, space-unlimited 1.7-liter catalysts, placed close to the water-mixing point in the exhaust pipes, resulted in no power degradation of the engine. Another set of compact 0.8-liter catalysts, placed well upstream of the water mixing point in the exhaust pipes, achieved composite emission results of 3.6 g/kW-hr HC+NOx and resulted in a power loss of the engine of about 6 kW (from 219 kW base-engine to 213 kW with catalysts). This corresponds to a base-engine exhaust backpressure at full power of 10 inches of mercury gauge, and a backpressure with catalysts of 14 inches of mercury gauge. This is a relatively small, acceptable power loss, and a correspondingly acceptable backpressure increase.

The compact catalyst design alternative represents a compromise between catalyst vessel inside cross-sectional flow area, outside dimensions, and the amount or volume of precious metal catalyst. The size of the compact catalysts was chosen to keep the engine width approximately the same as a standard engine, but instead increasing the height of the engine "envelope" by six inches. This was the same increase of dimensions as obtained from installing commonly available exhaust riser extensions. Keeping the catalyst width to be the same as the rest of the exhaust system results in a high exhaust flow-velocity (due to a small exhaust-pipe inner cross-sectional area). This can lead to engine power degradation due to the increased resistance-to-flow of the exhaust gases leaving the engine. The other dimensional constraint on the catalyst is the interfacial area available to contact the exhaust gases, which is directly proportional to the internal volume (length times cross-sectional area) and proportional to the substrate cell spacing to the one-half power. The normal 7.4-liter engine in a truck would have a single catalyst vessel of about 3 liters in volume. The two rectangular riser catalysts we tried were about one-quarter of this size combined. The expanded diameter cylindrical riser catalysts were about half of this volume combined.

3. Proposed Standards

<u>2003 Emission Standards</u>: The 2003 emission standard was selected to maintain the current average emission level from inboard and sterndrive marine engines. Staff is proposing an HC+NOx cap of 15 g/kW-hr starting in 2003. Staff estimates that in 2003 half the inboard and sterndrive sales will be carbureted and half will be fuel-injected. To achieve the proposed 2003 cap standards, the engine manufacturers can use their present-day air-fuel ratio calibration or can use the leaner calibrations developed for the European standards. Thus, the need for additional hardware or recalibration to comply with the proposed standards is not expected.

The objective of the HC+NOx emission cap is to assure that NOx emissions do not increase excessively due to air-fuel ratio enleanment. In the absence of the cap, excess enleanment could increase NOx emissions beyond what is necessary, and result in a net increase in HC+NOx relative to the baseline. The proposed cap is set just above the current inboard and sterndrive marine engine HC+NOx levels of 14 and 14.6 g/kW-hr HC+NOx for carbureted and fuel-injected designs, respectively, as shown in Table 5 below. Test data indicate that lean-calibration (European-compliant) engines may have HC+NOx emission levels ranging from 14 to 16 g/kW-hr, which can be corporate-averaged with lower-emitting engines to meet the proposed cap. Thus, this standard will provide California with assurance that ozone precursor emissions will not increase over current levels.

Table 5 Expected Candidate Engine Emissions			
	HC g/kW-hr	NOx g/kW-hr	HC+NOx g/kW-hr
Baseline Carbureted	7.8	6.2	14.0
Baseline Electronically Fuel-injected	4.7	9.9	14.6
Lean Calibration, Carbureted	2.5	11.7	14.2
Lean Calibration, EFI	2.8	13.6	16.4

Figures shown are for new engines
EFI means electronically fuel-injected

These 2003 emission standards are more stringent than the standards under consideration in Europe in 2002 (approximately 19 g/kW-hr HC+NOx), for which the engine manufacturers have been preparing and offering complying engines and retrofit kits since 1993. However, the proposed European standards have a relatively stringent CO standard of 60 g/kW-hr, which tends to drive emission results to undercut the proposed European HC standard of 4.0 to 4.5 g/kW-hr, with higher NOx. The European standards are based on a different test cycle (the BSO 9-mode cycle) than our proposed test cycle (the 5-mode E4 cycle) and the standards vary based on the power of the engine. In addition, HC results on the E4 test-cycle are about 10% higher than HC results using the BSO cycle. Staff is proposing to allow the manufacturers to average their emission results across their product lines, allowing some high models as long as there is an offsetting number of low models.

2007 Standard. The proposed 2007 emission standard for inboard and sterndrive engines is 5 g/kW-hr HC+NOx. The uncontrolled levels are about 15 g/kW-hr HC+NOx, so this represents a nominal 67% reduction. Emission testing at Southwest Research Institute with automotive-style catalysts achieved 3 to 4 g/kW-hr HC+NOx. Since 1996, the Swiss have required boats on Lake Constance to meet about 6 g/kW-hr HC+NOx. Large off-road gasoline engines sold in California this year will be meeting 4 g/kW-hr HC+NOx. A level of 5 g/kW-hr HC+NOx represents a significant reduction from the uncontrolled level, but one which is still higher than the best achievable. This was done in recognition that our test engine might represent the worst-case engine, that other engines might not perform as well, and to allow for aging (deterioration of emission conversion) in service (emission tests were performed with new (green) catalysts).

The proposal does not contain CO standards for inboard marine engines. Nevertheless, the application of feedback catalyst control to these engines is expected to result in a 50% reduction of carbon monoxide emissions over uncontrolled engines.

Improvements in catalyst conversion efficiency could likely be achieved with greater catalyst volumes and precious-metal loading. However, one of the test modes is wide-open throttle full speed, and air-fuel ratios must be rich to prolong engine life of these engines in this condition. In addition, an oxidizing catalyst is ineffective in this condition because of lack of oxygen reactant. This mode alone contributes approximately 0.7 g/kW-hr of HC to the weighted E4 results, thus levels below 1 g/kW-hr HC+NOx are probably unachievable with conventional gasoline engine designs.

Compliance Period: The proposal requires that engines meet the 2007 model year emission standard for 480 hours. This represents about 7 years of average use--a lower compliance period compared to other off-road categories. The shorter compliance period is proposed because marine engines typically operate under a unique duty cycle (wide-open throttle for sustained periods of time) and this leads to a shorter engine life.

Expected deterioration: Certification emission test-results from a new engine will have a "deterioration factor" added or applied to it to account for growth of emissions by the age of 480 hours. The manufacturers determine the deterioration factor from tests or from good engineering judgment. Estimates obtained from engine manufacturers indicate that HC+NOx emissions will likely increase by about 20% over 480 hours of operation on the water.

4. Phase-in

The proposal requires that 10% of each manufacturer's engine sales must comply with 5.0 g/kW-hr HC+NOx in 2007, 50% in 2008, and 100% in 2009. This will allow manufacturers to resolve any unforeseen technical challenges on a small scale prior to full-line production in 2009. Model-year 2007 was chosen because it provides adequate lead time for development efforts to be completed following the conclusion of an in-boat catalyst test program with U.S. EPA and the ARB at Southwest Research Institute. For the industry as a whole, the 350 cubic-inch displacement V-8 represents more than a third of sales, so this will be the likely first model to be introduced with a catalyst. The manufacturers may choose which engine families to introduce, but it must constitute the California sales fractions indicated.

5. Small Volume Manufacturers

Engines from small-volume manufacturers represent approximately 1.5 percent of the total engines (1999 nationwide and California sales) in this category. The staff recognizes that small-volume manufacturers may be less able to fund research and development programs to integrate automotive controls on their engines and will have to utilize equipment or packages developed by others. Therefore, the proposal would provide a time-delay for manufacturers that produce less than 2000 inboard and sterndrive gasoline marine engines annually for the United States. Small-volume manufacturers would not be required to comply until 2009, at which time, like all other manufacturers, 100 percent of production would have to comply. The staff also proposes to allow the small-volume manufacturers to use an assigned deterioration factor.

D. Labeling Requirements

In order to clearly identify California-certified gasoline marine engines, staff proposes that each engine be affixed with a permanent engine label that would indicate that the engine complies with California's regulations. Also, the label would serve as an effective tool for in-use testing and other enforcement programs. It provides the engine family name, a list of emission-related devices, fuel to be used, date produced, and engine displacement. The label provisions also allow manufacturers some flexibility to include other relevant engine and compliance information. Engine certification labels are currently required as part of all of California's on- and off-road mobile source regulations.

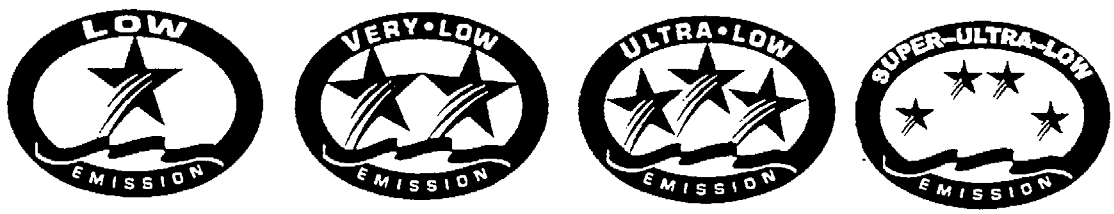
Manufacturers of engines used solely for competition are encouraged to incorporate engine labels to identify the engines for their intended use. Staff proposes that such labels be done in accordance with the engine label specifications noted above. The labeling of competition engines provides a simple mechanism for field enforcement.

Since it is common for marine engine manufacturers to sell their certified engines to boat-builders, 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 a watercraft 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 watercraft, including the engine itself. This action will not impact the certifying manufacturer since its unique identification code is integrated into the engine family name.

Besides the certification label, the proposal extends the 3-tiered environmental labeling program already in place for outboards and personal watercraft engines to inboard and sterndrive engine applications. Inboard and sterndrive marine engines complying with the 2003 standards will be eligible for the 3-star environmental label. This is the same emission level required for 2008 model-year outboard and personal watercraft engine applications. A new, four-star label, indicating super ultra-low emissions would be used on inboard and sterndrive watercraft that comply with the 2007 5.0 g/kW-hr standard for HC+NOx.

Examples are shown below in Figure 7.

Figure 7
Marine Engine Consumer Labels



The primary purpose of the labeling program is to inform consumers of the relative emissions level of new engines. Staff anticipates that increased consumer awareness of these engines may establish a positive market trend toward clean technologies, thereby accelerating the benefits of the program by encouraging the acquisition of engines that comply with more stringent emission standards than required at the time of purchase.

E. Emission Parts Warranty Requirements

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 cover parts past their designed replacement interval. For each new marine engine sold in California, the 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.

F. In-Use Compliance Program

To ensure that certified engines are meeting the emission standards through the compliance period, the staff proposes to incorporate inboard and sterndrive marine engines into the existing California in-use test program. The ARB administers and funds the in-use test program. Based on a variety of data collected, the ARB could choose an engine family to test. The ARB procures a limited sample of engines from a given engine family. The engines are restored to the manufacturer's specifications, and tested in accordance with the applicable test procedures. ARB and the manufacturer's representatives are present to oversee all aspects of the test program. Should a noncompliance situation occur within a given engine family, the ARB will work with the manufacturer to correct the problem on all affected engines. The corrective action is usually in the form of a statewide recall in which the manufacturer will notify all affected engine owners and state when and where to seek the recall repair. The cost of the repair and service is free to the engine owner.

G. Emission Control On-board Diagnostics

Staff proposes that inboard and sterndrive engines certified to meet the 2007 and later standards be equipped with an on-board malfunction detection system (OBD-M). The detection system is required to identify emission-related engine malfunctions and store such information in non-volatile computer memory as standardized diagnostic trouble codes. Emission-related malfunctions are not limited to emission control components and systems only, but to any other electronic component or system that can affect emissions including the on-board computer itself. Additionally, the diagnostic system is required to alert the operator after a malfunction has been detected by means of either an audio or visual alert device.

Staff is proposing that the minimum complement of monitoring be:

- Catalyst Monitoring (conversion efficiency)
- Oxygen Sensor Monitoring, if equipped (checks sensor response rate and lean-to-rich and rich-to-lean switch times; also checks for proper temperature if sensor is heated)
- Engine control module (verifies that the module's memory is working properly
- Fuel system monitoring (checks for appropriate long and short term fuel correction and learning)
- Misfire monitoring (checks for incomplete or completely absent combustion events)
- Sensor and solenoid monitoring (checks for the proper performance of comprehensive components such as manifold air pressure sensor, coolant temperature sensor, throttle-position sensor, crankshaft position sensor
- Engine control module self-check

In addition, the diagnostic system information must be accessible through a generic scan-tool connected to a standardized data link connector within the boat, and the diagnostic fault codes must be standardized according to Society of Automotive Engineers protocol.

This system is designed to assure proper performance and facilitate the maintenance of emission control systems and components. Thus, the proposal exempts from OBD-M compliance inboard and sterndrive engines not required to meet the 5 g/kW-hr HC+NOx standard (through 2008). Note also that, for the phase-in years of 2007 and 2008, the catalyst-controlled engine families will be required to incorporate all these monitors except for misfire monitoring and the more advanced features associated with the comprehensive components (rationality monitoring). Furthermore, manufacturers will not be required to activate the audio or visual alert device for catalyst, fuel system, and oxygen sensor functional malfunctions until 2009. Only fault codes need be stored for those malfunctions. This is to allow the manufacturers to concentrate on introducing the catalyst systems, and not have to simultaneously debug the malfunction indication system.

H. Technology Review

Staff believes that three-way catalyst, closed-loop controls provide excellent emission reduction capability, and that those reductions can be maintained over the life of gasoline marine engine applications. Nevertheless, staff believes that additional emissions durability testing would be beneficial to support the proposed 2007 emission standards. Staff believes that this can be best accomplished through co-funded demonstrations to confirm that the emission standards can be met in-use with the technology of choice. Plans are underway for a cooperative effort between U.S. EPA, ARB, the National Marine Manufacturers' Association, and the U.S. Coast Guard to develop and test these systems in boats on the water, resolve any problems of salt water exposure, heat management, boat space, *etc*, and share the results among the manufacturers. The results of this multi-government/ industry effort would be presented to the Board as part of a technology review.

For these reasons, the staff proposes to hold a technology review in 2003, and if necessary, in 2005. The review(s) will enable industry and ARB to determine how the application of technology is progressing, identify any unforeseen challenges, and recommend regulatory changes if warranted.

VI. TECHNOLOGICAL FEASIBILITY

A. Overview

The proposed measure would require emission control technologies on inboard and sterndrive engines which have already proved successful on automotive engines. The engine manufacturers have been phasing out their carbureted engines in favor of electronic fuel-injection over the last 5 or 7 years. The proposed exhaust emission standards remain performance-based;

manufacturers will have the flexibility to employ the emission control technology of their choice to accomplish the ultimate emission reduction goals. However, practically speaking, the staff's proposal would, in the near-term, likely require manufacturers to accelerate the introduction of lean air-fuel calibration strategies and, in the mid-term, likely require the use of aftertreatment strategies (*e.g.* catalytic converters) to achieve significant emission reductions. A discussion of these control strategies follows.

B. Control Technology Options

1. Lean Air-fuel Calibration

Marine gasoline engines are normally calibrated for slightly rich air-fuel mixture. "Rich" means fuel rich or less air than is theoretically required to combust all the hydrogen and carbon in the fuel. Compared to stoichiometric or lean operation, running slightly rich keeps combustion temperatures low, which helps protect the engine, and usually results in lower NOx emissions. However, it also typically results in poorer fuel economy and higher HC and CO emissions.

A lean air-fuel calibration slightly leans the fuel-air mixture closer to stoichiometric, resulting in more efficient combustion, thereby resulting in lower HC and CO emissions. The result is often a concomitant increase of NOx emissions due to the higher temperatures. This technology by itself will typically reduce emissions from a carbureted engine by about half for HC, but is estimated to increase NOx emissions also by about half. This strategy is currently being employed in boats for sale to Europe and, to some extent, in the United States as well.

2. Electronic Fuel Injection

A fuel system which introduces the fuel for combustion through individual injectors is used to precisely time and meter fueling (electronic fuel injection). This is an improvement over the older fuel metering system of carburetion, where constant air-fuel ratio is achieved by introducing liquid fuel at the neck of a venturi which the air is drawn through. The difference in emissions between an EFI engine and a carbureted engine with a factory-set calibration is about 40% (reduction) for HC and 60% (increase) for NOx. This technology is already available as an option on most inboard and sterndrive engine models.

3. Oxygen-Feedback Fuel Control

Oxygen-feedback fuel-control uses a sensor which measures the oxygen content of the exhaust gases. The signal is used by the engine control module to lean or richen the air-fuel mixture as needed to achieve the proper air-fuel set-point. Feedback to the engine control module allows the air-fuel mixture to be "tailored" and set precisely. Precisely setting the air-fuel mixture lean or near stoichiometric in and of itself reduces HC and CO. This mixture range is also optimum for three-way (reducing and oxidizing) catalysts, which are discussed below. The difference in emissions between a stoichiometric feedback-controlled EFI engine and a "basic" EFI engine is about 25% (reduction) for HC and about 20% (increase) for NOx. This technology is not now available on inboard/sterndrive engines.

4. Catalytic Converters

The catalytic converter is the primary technology responsible for the remarkable improvements in automotive emission control over the past two to three decades. Due largely to the use of the catalytic converter on gasoline automobile engines, ozone-forming emissions from a modern automobile are less than ten percent of the levels of an uncontrolled vehicle of the 1960s, with improved operability and fuel economy as an added bonus.

A "catalyst" or "catalytically active material" is a material which causes a chemical reaction to happen more quickly without being itself consumed. Since chemical reactions are sped by higher temperatures, the catalyst allows a reaction which would normally happen only at a high temperature to be performed at a much lower temperature. In this case, we are speaking of gas-phase reactions of HC, NOx, CO, and O_2, reacting on the surface of a solid. The solid must be refractory (resistant to the high temperatures which happen as the oxidation reactions proceed) and have a high specific surface area to maximize the interaction of the gas molecules.

The typical modern automotive catalytic converter consists of an active catalytic material (usually one or more noble metals such as platinum, palladium or rhodium) applied as a washcoat to a substrate (usually ceramic or metal), surrounded by a mat and placed in a housing ("can"). The can and inlet/ plumbing act to direct the exhaust flow over the active material to be exposed to the porous surface containing the grains or sites of active metals.

The most common and successful type of catalytic converter is called a "three-way" catalyst because it simultaneously allows reduction of nitric oxide to nitrogen, and oxidation of unburned HC and CO to water and carbon dioxide.

Controlling the amount of air entering the catalyst is particularly important for NOx control. As previously mentioned, precise air-fuel-ratio control is done by measuring the oxygen content in the exhaust gases and sending the resulting signal to the air-fuel controller in the engine control module. The engine control module then sends a signal to the fuel-injectors to increase or decrease fuel delivery to achieve the desired air-fuel ratio. Thus the engine control module and oxygen sensor are critically important for the proper performance of the catalyst.

While it has been used on automobiles for nearly 30 years, the catalytic converter has not been commercially demonstrated on boat engines with their wet exhaust systems. The concern is that water exposure can poison or severely damage both the catalyst and the oxygen sensor. However, recent studies have shown that exhaust systems can be modified to minimize water exposure, and thus this technical challenge will likely be resolved in the next few years. A further discussion on this durability issue can be found later in this report.

ARB testing of three-way catalysts in combination with stoichiometric feedback air-fuel control resulted in reductions of 60% for HC and 80% for NOx compared to a factory-set EFI engine without a catalyst and feedback control system.

5. Exhaust Gas Recirculation

Exhaust gas recirculation (EGR) is an emission control strategy aimed at reducing NOx. By recirculating inert exhaust gases into the combustion chamber, less oxygen is available to oxidize nitrogen to form NOx.

While EGR has been demonstrated to be very effective at reducing NOx in automotive applications, little is known on how effective it would be in marine applications. Of particular concern is the EGR valve (which controls the amount of EGR flow). The durability of this valve in a marine environment has not been fully demonstrated. Emission reductions with the use of EGR are typically found to be about 40% for NOx.

6. Malfunction Indication

The emission performance of an engine certified to the proposed 2007 emission standard is primarily dependent on the proper function of the oxygen sensor and catalyst. Thus the staff proposal includes provisions which would require an on-board system to monitor and indicate emission control-related malfunctions.

The on-board diagnostic system would be designed to alert the boat operator if the emission control devices are not performing properly. The indicators required by this regulation are not envisioned to limit the performance of the boat engine, merely to notify the owner of a problem.

The proposal would require marine inboard and sterndrive engines to have malfunction-indication systems installed, similar to the automobiles for which the engines were designed, which monitor

- Catalyst performance (done in cars by timing the duration of warm-up or by comparison of inlet and outlet oxygen concentrations)

- Fuel-controller trim (checks that the engine control module's ability to correct air-fuel ratios is still within controllable limits)
- Oxygen sensor performance (checks sensor response rate and lean-to-rich and rich-to-lean switch times; also checks for proper temperature if sensor is heated)
- Cylinder misfire monitoring (done by monitoring camshaft acceleration or changes in exhaust pressure) to prevent catalyst overheat damage
- Comprehensive component checks (circuit continuity, and 'rationality' or 'functionality' monitoring for crank speed/position sensor, throttle-position sensor, manifold air pressure sensor, coolant temperature sensor, *etc.*)
- Engine control module self-check, memory integrity, execution timing, software revision date, program checksum.

With the exceptions of fuel system and comprehensive component monitoring, these parameters are, in general, not monitored continuously like oil pressure and engine coolant temperature, but instead are polled or checked at least once per engine operation. Sensor/solenoid continuity, misfire, and the fuel system are checked on a continuous basis. Two successive failures are required to trigger a fault code. The indicators, in case of a fault, are not required to limit engine performance in any way, unlike some engines which are designed to cut fuel or spark on overspeed, for example.

The technology and programs for all these checks exist today, and have been proved for many years now. The marine engines are presently, or will be by 2004, supplied with an engine control module which is ready for and capable of precise fuel-control and storage of programs and fault codes. Staff expects that the engine manufacturers will purchase systems developed by others for their products derived from the automotive field. However, at least one manufacturer has developed its own controller which is reportedly more sophisticated than the standard General Motors version available today. The Mercury "PCM 555" controller on the new 8.1-liter engine introduced in 2000 was developed in-house and has truly sequential fuel-injection, an advance over the factory-installed multi-point fuel-injection or port fuel-injection.

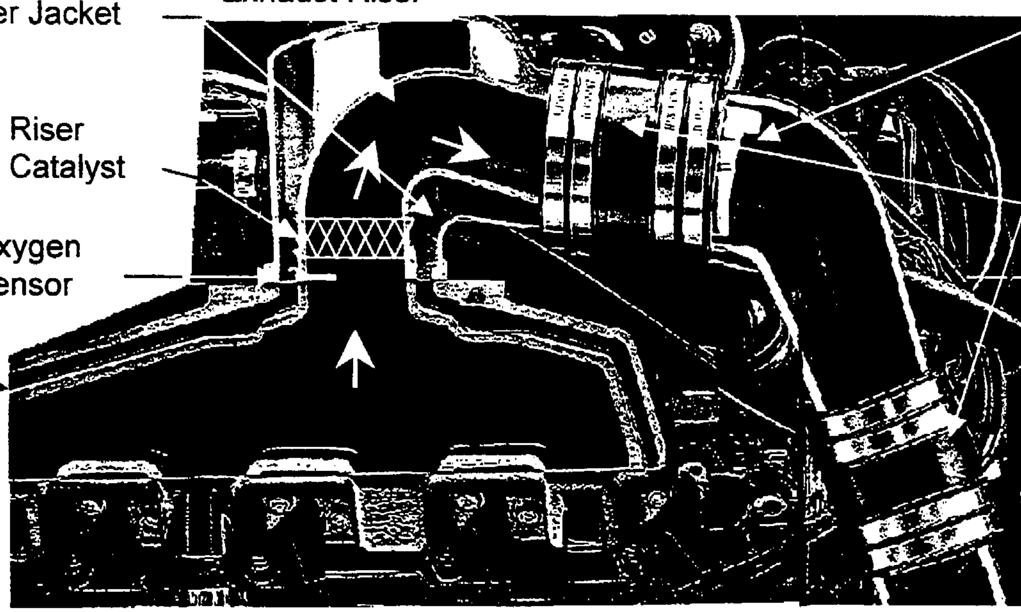
C. Marine Durability Issues

1. Catalytic Converters

As previously discussed water is mixed with the exhaust gases in inboard and sterndrive engines. This practice of mixing water with the exhaust gases has been the biggest technical challenge to the application of the three-way catalyst and feedback air-fuel control to these otherwise automobile-like engines. The presence of liquid water in the exhaust gases requires that the catalyst (as well as the oxygen sensor) be placed upstream of the exhaust gas/water mixing point.

Thus the choice of the location for a catalyst and oxygen sensor is limited. Figure 8 below illustrates a likely location of the catalyst and oxygen sensor. Exposing a three-way catalyst to lake or sea water could be detrimental because of potential for thermal shock and poisoning or masking by soluble salts. Sodium (a component of sea salt) is known to poison catalyst metal sites. The effect, however, is slow and cumulative, happening over many applications. Thermal shock from a sudden exposure of water would likely result in immediate and catastrophic breakage of the ceramic core of an oxygen sensor and ceramic catalyst substrate. It is unlikely that spraying a mist on a hot catalyst could do this; it is more likely that actual immersion in water would be required.

Figure 8
Cut-away view of marine exhaust manifold



Located upstream (and above) the water injection point, the catalyst is protected from immersion and spray exposure because the exhaust gases and cooling water spray flow away from the catalyst. However, during periods of sudden deceleration or sudden closing of the throttle, vacuum can build up in the exhaust manifold and this cooling water spray can reverse direction, traveling back into the exhaust manifold and, in some cases, back as far as the cylinders.

To address this concern, ARB is funding an in-boat study of water ingestion/ accumulation at Southwest Research Institute. After 200 hours of testing of a marine engine on a test-cell, no catalyst degradation or evidence of water exposure has been observed. Southwest Research Institute also relocated the oxygen sensor to the joint between the exhaust manifold and riser and, as a result, has not observed any oxygen sensor failures. The results indicate thus far that condensation of the water from the combustion process is the main source of water, and that redirecting the manifold cooling water to keep the manifolds warm eliminates this problem. Thus staff believes that this problem is entirely resolvable in the next few years, well before catalysts are used in 2007.

Yamaha has offered for the last two years a personal watercraft with a catalyst-controlled engine. The engine is a three-cylinder 1.2-liter displacement carbureted two-stroke. With the catalyst, the HC emissions are reduced about 50% compared to a typical personal watercraft engine (to about 80 g/kW-hr).

2. Diagnostics/Malfunction Indication

The proposed malfunction indication system would warn or alert the boater to a malfunction through the use of a light or other warning device. The durability issue raised by some manufacturers for the proposed malfunction indication system is one of false test-failures or failures of fragile components that could potentially affect the startability or performance of the boat engine. However, the proposal does not require the malfunction indication system to interfere in any way with the engine performance or inhibit or interlock starting or full-throttle operation.

D. Safety Issues

Several concerns have been raised primarily over catalyst control systems in boats. The U.S. Coast Guard, in particular, is concerned with the following:

- Hot surfaces would be present in the engine compartment leading to burning or damage of the boat hull materials, personnel burns, or igniting of fugitive gasoline vapors.
- Catalysts may continue to heat up or "run away" in situations of idling or after the engine is shut off.
- Leakage or increased chance of leakage of CO-containing gas (engine exhaust) from the exhaust pipes due to an increased number of joints or connections required, or increased frequency of disassembly of exhaust components for inspection or repair.

1. Hot Surfaces/Engine Compartment Cooling

Concerns have been expressed over potential hot surfaces caused by the inclusion of three-way catalysts in the exhaust system. This is of concern to minimize the potential for

- ignition or combustion of materials in the boat or hull materials
- melting or weakening of the hull materials,
- burning of people's skin on contact with hot surfaces such as exhaust pipes.

The most common practice to address these issues is to employ water-jacketing and cooling with raw water or circulating engine-jacket water. As previously discussed, the exhaust gases are most commonly cooled downstream of the water-jacketed exhaust manifolds by direct mixing with the cooling water. As shown in Figure 8 a likely catalyst location would be in the exhaust riser upstream of the exhaust gas/water mixing point. The catalyst will cause exhaust manifold/riser temperatures to increase because as the hot exhaust passes through it, it generates additional heat due to the oxidation process. Also, increased resistance-to-flow in the exhaust system due to the presence of the catalyst can cause high exhaust temperatures.

In a boat engine after the engine ignition is turned off, the combustion of gasoline (thus the generation of heat) ceases immediately, but heat radiation or convection continues from the warm engine block walls and exhaust pipe walls (so called "thermal mass"). At this time raw water cooling has ceased when the engine ceases to turn, but the lake or sea water remains in the engine block, and probably drains out of the exhaust manifolds, leaving them warm and dry.

The point is, after the engine and cooling water are shut off, heat is still released into the engine compartment, but at no faster a rate than when the engine is running. Residual heat release after the engine is shut off will proceed from the engine block walls, which are kept by the cooling water during operation to approximately 170 to 180°F.

The addition of a catalyst in the exhaust riser will add some thermal mass to the exhaust system. In the catalyst, oxidation of CO and HC will stop immediately when the exhaust gases stop flowing, but during operation the catalytic surface sees local temperatures up to 1600°F, building up heat in the catalyst substrate. On shutdown, the catalyst water jacket will drain away, leaving an air gap between the inner and outer steel walls of the catalyst vessel. This gap will tend to insulate and impede cooling of the catalyst substrate by conduction and natural convection to the air in the engine compartment. It is possible that the steel flanges connecting the catalyst to the rest of the exhaust system could heat up above 200°F during catalyst residual cool-down. This is thought to be an unlikely event, and one that could be easily designed around through either thermally insulating the catalyst brick from the shell, or improving the water-jacketing surrounding the catalyst to provide more heat transfer.

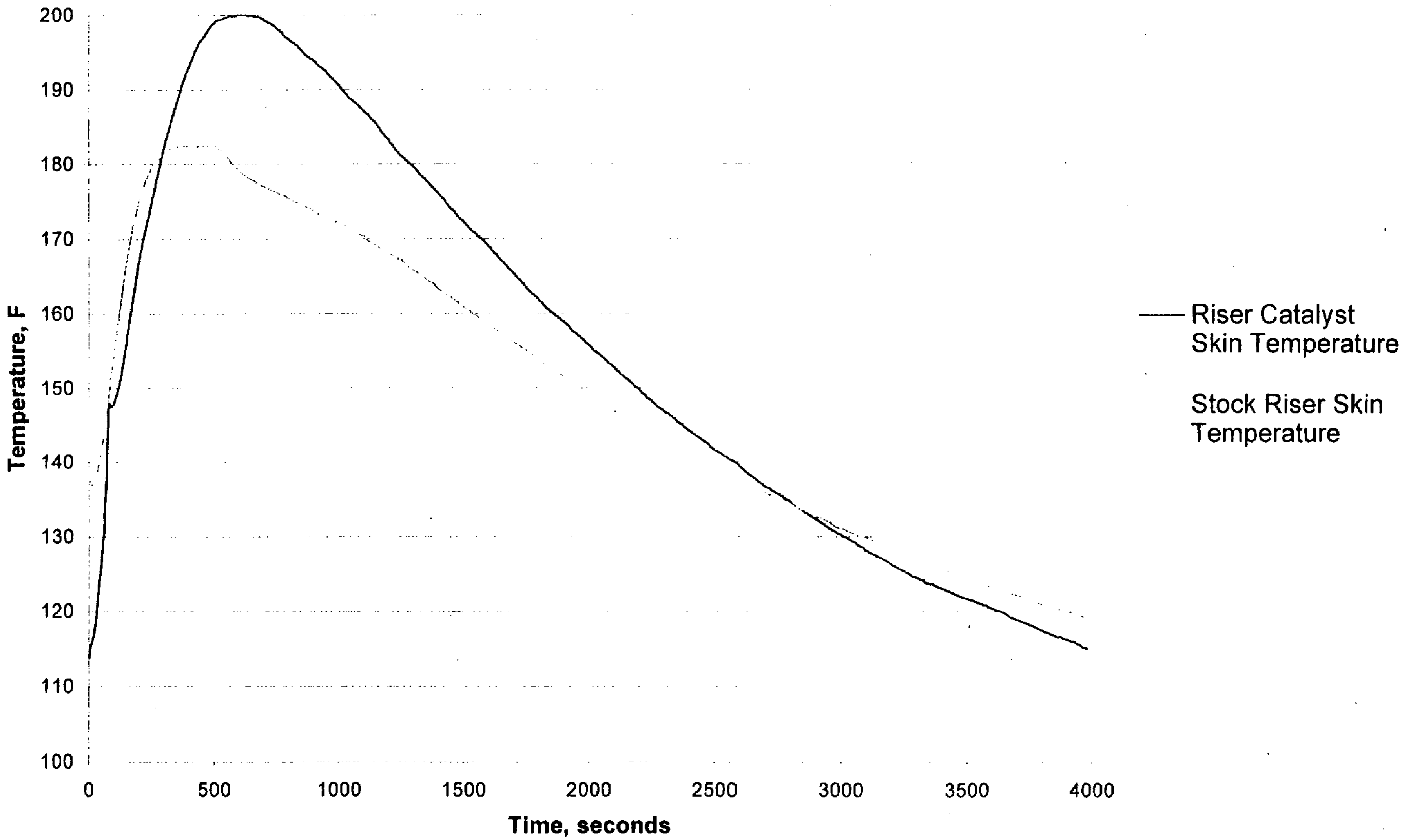
To study this phenomenon, Southwest Research Institute instrumented and ran a marine engine with thermocouples on the exhaust pipe skin and the skin of the exhaust riser surrounding the catalyst. After the catalyst reached highest observed operating temperature, the engine was shut off, the exhaust manifolds were drained of water, and temperatures were recorded as the engine cooled down.

The temperature traces are shown in Figure 9. The lighter, stippled curve is the skin temperature of a factory cast-iron riser with no catalyst in it. The solid curve is the skin temperature of a cylindrical riser catalyst placed in the same position.

In this cooling run the outer exhaust skin temperature of the original factory riser rose about 40°F in 7 minutes, then cooled to where it started in about 40 minutes. The skin temperature of the riser with a catalyst in it rose 85°F in 12 minutes, then cooled back to where it started in about 70 minutes. The reason for this high, fast rise was that the catalyst held a lot of heat, and the cylindrical riser catalyst had a relatively low "thermal mass" in the wall material or packaging.

The skin temperature rose up to the criterion of 200°F, although this was done dry (no jacket water). The 200°F criterion is the threshold for insulation, covering, or water-jacketing for exhaust systems in boats from American Boating and Yachting Council Standard P-1 paragraph 1.5.9.

Figure 9
Comparison of Marine Engine Exhaust Skin Temperatures with and without Catalyst



2. Catalyst Overheating

As discussed above, ARB staff expects the catalyst to reach temperatures up to 1600°F during operation. This is based on observed on-engine tests. Overheating of the catalyst would only occur when both fuel and air reach the catalyst simultaneously. This could occur inadvertently during a major misfire event, where fuel is not combusted and oxygen is not consumed in the combustion chambers. The remedy for arresting this situation would be to stop the engine. Once the oxygen in the exhaust is consumed, the heating would stop. This would be an emergency situation and the malfunction diagnosis system would be designed to detect and warn against this occurrence.

ARB's contractor for the engine testing (Southwest Research Institute) noticed only one incident of catalyst overheating in over 200 hours and a year of testing. All the catalysts tested were water-jacketed. The catalyst in the incident heated up to about 1600°F (in the bed) at idle. The catalyst bed on the other exhaust bank of the engine did not overheat. An ignition miss was noted (by low exhaust port temperatures) in three of the cylinders on the bank that the catalyst was installed on. The incident was ended by turning off the engine. The situation that led to the overheating was a loss of compression due to warped intake valves (probably as a result of running the engine at full power and speed with stoichiometric air)*. The situation was corrected by replacing the cylinder heads with new ones and installing a more advanced fuel controller. No more overheating events were noted after 100 further hours of testing. The catalyst was reused without cleaning or loss of performance.

3. Carbon Monoxide Exposure

The U.S. Coast Guard has commented that installing equipment in the exhaust system of the engines will lead to more exhaust pipe connections or joints which would increase the chance of an exhaust gas CO leak into the engine compartment or into occupied areas of the boat. The U.S. Coast Guard also commented that increased inspection requirements that involve periodic disassembly of the exhaust pipe connections might also lead to higher frequency of CO leaks.

While the chances of CO exposure are higher in a boat, especially where non-ventilated living areas conjoin the engine compartment, the conventional leak-

* The engine was run at full speed, wide-open throttle with stoichiometric air in order to achieve the maximum amount of emission reductions over the whole operating range of the engine. The engine maker warned us that structurally the engine could only stand a few minutes at this condition before deformation damage might occur. This apparently is an inherent problem with even the state-of-the-art aluminum overhead-cam catalyst-controlled engines. We understand that lean-burn gasoline engines used in Europe can withstand these conditions. Of course, diesel engine blocks, heads and valves withstand these conditions also.

minimization strategy has been to minimize the number of connections and joints in the lines carrying exhaust gas, and to design the few remaining joints not to leak. The addition of the catalyst vessel could be done with one extra flanged connection on each side of a V-8 engine. The catalyst flange connections would be identical to the present successful flanged designs used on boats.

Also, since the exhaust manifolds and pipes in boats are typically water-jacketed for some of their length, and then the water is mixed inside into the exhaust gases, leakage sites would leak water first (for the jacketed length) or the leak would be accompanied with water. That water would be the first sign of a leak, conversely water-tight would signify "exhaust gas leak-tight." In addition it should be noted that installing catalysts which convert CO to carbon dioxide would reduce the CO concentration in the exhaust downstream of the catalyst by a factor of four during cruise and by a factor of 10 during idle compared to a non catalyst-equipped engine. The leaner engine calibration will also reduce the CO concentration upstream of the catalyst. The lower CO emissions from engines meeting the proposed standards will therefore reduce potential harm from leaks anywhere in the exhaust system.

VII. COST OF COMPLIANCE/COST BENEFIT

A. Cost Methodology

Component costs were estimated for a 350 cubic-inch displacement V-8 engine, the most popular engine size for inboard and sterndrive engines, representing 30 to 40 percent of all sales. Component costs for other engines which are smaller (the V-6 and the in-line 4-cylinder) will probably be less than shown. Conversely, component costs for the large V-8 engines will be larger than shown. Wholesale or vendor costs were solicited to determine the incremental cost of applying feedback fuel-control automotive components and a three-way catalyst to a base-calibration electronically fuel-injected engine. For these cost estimates, the baseline engine was assumed to be equipped with fuel injectors and an engine control module already. The engine manufacturers expect that new marine engines will be 100% electronic fuel-injected models by 2005.

As part of the rule development process, all the engine manufacturers were queried by questionnaire and by telephone interview for the estimated control-system costs. Two catalyst vendors were also contacted about the packaging and canning of their products. As part of the development of the ARB off-road large gasoline engine regulations, Southwest Research Institute surveyed engine parts vendors and estimated the costs of adding catalyst control to a 2.5-liter 4-cylinder gasoline industrial engine (White *et al.* 1999). These are valuable for comparison to the marine case because they estimated the costs of applying automotive feedback catalyst control to previously uncontrolled automobile derived engines for land-based off-road engines. In addition, previous ARB analyses of applying on-board diagnostics to automobiles (ARB 1994a; ARB 1998b) were consulted.

B. Costs of 2003-2008 Model-year Standards

Compliance with the proposed 2003 emission standards can be done with present-day air-fuel calibrations, or by leaning the engine's air-fuel mixture without the addition of any other exhaust control or fuel-control devices, resulting in lowered HC emissions.

Since no hardware needs to be added by the manufacturers to comply with the standards, minimal costs will be incurred. There might be some costs incurred with testing recalibrated engines, but the number of such engines is expected to be small. For these reasons no costs are shown for compliance with the proposed 2003 standards.

C. Costs of Catalyst-based (2007) Emission Standards

The incremental cost of complying with the 2007 catalyst-based standard is $756 to $1231 per engine. Table 6 identifies the individual component and system costs. The fixed research and development costs account for the greatest cost, due to the relatively low sales volume of these engines, followed by the catalyst and the on-board diagnostic system. These estimates are based on information from engine manufacturers, the catalyst vendors, and ARB staff reports on automotive engine emission regulations (ARB 1994a; ARB 1998b). They assume all engines will have changed from carburetors to fuel-injection by 2005 even in the absence of regulations, following the current industry trend. Thus the engine control module, fuel pump/regulator/rail, and gasoline-to-water cooler are considered to be part of the base engine, and their cost is not included in estimating the cost of this proposal.

Table 6 Control System Costs for a Typical Marine Engine—2007 Standards ($/engine)	Catalyst-Controlled Engine (Incremental Cost)
Fuel Injection Injectors Fuel Pump, Pressure Regulator, Fuel rail Intake Manifold, Throttle body and position sensor, Fuel Cooler	$5
Engine Control Module Intake Air Temperature Manifold Air Pressure Crank Position Sensor Wiring	25
Front Oxygen Sensors (2)	38
Exhaust Manifold	20
Catalysts, including canning Cylindrical riser cat	200
Total Capital	288
Malfunction Indication Basic mandatory system: Post-catalyst O_2 Sensors + programming	183
Manufacturer and Retailing costs Tooling, R&D, Assembly labor Dealer markup	216-648 69-112
Total	$756-1231

The $183 cost of the basic malfunction indication system is primarily due to the hardware required, as shown in Table 7. The hardware includes two additional oxygen sensors used to monitor catalyst efficiency, and the cost of splitting the catalyst into two bricks to allow installation of the oxygen sensor within the catalyst. This was the incremental quote from the catalyst vendor for a two-piece catalyst in comparison with a one-piece. Staff believes that with commercialization and economies of scale this incremental cost will decrease with time. The camshaft position sensor may be standard on many engines, especially distributorless engines, but for the sake of providing a conservative cost estimate, a $25 cost is included. A nominal cost of $20 per unit was estimated for additional engine control module programming. This estimate was based on assuming 3 person-months of programming time distributed over about 3000 units per engine family (one-year payout).

Table 7 **Malfunction Indication Costs for 350 Cubic-Inch Displacement Engine**	
Item	**Cost $/unit**
Mandatory malfunction indication	
Rear Oxygen Sensors	$138
ECM Programming	20
Camshaft Position Sensor	25
Total per unit cost	$183

Table 8 provides a breakdown of R&D and tooling costs. Depending on whether these fixed costs are written off against national sales (in anticipation of U.S. EPA adopting a similar standard) or only California sales, $48 to $480 is the cost per engine sold. Added to this is $8 for engine-specific R&D, $137 for engine manufacturer's incremental mark-up, and $23 incremental warranty mark-up, yielding the $216 to $648 incremental cost per engine shown in Table 6 for Manufacturing and Retailing Costs.

Table 8 **R&D Costs for the Marine Inboard Industry**	
Item	**Total Cost**
Engineering Labor, Technical Support, Other Engineering Costs	$39,000,000
Test Costs	200,000
Tooling Costs	9,000,000
Total R&D and Tooling	48,200,000
10 years of Engine Sales (nationwide)	1,000,000
10 years of Engine Sales (California only)	100,000
Per unit cost	$48-480

Total costs for 5 manufacturers, 30 product lines. For test costs, the biggest two manufacturers were assumed to already have their own in-house emissions test equipment.

D. Cost Effectiveness

To determine the cost effectiveness of the proposed regulations, the incremental cost per engine for the expected emission controls is divided by the expected emission reductions per engine due to the use of those controls. Table 9 presents the anticipated lifetime emission reductions for an engine complying with the 2003-2008 standards, and an engine meeting the proposed 2007 standards. The lifetime emissions are derived using the average power rating of the engine, annual usage, load factor, and lifetime for inboard and sterndrive engines. The emission factors shown in columns 3 and 4 of Table 9 are the lifetime-average emission factors. The lifetime emission reduction is the difference between the lifetime emissions of the engines complying with the 2003 emission standards and those complying with the 2007 emission standards.

Table 9
Benefit of the Proposed 2007 Emission Standards
Lifetime Emissions for an Average Inboard and Sterndrive Engine

	Usage, kW-hr/LT	HC g/kW-hr	NOx g/kW-hr	HC+NOx lb/LT
Pre-2007 Engine	15,860	4.9	9.9	517
Catalyst-based (2007 standard)	15,860	2.1	2.3	154
Benefit				363

* Based on 21% load factor, 157 kW engine power rating, and a 480-hr lifetime. Emission levels are the lifetime-average values.

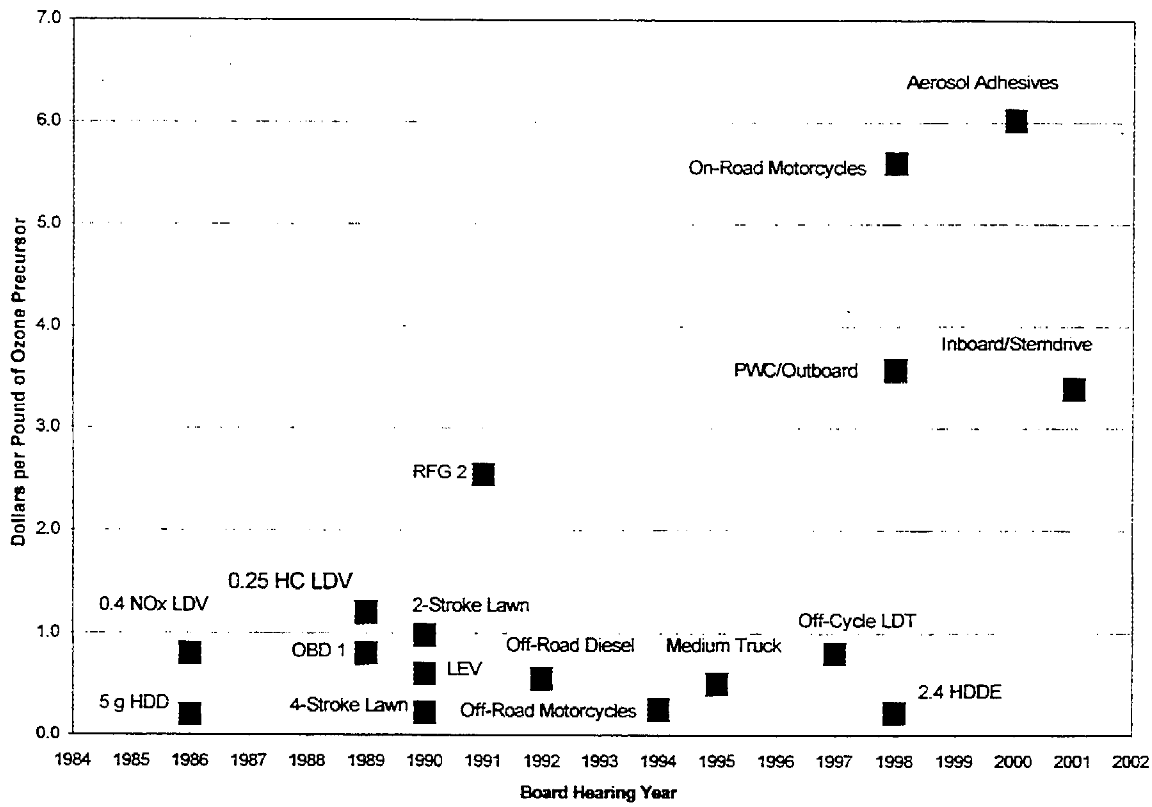
Thus the cost-effectiveness associated with the staff's proposal is

$756 to 1231/unit/lifetime ÷ (517-154) lb HC+NOx benefit/unit/lifetime = $2.08 to 3.39/lb HC+NOx reduced

Below in Figure 10 are shown the cost-effectiveness values for many of the ozone reduction measures adopted over the last 15 years. The cost-effectiveness of the proposal is well within the range of cost-effectiveness for other mobile source control measures.

Figure 10

Cost Effectiveness of Major Regulations
Mobile Sources and Fuel



VIII. AIR QUALITY, ENVIRONMENTAL AND ECONOMIC IMPACTS

A. Air Quality Impacts

1. Statewide Inventory/Effect of Proposal

The emission inventory assumptions have been updated since the adopted marine inventory (ARB 1998c). These changes have been detailed in Attachment D.

The emissions inventory for inboard and sterndrive gasoline boats is shown in Table 10 for the 2020 and 2010 calendar years. As shown in the table, emission levels associated with summer weekend operation are approximately 3.6 times higher than corresponding annual average levels due to increased boating activity during the summer months. This is especially relevant since ozone levels reach their highest values during summer weekends. Therefore, to properly represent the benefits from this control measure, emission reduction comparisons in this report are presented using summer weekend values rather than annual averages.

Table 10

Inboard and Sterndrive Statewide Baseline Emissions Inventory

Air Basin	Pollutant	Baseline (TPD)	Ratio to Statewide Annual
2020 Baseline Inventory			
Statewide *Annual Average*	HC	18.55	**1.00**
	NOx	31.20	**1.00**
Statewide *Summer Average*	HC	30.23	**1.63**
	NOx	50.85	**1.63**
Statewide *Summer Weekend*	HC	67.51	**3.64**
	NOx	113.56	**3.64**
South Coast *Annual Average*	HC	5.01	**0.27**
	NOx	8.42	**0.27**
2010 Baseline Inventory			
Air Basin	Pollutant	Baseline (TPD)	Ratio to Statewide Annual
Statewide *Annual Average*	HC	18.46	**1.00**
	NOx	23.48	**1.00**
Statewide *Summer Average*	HC	30.10	**1.63**
	NOx	38.27	**1.63**
Statewide *Summer Weekend*	HC	67.21	**3.64**
	NOx	85.47	**3.64**
South Coast *Annual Average*	HC	4.99	**0.27**
	NOx	6.34	**0.27**

Table 10 lists baseline hydrocarbon emissions which are very close (given the precision of our estimating methods) in 2010 and 2020. While the boat population increases by about 16% over the 10 years as shown in Table D-1, the hydrocarbon emissions are not projected to increase commensurately because of the shift of the boat population from carbureted engines (about 80% of the population in 2010, about 40% of the population in 2020) emitting high hydrocarbons to fuel-injected engines emitting 65% less hydrocarbons.

A summary of the benefits of the proposal is shown in Table 11 for 2020 and 2010. The emission reductions of the proposal were determined by assuming emission controlled engines will meet the applicable emission standards for the certification periods. Table 11 shows that the combined HC+NOx emissions from inboard and sterndrive marine engines are reduced by about 30% compared to the baseline condition by 2020. This is a reduction of 56 tons of HC+NOx per day (summer weekend average), or the equivalent of the exhaust emitted by 1,600,000 cars in 2020 (based on annual-average tail-pipe emissions).

Table 11

Statewide Emissions Benefits from Proposed Emission Standards

2020 Statewide Emissions Benefits				
Air Basin	Pollutant	Baseline (TPD)	Control (TPD)	Benefit (TPD)
Statewide *Summer Weekend*	HC	67.5	56.1	**11.4**
	NOx	113.6	68.8	**44.8**
2010 Statewide Emissions Benefits				
Air Basin	Pollutant	Baseline (TPD)	Control (TPD)	Benefit (TPD)
Statewide *Summer Weekend*	HC	67.2	65.5	**1.7**
	NOx	85.5	77.2	**8.3**

Organic toxic gases present in the exhaust of gasoline engines will also be reduced to a similar extent as the reduction of HC. The important organic toxic species are benzene, toluene, 1,3 butadiene, formaldehyde and acetaldehyde, which, in total, constitute about 15% of the measured HC (U.S. EPA 2000).

Table 12 lists the emission factors used to develop these inventories. From this table the reader can judge quickly what the relative improvements in emission control rates are.

Table 12 Gasoline Inboard and Sterndrive Zero-Hour Emission Factors			
Emission Factors	HC g/kW-hr	NOx g/kW-hr	HC+NOx g/kW-hr
Baseline Carbureted	7.80	6.23	14.03
Baseline EFI	4.73	9.92	14.65
Catalyst	1.88	2.01	3.89

Note: EFI means electronic fuel-injected

2. Comparison with 1994 State Implementation Plan (SIP)

Table 13 presents the emission rates and emission inventory for gasoline inboard and sterndrive engines in the South Coast Air Basin for the year 2010, as documented in the 1994 SIP (ARB 1994b). As the data in the table illustrate, the 1994 estimates of population and NOx emission rate were too low, and HC emission rate too high, compared to data used in the current inventory. The calculated reductions, based on using these estimates and staff's proposed standards and implementation schedule, fall short of the 1994 SIP HC emission reduction commitment of 2 tpd.

Table 13 SIP-basis 2010 emissions, South Coast Air Basin					
	Population	HC g/kW-hr	NOx g/kW-hr	HC tpd	NOx tpd
Baseline	66,300	12	5	8	3
Reductions				1.1	(0.8)

Note: Numbers in parentheses are emission increases

B. Economic Impacts

Overall, the proposed amendments are not expected to impose a significant cost burden on sterndrive and inboard marine engine manufacturers. None of the major manufacturers are located inside California, although some may have small operations within the State. A few manufacturers control the bulk of the market share for these engines. Annual costs of the proposed amendments are estimated to be around $7 to 11 million in 2009. These costs are likely to be passed on by manufacturers to boat buyers, resulting in an increase of about 3 to 4 percent in average retail prices of a sterndrive or inboard boats. NMMA has indicated that marine engine sales are price-elastic, decreasing by about 2.7 percent for every one percent increase in price of the product. However, as a luxury good, it is also income-elastic, indicating that demand for boats tends to rise as income increases, and income has been rising steadily in California. The negative effect of the price increase on boat sales, thus, is likely to be at least partially offset by the positive effect of the income increase. As a result, and as explained in further detail below, staff expects the proposed amendments 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.

Health and Safety Code section 57005 requires the ARB to perform an economic impact analysis of submitted alternatives to a proposed regulation before adopting any major regulation. A major regulation is defined as a regulation that will have a potential cost to California business enterprises in an amount exceeding ten million dollars in any single year. The proposed amendments are not a major regulation.

2. Businesses Affected

Any business involved in manufacturing sterndrive and inboard gasoline marine engines would potentially be affected by the proposed amendments[2]. Also potentially affected are businesses that manufacture boats, supply parts to these manufacturers, and distribute, sell and service sterndrive and inboard marine engines.

The inboard and sterndrive marine industry consists of about 30 engine manufacturers and a large number of boat manufacturers nationwide. The largest four manufacturers control over 95 percent of the market. None of major engine manufacturers are located in California, although some may have part of

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

their operations within the state. Table 14 provides a list of major manufacturers of sterndrive and inboard gasoline marine engines in the United States.

Table 14 **Major Inboard and Sterndrive Marine Engine Manufacturers**
Indmar Products
Marine Power
Mercury MerCruiser
Volvo Penta of the Americas

3. Potential Impact on Engine Manufacturers

Inboard and sterndrive engine manufacturers currently are expected to use common automotive emission control technologies such as closed-loop fuel-control systems and three-way catalytic converters to comply with the proposed regulations.

Based on the application of the best available automotive technologies, staff estimates that the proposed amendments will increase average costs of manufacturing inboard and sterndrive marine engines by about $7 to 11 million annually. 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 is 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 amendments 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 estimate that the long-term price elasticity is 2.7 for boats, implying that boat sales will fall by 2.7 percent for every one percent increase in boat prices. Although the initial boat price is a major factor in a buyer's decision, it is not the crucial factor, according to the industry's studies (NMMA, 1997). The purchase of a boat is a major decision for most boat buyers and usually it 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, storage cost, the initial price and maintenance routines. Industry studies indicate that maintenance routines are more important to a prospective buyer than the initial cost of a boat (NMMA, 1996). The industry 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 price. Thus, it is most likely that boat buyers are willing to pay higher prices for new boats that are more fuel-efficient and require less maintenance. Most manufacturers, therefore, should be able to pass on the cost increase to consumers in the long run if they are unable to lower their production costs. As a result, the proposed amendments are not expected to have a noticeable adverse impact on affected manufacturers.

4. Potential Impact on Distributors and Dealers

Most engine and boat manufacturers sell their products through distributors and dealers, some of which are owned by manufacturers and some are independent. Most independently owned dealers are small businesses. Some low-volume manufacturers also deal directly with their customers. The distributors and dealers sell about 11,000 units of sterndrive and inboard engines per year in California. Although they are not directly affected by the proposed amendments, the amendments may affect them indirectly if an increase in prices of inboard and sterndrive marine engines reduces sales volume. Dealers' revenue would be affected adversely if the reduction in sales volume exceeds the increase in prices.

5. Potential Impact on Customers

The potential impact of the proposed amendments on the retail prices of sterndrive and inboard marine engines hinges on the ability of manufacturers to pass on the cost increases to their customers. In the short run, customer sensitivity to price increases and growing competition from used boat sales may prevent manufacturers from passing their cost increases on to customers. In the long run, however, if manufacturers are unable to bring down their costs of compliance, they would pass on their costs increases to marine engine customers. In such a case, staff estimates the average price of a marine engine would increase by $756 to 1231 for California customers. This represents an average increase of 3 to 4 percent in the price of an inboard or sterndrive boat. The price increase is within the range of California personal income gains in recent years. During 1990 to 1999, California personal income rose by about 1.8 to 8.1 percent annually (Department of Finance, 2001). 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 amendments 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 inboard and sterndrive marine engines for sale in California are subject to the proposed amendments regardless of their location. None of the major manufacturers have engine-manufacturing facilities located in California.

7. Potential Impact on Employment

According to a survey of the industry by U.S. EPA as part of its rulemaking process, nationwide employment in inboard and sterndrive marine engine industry was about 1,600 persons in 2000. California accounted only for a small share of this employment. There were also 347 retail outlets in California in 1997 (U.S. Department of Commerce, 2000), which were primarily involved in the retail sale of new and used motorboats and other marine engines, marine supplies, and outboard and inboard motors. These retail outlets employed an estimated 2,000 employees with an annual payroll of approximately $58 million in California. These employees are not likely to be affected adversely, because a small price increase is unlikely to dampen the demand for sterndrive and inboard in California substantially, and these boats account for less than 20 percent of all boats sold. Thus, the proposed amendments are not expected to cause a noticeable adverse impact on the California employment.

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

The proposed amendments would have no noticeable impact on the status of California marine engine manufacturers. As stated above, none of the major manufacturers of inboard and sterndrive engines is located in California. The amendments would potentially increase retail prices of marine engines by an average of about 4 percent. The increase in prices is unlikely to dampen demand for regulated products significantly because the impact of a price increase is likely to be offset by a faster rise in California personal income.

9. Potential Impact to State, Local or Federal Agencies

The only direct effect on local and federal agencies would be an increase in the price of boats they purchase. The number of boats purchased by these agencies in California is unknown, but is expected to be small.

The same is true for State agencies which purchase inboard and sterndrive boats. The State agencies involved in enforcing this rule; *i.e.*, the ARB, will incur higher costs due to inspecting boat dealerships for certified or complying engines, and the emission testing of in-use engines for compliance.

IX. ALTERNATIVES

A. Wait for the adoption of U.S. EPA Regulations

ARB staff has been working closely with U.S. EPA staff on a coordinated rulemaking process. ARB's intent has been to develop a regulation which is harmonized in terms of emission standards, applicability, and timing with the federal rule. Because the State's rulemaking process is currently on a faster track than U.S. EPA's, staff has proceeded to "take the lead" with its proposal. The alternative would be to allow the federal rule to be implemented in California at a later date and not adopt a specific state regulation.

The advantage of a national regulation is harmonization. Manufacturers would have to comply with only one set of regulations for all nationwide sales. The U.S. EPA has indicated it will consider harmonizing with adopted ARB standards, although with a potentially delayed implementation date.

The disadvantage of relying on the federal rulemaking is largely one of uncertainty and timing. U.S. EPA has yet to publish a proposed regulation, and thus adoption is at least one year away. Because of lead-time requirements, it is possible that future implementation may be delayed compared to the dates ARB staff has proposed. This will result in less emission reductions compared to adoption of the ARB staff proposal.

B. No Marine Inboard Engine Regulation

If no emission control regulation was pursued, the emission reduction needed to meet clean-air standards would not be achieved. The ARB's SIP obligation would not be met.

C. Lean-calibration engines from 2003 to 2008

Staff considered an emission control scenario under which manufacturers would have leaned the engines' air-fuel mixtures resulting in lower HC emissions but higher NOx emissions. Also under this scenario, only small numbers (10% of California sales) of catalyst-controlled engines were subject to the strict 5.0 g/kW-hr standards in 2007 and 2008. Staff based its proposal on the need to achieve early HC emission benefits as required by the SIP Settlement Agreement. HC+NOx emissions would increase during 2003 to 2008, based on recently obtained test data showing NOx increases at a faster rate than HC emissions decrease, due to enleanment of the air-fuel ratio. This alternative was rejected on this basis.

X. OUTSTANDING ISSUES

A. Emissions Inventory

Industry commented during the outboard engine rulemaking and early in the process for this rulemaking that the ARB's figures for the emissions impact due to boating were higher than their estimates. In Chapter VIII of this report, Air Quality, Environmental, and Economic Impacts, and in Attachment D, detailed changes to the emission inventory are summarized. A summary of the previous assumptions, industry's estimates and staff's revised estimates are shown in Table 14.

The changes in the inventory result in about a 3-fold reduction in the total estimated emissions contribution from inboard and sterndrive engines. Industry has still commented that the usage rate of 78 hours per year is much above their estimates. In Attachment D the various usage rate data and determinations are discussed. They are based on ECM operating hour data collected at service centers, mail survey of owners, reading of hour-meters at dockside, and boater surveys. They vary from about 55 hours per year to 100 hours per year. For comparison, an automobile driven 13,000 miles per year at 40 miles per hour annual average would have been used about 300 hours per year. Large gasoline engines used commercially see about 500 to 1000 hours per year of usage.

Table 14

Comparison of Emission Inventory Assumptions

	98 ARB inventory	Industry estimates	Present ARB estimates
Uncontrolled deteriorated emission factors*	14 g/kW-hr HC 7 g/kW-hr NOx		6** g/kW-hr HC 9** g/kW-hr NOx
State Inboard boat-engine population, 2010	445,000	114,000	387,000
Average Power	175 hp		211 hp
Usage load fraction	38%	21%	21%
Usage rate	78 hours per year	48 hr/yr	78 hr/yr
New engine replenishment rate	32,000/yr	11,400/yr	14,000/yr
Statewide HC 2010, annual average	83 tpd		19 tpd
Statewide NOx 2010, annual average	42 tpd		24 tpd

* Lifetime average, for 480-hour life
**Assumed 65% EFI, 35% Carbureted in 2010.

B. Catalyst Durability

The emission results from dynamometer testing are based on new catalysts on a young, optimized engine, operating in laboratory conditions. The marine engine manufacturers have raised concerns regarding catalyst durability and reliability in light of water ingestion or accumulation in the exhaust pipes, leading to catalyst or oxygen sensor damage.

ARB is presently funding in-boat tests to investigate the amount and causes of water accumulation and ingestion in wet marine exhaust manifolds. Testing has revealed oxygen sensors can easily be damaged by liquid water exposure, but this has been successfully avoided by locating the oxygen sensor upstream of the catalyst. The research project with Southwest Research Institute is expected to yield some relatively simple design fixes which will minimize this water exposure, and prolong oxygen sensor life. While the boat being tested does not have catalysts installed, we expect to install oxygen sensors and quantify the lifetime improvement.

ARB is presently developing a test program with Southwest Research Institute to further examine catalyst-equipped engines in boats. The envisioned program will be conducted in coordination with the engine manufacturers, U.S. Coast Guard, and the catalyst manufacturers. We expect to jointly tackle the remaining catalyst adaptability issues for the engine manufacturers large and small, well before the proposed 2003 technology review before the Board.

C. Safety

The U.S. Coast Guard expressed concerns about run-away catalyst overheating, potential carbon monoxide leakage from exhaust pipe joints, and increased engine-compartment heat load.

In many hours of testing, we have noticed only two incidents of catalyst overheating, and a few exhaust leaks (showed up by water leaks on initial installation of water jacket catalyst pieces). The catalyst overheating was caused by cylinder misfire from poor fuel control (worst at idle condition) and loss-of-compression (engine cylinder head damage) due to running the engine too hard during testing. Replacing the cylinder heads with new ones restored compression and engine performance, and upgrading the air-fuel control software has allowed precise and lean fuel-control at idle, eliminating misfires. In this incident the only damage was to the catalyst ceramic itself—sintering of the precious metal sites, leading to deactivation. The exterior exhaust pipe walls were cooled with water at all times. There was no explosion or burn-hazard.

The exhaust pipe leaks which could have led to carbon monoxide leaks were immediately visible as water leaks. Flattening or truing flat metal flange surfaces, applying good gaskets, and using gasket sealant on the joints took care of the water leaks, evidence of water-tight joints and therefore gas-tight joints.

We have performed a battery of dry cool-down tests on hot catalysts, and have found only mild, short temperature excursions of the cast-iron exhaust pipe metal. The temperatures stayed below the American Boating and Yacht Council (ABYC) consensus skin temperature limits.

The cooperative test program discussed above with the engine manufacturers, U.S. Coast Guard, and catalyst manufacturers will also address these issues.

D. Effect on low-end sales

The manufacturers have commented that the inclusion of equipment on engines which raises the cost by about $500 will seriously reduce sales of the small four-cylinder engines which now cost $3000 to 4000. These engines are offered as entry-level economy choices. They are now about the same price as a similar power two-stroke outboard. Starting this year in California only direct-fuel-injected two-strokes and four-stroke outboard engines are able to be sold. The direct-injection two-strokes cost about $3000 more than the conventional outboards.

The economy inboard 4-cylinder engines are now sold only as carbureted versions. Most of the increased cost for these engines due to the regulation will be the conversion of the engine to electronic multi-point fuel injection. Electronic fuel-injection is not specifically required to meet the standards proposed in this rule. However, it offers computer-control which is able to be integrated with exhaust oxygen feedback to optimize the performance of the three-way exhaust catalyst. So, while not being a required feature, it is a desirable or important one. It should be added that the maker of these engines, General Motors, has projected that the low-end 4-cylinder engine will be replaced by a sequentially fuel-injected version in 2005 or so. In 1997 General Motors started only supplying the larger engines (*e.g.*, 454 cubic inch displacement) as factory-installed multi-port fuel-injected. Last year, they completely replaced larger engines with a sequentially fuel-injected model.

The projected price increase is well within the range of California personal income gains in recent years. During 1990 to 1999, California personal income rose by about 1.8 to 8.1 percent annually (Department of Finance, 2001). Thus, the estimated price increase is not expected to have a significant impact on the marine engine demand in California.

E. Research costs for small-volume manufacturers

Section VII (Cost of Control) lists development costs of millions of dollars to adapt automotive control to on-boat engines. This is a large expense for a company the size of the Mercury MerCruiser Division, but it is a nearly impossible expense for the six-odd small companies which together share 20% of the inboard and sterndrive gasoline engine market.

The cost-effectiveness or per-engine costs shown in Section VII assume that this development cost is spread out over sales of about 3300 units per year. This is only true of a few model-lines from the large manufacturers on a nationwide basis. The other models and manufacturers have much lower sales to spread these costs over.

The ARB and U.S. EPA have already spent more than $350,000 to develop marine catalyst engines. We expect the knowledge gained on catalyst placement and life, advanced ECM programming, and water exposure of exhaust components to be available and shared by all the engine manufacturers and boat builders with equal opportunity. As previously mentioned, the ARB and U.S. EPA have recently committed to the industry to organize and contribute funding to a multi-year in-boat demonstration program to prove many of the issues of catalyst durability and engine driveability, safety *etc.* Again, we expect this information to be shared among all the boat builders and engine manufacturers.

XI. CONCLUSIONS

Staff's goal in developing this regulation is to achieve emission reductions from marine gasoline engines commensurate with that achieved by feedback air-fuel control with three-way exhaust catalysts, a successful automotive technology. This proposal was developed in coordination with U.S. EPA, the engine manufacturers, the boat-builders, the catalyst makers, the U.S. Coast Guard, and was backed up with marine engine emission control device development and emission tests and in-boat, on-the-water testing. The proposed standards are achievable by applying presently available and effective technology to these largely uncontrolled engines. Cooperative development and testing will continue, and the staff will conduct technology reviews to be shared with the Board in 2003 and 2005.

Staff recommends adoption of the proposed regulation, estimated to achieve 56 tpd of combined HC+NOx reductions statewide in 2020, a 30% reduction from present uncontrolled levels.

The proposed emission reductions are necessary to help meet commitments made in the 1994 SIP, and a subsequent settlement agreement.

Finally, the ARB has determined that no reasonable alternative considered by the agency or that has otherwise been identified and brought to the attention of the agency would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons or businesses than the proposed action.

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ATTACHMENT A

PROPOSED REGULATION ORDER

Title 13 California Code of Regulations

PROPOSED REGULATION ORDER

NOTE: This document is written in a style to indicate changes from the existing provisions. All existing language is indicated by plain text. All additions to language are indicated by underlined text. All deletions to language are indicated by ~~strikeout~~. Only those portions containing the suggested modifications from existing provisions are included. All other portions remain unchanged and are indicated by the symbol "* * * * *" for reference.

Amend sections 2111, 2112, 2139, 2140, 2147, 2440, 2441, 2442, 2443.1, 2443.2, 2443.3, 2444, 2445.1, 2445.2, 2446, and 2471, and adopt section 2444.2, title 13 California Code of Regulations, and amend Appendix A to article 2.1, chapter 2 division 3, title 13, California Code of Regulations, to read as follows:

§ 2111. Applicability.

(a) These procedures shall apply to:

(1) California-certified 1982 and subsequent model-year passenger cars, light-duty trucks, medium-duty vehicles, heavy-duty vehicles, motorcycles, and California-certified 1997 and subsequent model-year off-road motorcycles and all-terrain vehicles, including those federally certified vehicles which are sold in California pursuant to Health and Safety Code section 43102,

(2) California-certified motor vehicle engines used in such vehicles, ~~and~~

(3) California-certified 2000 and subsequent model-year off-road compression-ignition engines~~.~~, and

(4) California-certified 2009 and subsequent model-year spark-ignition sterndrive and inboard marine engines.

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018 and 43105, Health and Safety Code.
Reference: Sections 43000, 43009.5, 43013, 43018, 43101, 43104, 43105, 43106, 43107, and 43204-43205.5, Health and Safety Code.

§ 2112. Definitions.

* * * * *

(l) "Useful life" means, for the purposes of this article:

* * * * *

(23) For 2009 and subsequent model year spark-ignition sterndrive and inboard marine engines, a period of ten years or 480 hours, whichever first occurs.

* * * * *

Appendix A
to Article 2.1

California In-Use Vehicle Emission-Related Recall Procedures, Enforcement Test Procedures, and Failure Reporting Procedures for 1982 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, Medium-Duty Vehicles, Heavy-Duty Vehicles and Engines, Motorcycles, 1997 and Subsequent Model-Year Off-Road Motorcycles and All-Terrain Vehicles, ~~and~~ 2000 and Subsequent Model-Year Off-Road Compression-Ignition Engines, and 2009 and Subsequent Model-Year Spark-Ignition Sterndrive and Inboard Marine Engines.

* * * * *

I. Passenger Car, Light-Duty Truck, Medium-Duty Vehicle, ~~and~~ Motorcycle, and Sterndrive and Inboard Parameters and Specifications.

* * * * *

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43104, and 43105, Health and Safety Code.
Reference: Sections 39002, 39003, 43000, 43009.5, 43013, 43018, 43100, 43101, 43101.5, 43102, 43104, 43105, 43106, 43107, and 43204-43205.5, Health and Safety Code.

§ 2139. Testing.

* * * * *

(h) For spark-ignition sterndrive and inboard marine engines, in-use compliance tests shall be performed pursuant to section 2442, Title 13, California Code of Regulations. The in-use compliance testing shall use the same test procedure utilized for the specific engine's original certification testing.

(~~h~~i) For any emission in-use compliance test performed pursuant to subsections (a) through (~~g~~h), the ARB may waive a specific test for subsequent vehicle samples if results from vehicle samples already tested are deemed sufficient to establish complying emission levels. The ARB shall inform the manufacturer at least 30 days prior to enforcement testing of its vehicles or engines and shall permit a manufacturer representative to observe the enforcement testing.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43104 and 43105, Health and Safety Code.
Reference: Sections 39002, 39003, 43000, 43009.5, 43013, 43018, 43100, 43101, 43101.5, 43102, 43103, 43104, 43105, 43106, 43107, 43204-43205.5 and 43211-43213 Health and Safety Code.

§ 2140. Notification and Use of Test Results.

* * * * *

(b) If the results of the in-use vehicle emission tests conducted pursuant to Section 2139 indicate that the average emissions of the test vehicles for any pollutant exceed the applicable emission standards specified in Title 13, California Code of Regulations, Sections 1960.1, 1961, 1956.8, 1958, 2412, ~~or~~ 2423 or 2442, the entire vehicle population so represented shall be deemed to exceed such standards. The Executive Officer shall notify the manufacturer of the test results and upon receipt of the notification, the manufacturer shall have 45 days to submit an influenced recall plan in accordance with Sections 2113 through 2121, Title 13, California Code of Regulations. If no such recall plan is submitted, the Executive Officer may order corrective action including recall of the affected vehicles in accordance with Sections 2122 through 2135, Title 13, California Code of Regulations.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018 and 43105, Health and Safety Code.
Reference: Sections 43000, 43009.5, 43013, 43018, 43101, 43104, 43105, 43106, 43107, 43204-43205.5 and 43211-43213, Health and Safety Code.

§ 2147. Demonstration of Compliance with Emission Standards.

* * * * *

(b) A manufacturer may test properly maintained in-use vehicles with the failed emission-related component pursuant to the applicable certification emission tests specified in Title 13, California Code of Regulations, Section 1960.1 or 1961, as applicable, for passenger cars, light-duty trucks and medium-duty vehicles, Section 1956.8 for heavy-duty engines and vehicles, ~~and~~ Section 1958 for motorcycles, and Section 2442 for inboard and sterndrive marine engines. The emissions shall be projected to the end of the vehicle's or engine's useful life using in-use deterioration factors. The in-use deterioration factors shall be chosen by the manufacturer from among the following:

* * * * *

NOTE: Authority cited: Sections 39600, 39601, and 43105, Health and Safety Code.
Reference: Sections 43000, 43009.5, 43018, 43101, 43104, 43105, 43106, 43107 and 43204-43205.5, Health and Safety Code.

§ 2440. Applicability.

(a)(1) This article applies to model year 2001 and later ~~subsequent model year~~ spark-ignition marine engines ~~used to propel marine watercraft~~, unless otherwise indicated.

~~(2) Sterndrive and inboard engines are exempt from this article.~~

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

(3) Spark-ignition sterndrive and inboard marine engines produced by the engine manufacturer specifically for competition are exempt from the requirements of this article, except section 2443.1, provided that the marine watercraft in which the engine is installed is designed, built, and used solely for competition. Marine watercraft not registered with a nationally-recognized organization that sanctions professional competitive events or used for amateur or occasional competition do not meet the competition exemption criteria.

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

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

(2) This article shall not apply to engines used in off-road military tactical vehicles or equipment which have been exempted from regulations under the federal national security exemption, 40 CFR, subpart J, section 90.908, which is incorporated by reference herein. It shall also not apply to those vehicles and equipment covered by the definition of military tactical vehicle that are commercially available and for which a federal certificate of conformity has been issued under 40 CFR Part 91., subpart B, which is incorporated by reference herein.

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

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2441. Definitions.

(a) Definitions in section 1900(b), Division 3, Chapter 9, Title 13 of the California Code of Regulations, apply with the following additions:

(1) "Abuse" means incorrect or improper operation of an engine or equipment unit that results in the failure of an emission-related part.

(2) "Acceptable quality level" (AQL) means the maximum percentage of failing engines that can be considered a satisfactory process average for sampling inspections.

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

(4) "Base Fuel Schedule" refers to the fuel calibration schedule programmed into the Engine Control Module or PROM when manufactured or when updated by some off-board source, prior to any learned on-board correction.

(5) "Calculated load value" (CLV) refers to an indication of the current airflow divided by peak airflow, where peak airflow is corrected for altitude, if available. This definition provides a unitless number that is not engine specific, and provides the service technician with an indication of the percent engine capacity that is being used (with wide open throttle as 100%). See equation below:

$$CLV = \left(\frac{\text{Current airflow}}{\text{Peak airflow (at sea level)}} \text{ X } \frac{\text{Atmospheric pressure (at sea level)}}{\text{Barometric pressure}} \right)$$

~~(4)~~(6) "Capture rate" means the percentage of in-use engines subject to recall which must be corrected to bring the class of engines into compliance. The number of engines subject to recall shall be based on the actual number of engines in use as verified by engine registration records compiled and prepared by industry, or a comparable source as determined by the Executive Officer at the time a recall is initiated.

~~(5)~~(7) "Carryover engine family" means an engine family that undergoes certification using carryover test data from previous model years.

~~(6)~~(8) "Certification" means, with respect to new spark-ignition marine engines, obtaining an Executive Order for an engine family complying with the spark-ignition marine engine exhaust emission standards and requirements specified in Title 13, California Code of Regulations, sections 2442 and 2447.

~~(7)~~(9) "Complete engine assembly" or "complete engine configuration" means an assembly of a basic engine and all of the specific applicable components (e.g., air inlet, fuel and exhaust systems, etc.) and calibrations (e.g., carburetor jet size, valve timing, etc.) required for the assembly to be installed in a new unit of equipment.

(10) "Continuous monitoring" means sampling at a rate no less than two samples per second. If for engine control purposes, a computer input component is sampled less frequently, the value of the component may instead be evaluated each time sampling occurs.

~~(8)~~(11) "Emission control system" means any device, system, or element of design that controls or reduces the emission of substances from an engine.

~~(9)~~(12) "Enforcement test results" means data or information gathered through enforcement programs conducted by the Air Resources Board. These programs include, but are not limited to, field inspections, in-use compliance testing, assembly-line testing.

~~(10)~~(13) "Engine family" means a subclass of a basic engine based on similar emission characteristics. The engine family is the grouping of engines that is used for the purposes of certification.

~~(11)~~(14) "Engine identification number" means a unique specification (for example, model number/serial number combination) that allows each spark-ignition marine engine to be distinguished from other similar engines.

(15) "Engine misfire" means lack of combustion in the cylinder due to absence of spark, poor fuel metering, poor compression, or any other cause.

(16) "Engine start" is defined as the point at which normal, synchronized spark and fuel control is obtained or when the engine reaches a speed 150 revolutions per minute (rpm) below the normal, warmed-up idle speed.

~~(12)~~(17) "Exhaust emissions" means matter emitted into the environment from any opening downstream from the exhaust port of a spark-ignition marine engine.

~~(13)~~(18) "Executive Officer" means the Executive Officer of the Air Resources Board or his or her authorized representative.

~~(14)~~(19) "Executive Order" means an order issued by the Executive Officer certifying engines for sale in California.

~~(15)~~(20) "Family Emission Limit" means an emission value assigned by a marine engine manufacturer to an engine family for the purpose of complying with a corporate average exhaust emission standard. The Family Emission Limit (FEL) must not exceed the limit specified in this Article.

~~(16)~~(21) "Fuel system" means all components involved in the transport, metering, and mixture of the fuel from the fuel tank to the combustion chamber(s) including, but not limited to the following: fuel tank, fuel tank cap, fuel pump, fuel lines, oil injection metering system, carburetor or fuel injection components, and all fuel system vents.

(22) "Fuel trim" refers to feedback adjustments to the base fuel schedule. Short-term fuel trim refers to dynamic or instantaneous adjustments. Long-term fuel trim refers to much more gradual adjustments to the fuel calibration schedule than short-term trim adjustments. These long-term adjustments compensate for engine differences and gradual changes that occur over time.

(23) "Functional check" for an output component means verification of proper response to a computer command. For an input component, functional check means verification of the input signal being in the range of normal operation, including evaluation of the signal's rationality in comparison to all available information.

~~(17)~~(24) "Inboard Engine" means a ~~four-stroke~~ spark-ignition marine engine not used in a personal watercraft that is designed such that the propeller shaft penetrates the hull of the marine watercraft while the engine and the remainder of the drive unit is internal to the hull of the marine watercraft.

~~(18)~~(25) "Inspection criteria" means the pass and fail numbers associated with a particular sampling plan.

(26) "Malfunction" means the inability of an emission-related component or system to remain within design specifications. Further, malfunction refers to the deterioration of any of the above components or systems to a degree that would likely cause the emissions of an aged engine with the deteriorated components or systems present at the beginning of the applicable certification emission test to exceed the $HC+NO_x$ emission standard by more than 50 percent, unless otherwise specified, as applicable pursuant to Subchapter 1 (commencing with Section 1900), Chapter 3 of Title 13.

~~(19)~~(27) "Marine engine manufacturer" means any person engaged in the manufacturing or assembling of new spark-ignition marine engines or the importing of such engines for resale, or who acts for and is under the control of any such person in connection with the distribution of such engines. A spark-ignition marine engine manufacturer does not include any dealer with respect to new spark-ignition marine engines received by such person in commerce.

~~(20)~~(28) "Marine watercraft" means every description of boat, ship or other artificial contrivance used, or capable of being operated on water.

~~(21)~~(29) "Model year" means the engine manufacturer's annual new model production period which includes January 1 of the calendar year for which the model year is named, ends no later than December 31 of the calendar year, and does not begin earlier than January 2 of the previous calendar year. Where an engine manufacturer has no annual new model production period, model year means the calendar year.

~~(22)~~(30) "New", for purposes of this Article, means a spark-ignition marine engine or watercraft the equitable or legal title to which has never been transferred to an ultimate purchaser. Where the equitable or legal title to the engine or watercraft is not transferred to an ultimate purchaser until after the engine or watercraft is placed into service, then the engine or watercraft will no longer be new after it is placed into service. A spark-ignition marine engine or watercraft is placed into service when it is used for its functional purposes. With respect to imported spark-ignition marine engines or watercraft, the term "Anew" means an engine or watercraft that is not covered by an Executive Order issued under this Article at the time of importation, and that is manufactured after the effective date of a section in this Article which is applicable to such engine or watercraft, or which would be applicable to such engine or watercraft had it been manufactured for importation into the United States.

~~(23)~~(31) "Nonconformity" or "Noncompliance", for purposes of Title 13, California Code of Regulations, section 2444, means that:

(A) a significant number, determined by the Executive Officer, of a class of engines, although properly maintained and used, experience a failure of the same emission-related component(s) within their useful lives which, if uncorrected, results in the engines' failure to comply with the emission standards prescribed under section 2442 which are applicable to the model year of such engines; or

(B) a class of engines that at any time within their useful lives, although properly maintained and used, on average does not comply with the emission standards prescribed under section 2442 which are applicable to the model year of such engines.

(32) "Operating cycle" consists of engine startup, engine run, and engine shutoff.

~~(24)~~(33) "Original equipment manufacturer" means a manufacturer who purchases engines for installation in its equipment for sale to ultimate purchasers.

~~(25)~~(34) "Outboard engine" means a spark-ignition marine engine that, when properly mounted on a marine watercraft in the position to operate, houses the engine and drive unit external to the hull of the marine watercraft.

~~(26)~~(35) "Personal watercraft engine" means a spark-ignition marine engine that does not meet the definition of outboard engine, inboard engine or sterndrive engine, except that the Executive Officer may, in his or her discretion, ~~may~~ classify a personal watercraft engine as an inboard or sterndrive engine if it is comparable in technology and emissions to an inboard or sterndrive engine.

~~(27)~~(36) "Production-line tests" are emission tests performed on a sample of production engines produced for sale in California and conducted in accordance with Title 13, California Code of Regulations, section 2446(a).

(37) "Redline engine speed" means the engine manufacturer recommended maximum engine speed as normally displayed on instrument panel tachometers, or the engine speed at which fuel shutoff occurs.

(38) "Response rate," with regards to oxygen sensors, refers to the delay (measured in milliseconds) between a switch of the sensor from lean to rich or vice versa in response to a change in fuel/air ratio above and below stoichiometric.

~~(28)~~(39) "Sales" or "Eligible sales" means the actual or calculated sales of an engine family in California for the purposes of corporate averaging and production-line testing. Upon Executive Officer approval, an engine manufacturer may calculate its eligible sales through market analysis of actual federal production or sales volumes.

~~(29)~~(40) "Scheduled maintenance" means any adjustment, repair, removal, disassembly, cleaning, or replacement of components or systems required by the engine manufacturer to be performed on a periodic basis to prevent part failure or marine watercraft or engine malfunction, or those actions anticipated as necessary to correct an overt indication of malfunction or failure for which periodic maintenance is not appropriate.

(41) "Small volume manufacturer" means a marine engine manufacturer with spark-ignition marine engine sales less than 2,000 per year in the United States. It is the responsibility of the manufacturer to document the sales rate to the Executive Officer.

~~(30)~~(42) "Spark-ignition marine engine" means any engine used to propel a marine watercraft, and which utilizes the spark-ignition combustion cycle; including, but not limited to personal watercraft, outboard, inboard and sterndrive engines.

~~(31)~~(43) "Sterndrive engine" means a ~~four-stroke~~ spark-ignition marine engine not used in a personal watercraft that is designed such that the drive unit is external to the hull of the marine watercraft, while the engine is internal to the hull of the marine watercraft.

~~(32)~~(44) "Test engine" means the engine or group of engines that an engine manufacturer uses during certification, production-line and in-use testing to determine compliance with emission standards.

(45) "Test Procedures" means the document entitled "California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines," which includes the standards and test procedures applicable to 2001 and later spark-ignition personal watercraft, outboard, inboard and sterndrive marine engines, as adopted October 21, 1999 and as amended (**insert date of amendment**). This document is incorporated by reference herein.

~~(33)~~(46) "Ultimate purchaser" means, with respect to any new spark-ignition marine engine, the first person who in good faith purchases such new spark-ignition marine engine for purposes other than resale.

~~(34)~~(47) "U.S.C." means United States Code.

(48) "Used solely for competition" means exhibiting features that are not easily removed and that would render its use other than in competition unsafe, impractical, or highly unlikely.

~~(35)~~(49) "Useful life" for spark-ignition marine engines means nine years for personal watercraft engines and sixteen years for ~~an~~ outboard, ~~engine~~ sterndrive, and inboard engines.

(50) "Warm-up cycle" means sufficient engine operation such that the coolant temperature has risen by at least 40 degrees Fahrenheit from engine starting and reaches a minimum temperature of at least 160 degrees Fahrenheit.

~~(36)~~(51) "Warranty period" means the period of time the engine or part is covered by the warranty provisions.

~~(37)~~(52) "Warranty station" means any dealer, service center or other agent that is authorized by the engine manufacturer to perform diagnostic labor, repairs or replacements of warranted engine components.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2442. Emission Standards.

(a) Model year 2001 and later model year spark-ignition personal watercraft and outboard marine engines:

(1) Exhaust emissions from new spark-ignition marine engines manufactured for sale, sold, or offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce must not exceed the hydrocarbon plus oxides of nitrogen ($HC+NO_x$) exhaust emission standards listed in Table 1 during its designated useful life:

Table 1.

Corporate Average Emission Standards by Implementation Date $HC+NO_x$ (g/kW-hr)			
Model Year	**Max. Family Emission Limit (FEL)**	**$P_{tx} < 4.3$ kW**	**$P_{tx} \geq 4.3$ kW**
2001-2003	Not Applicable	81.00	$(0.25 \times (151+557/P_{tx}^{0.9})) + 6.0$
2004-2007	80	64.80	$(0.20 \times (151+557/P_{tx}^{0.9})) + 4.8$
2008 and Later	44	30.00	$(0.09 \times (151+557/P_{tx}^{0.9})) + 2.1$

where:

P_{tx} is the average power in kilowatts (kW) (sales-weighted) of the total number of spark-ignition marine engines produced for sale in California in model year x. Engine power must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference. Engine manufacturers must not determine P_{tx} by combining the power outputs of outboard engines with the power outputs of personal watercraft engines.

~~(b)~~(2) An engine manufacturer may comply with the standards directly on an individual engine family basis. Consequently in Table 1, FELs are not applicable for any model year and P_{tx} means the average power in kW (sales-weighted) of the subject engine family produced for sale in California in model year x.

Compliance with the standards on a corporate average basis is determined as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(FEL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = STD_{ca}$$

where:

n	= tTotal number of engine families (by category)
$PROD_{jx}$	= nNumber of units each engine family j produced for sale in California in model year x.
FEL_{jx}	= tThe Family Emission Limit (FEL) for engine family j in model year x, which must be determined by the engine manufacturer subject to the following conditions: (1) no individual engine family FEL shall exceed the maximum allowed value as specified in Table 1; (2) no engine family designation or FEL shall be amended in a model year unless the engine family is recertified; and (3) prior to sale or offering for sale in California, each engine family must be certified in accordance with the test procedures referenced in section 2447 and must meet the engine manufacturer's FEL as a condition of the Executive Order. Before certification, the engine manufacturer must also submit estimated production volumes for each engine family to be offered for sale in California.
P_{jx}	= The average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.
STD_{ca}	= An engine manufacturer's calculated corporate average $HC+NO_x$ exhaust emissions from those California spark-ignition marine engines subject to the California corporate average $HC+NO_x$ exhaust emission standard determined from Table 1, as established by an Executive Order certifying the California production for the model year. This Executive Order must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

(1)(A) For purposes of compliance under this paragraph, engine manufacturers must not corporate average outboard engine families in combination with personal watercraft engine families.

(2)(B) During the engine manufacturer's production year, for each engine family, the engine manufacturer shall provide the Executive Officer within 45 days after the last day in each calendar quarter the total number of spark-ignition marine engines produced for sale in California and their applicable FEL(s).

~~(3)~~(C) The Executive Order certifying the California production for a model year must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

~~(4)~~(D) The engine manufacturer's average $HC+NO_x$ exhaust emissions must meet the corporate average standard at the end of the engine manufacturer's production for the model year. At the end of the model year, the manufacturer must calculate a corrected corporate average using sales or eligible sales rather than projected sales.

~~(5)~~(E) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

~~(6)~~(F) For each model, the engine manufacturer shall submit California sales data ninety (90) days after the end of the model year.

(b) Exhaust emissions from new model year 2003 and later spark-ignition sterndrive and inboard marine engines must not exceed the exhaust emission standards listed in Table 2 or Table 3, as applicable, for the designated emission durability test period.

Table 2.

Inboard and Sterndrive Exhaust Emission Standards (by Implementation Date)		
Model Year	**$HC+NO_x$** (grams per kilowatt-hour)	**Durability Test Period** (hours)
2003-2008[1]	15.0[2]	—
2007 and Later[3, 4]	5.0	480

1. Engines with a maximum rated power exceeding 373 kilowatts (500 horsepower) are not required to comply with these standards.
2. Compliance to the $HC+NO_x$ standard may be averaged on a sales-weighted basis, across the engine manufacturers' California production.
3. For model year 2007, engine manufacturers shall certify a minimum of 10% of their California production to the 2009 model year emission standards and other requirements.
4. For model year 2008, engine manufacturers shall certify a minimum of 50% of their California production to the 2009 model year emission standards and other requirements.

Table 3.

Small Volume Manufacturers Inboard and Sterndrive Exhaust Emission Standards		
Model Year	**$HC+NO_x$** (grams per kilowatt-hour)	**Durability Test Period** (hours)
2009 and Later	5.0	480

(1) No crankcase emissions shall be discharged into the ambient atmosphere from 2003 and later spark-ignition sterndrive and inboard marine engines.

(2) Production and sale of spark-ignition marine engines that result in noncompliance with the California standard for the model year shall cause an engine manufacturer to be subject to: revocation or suspension of Executive Orders for the applicable engine families; enjoinment from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code; and all other remedies available under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

(3) For each engine family, the engine manufacturer shall submit California sales data ninety (90) days after the end of the model year.

(c) The test equipment and test procedures for determining compliance with these standards are set forth in Parts III and IV, respectively, of the "California Exhaust Emission Standards and Test Procedures for 2001 and Later Spark-Ignition Marine Engines" ("Test Procedures."), adopted October 21, 1999, which are incorporated by reference herein.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.1. Emission Control Labels – Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) Purpose. The Air Resources Board recognizes that certain emissions-critical or emissions-related parts must be properly identified and maintained to ensure that engines meet the applicable emission standards. The purpose of this section is to require engine manufacturers to affix a label (or labels) on each production engine (or watercraft, as applicable) to provide the engine owner and service mechanic with information necessary for the proper maintenance of these parts in customer use. These specifications also require the engine manufacturer to permanently identify the engine with a unique identification number that will be used for enforcement purposes, including in-use testing.

(b) Applicability. This section applies to:

(1) Model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition sterndrive and inboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013;

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

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

(c) Engine Label and Location.

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

(2) In selecting an acceptable location, the engine manufacturer must consider the possibility of accidental damage (e.g., possibility of tools or sharp instruments coming in contact with the label). Each engine label must be affixed in such a manner that it cannot be removed without destroying or defacing the label, and must not be affixed to any engine (or watercraft, as applicable) part that is likely to be replaced during the engine's (or watercraft's, as applicable) useful life or that is not integral to the engine's operation. The engine label must not be affixed to any engine (or watercraft as applicable) component that is easily detached from the engine. If the engine manufacturer claims there is inadequate space to attach the label, the Executive Officer will determine a suitable location.

(3) The engine label information must be written in the English language and use block letters (i.e., sans serif, uppercase characters) except for units of measurement, which may be sans serif, lower-case characters. The characters must be of a color that contrasts with the background of the label.

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

(A) The heading "**EMISSION CONTROL INFORMATION**."

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

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

(ii) Approval under paragraph (4)(B)(i) above does not relieve the engine manufacturer granted an engine family Executive Order of any requirements imposed by these provisions on the applicable engines.

(C) The statement, "**THIS (WATERCRAFT'S ENGINE** or **ENGINE**, as applicable) **IS CERTIFIED TO OPERATE ON** (specify operating fuel(s))."

(D) Identification of the Exhaust Emission Control System (Abbreviations may be used and must conform to the nomenclature and abbreviations provided in the latest revision of the Society of Automotive Engineer's (SAE) procedure J1930, "Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms", and as specified in section 1977, Title 13, California Code of Regulations.

(E) Any specific fuel or engine lubricant requirements (e.g., fuel-oil ratio(s), lead content, research octane number, engine lubricant type).

(F) Date of manufacture (day (optional), month and year).

(G) An unconditional statement of compliance with the appropriate model year California regulations. For example, "**THIS ENGINE CONFORMS TO** (model year) **CALIFORNIA EMISSION REGULATIONS FOR SPARK-IGNITION MARINE ENGINES**." For an engine family certified in California with an FEL different from the FEL assigned federally for the engine family, the following statement shall be appended to the unconditional statement of compliance: **AND IS CERTIFIED TO** (specify FEL) **g/kW-hr** **HC+**NO_x **ENGINE FAMILY EXHAUST EMISSION STANDARD IN CALIFORNIA**."

(H) The engine family identification (i.e., engine family name). The engine family identification shall be in accordance with the current format used by the United States Environmental Protection Agency.

(I) Engine displacement (in cubic centimeters, cubic inches, or liters) of the individual engine upon which the engine label is affixed.

(J) The maintenance specifications and adjustments recommended by the engine manufacturer, including, as applicable: valve lash, ignition timing, idle air/fuel setting procedure and value (e.g., idle speed drop), high idle speed and spark plug gap. These specifications must indicate the proper transmission position, if applicable, during tune-up and what accessories, if any, should be in operation, and what systems, if any (e.g., vacuum advance, battery, air pump), should be disconnected during the tune-up. If the engine manufacturer does not recommend adjustment of the foregoing specifications, the engine manufacturer may substitute in lieu of the specifications, the single statement, "**NO OTHER ADJUSTMENTS NEEDED**." For all engines, the instructions for tune-up adjustments must be sufficiently clear on the engine label to preclude the need for a mechanic or equipment operator to refer to another document in order to correctly perform the adjustments.

(5) If there is insufficient space on the engine to accommodate an engine label that contains all of the information in Subsection (4) above, the Executive eOfficer may allow the engine manufacturer to modify the engine label in one or more of the following ways:

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

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

(C) Exclude the information required by Subsection (4)(F) on the engine label if the date the engine was manufactured is stamped or labeled permanently on the engine (e.g., within the serial number), and this date is readily visible.

(d) For Sterndrive and Inboard Engines used solely for Competition.

Engines manufactured solely for use in sanctioned competition are not required to comply with the emission standards and other requirements. Manufacturers may incorporate the engine label to identify the engines as produced for competition according to the provisions in this subsection.

(1) A legible label must be welded, riveted or otherwise permanently attached by the engine manufacturer to an area of the engine (e.g., block or crankcase) in such a way that it will be readily visible to the average

person after installation of the engine in the watercraft. If such an attachment is not feasible, the Executive Officer may allow the label to be attached on components of the engine or watercraft assembly (as applicable) that satisfy the requirements of Subsection (d)(2). Such labels must be attached on all complete engine assemblies that are produced by an engine manufacturer.

(2) In selecting an acceptable location, the engine manufacturer must consider the possibility of accidental damage (e.g., possibility of tools or sharp instruments coming in contact with the label). Each engine label must be affixed in such a manner that it cannot be removed without destroying or defacing the label, and must not be affixed to any engine (or watercraft, as applicable) part that is likely to be replaced during the engine's (or watercraft's, as applicable) useful life or that is not integral to the engine's operation. The engine label must not be affixed to any engine (or watercraft as applicable) component that is easily detached from the engine. If the engine manufacturer claims there is inadequate space to attach the label, the Executive Officer will determine a suitable location.

(3) The engine label information must be written in the English language and use block letters (i.e., sans serif, uppercase characters) except for units of measurement, which may be sans serif, lower-case characters. The characters must be of a color that contrasts with the background of the label.

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

(A) The heading "**EMISSION CONTROL INFORMATION.**"

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

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

(ii) Approval under paragraph (4)(B)(i) above does not relieve the engine manufacturer granted an engine family Executive Order of any requirements imposed by these provisions on the applicable engines.

(C) Date of manufacture (day (optional), month and year).

(D) An unconditional statement of noncompliance with the appropriate model year California regulations. For example, "**THIS ENGINE DOES NOT CONFORM TO** (model year) **CALIFORNIA EMISSION REGULATIONS FOR SPARK-IGNITION MARINE ENGINES AND MAY NOT BE INSTALLED ON A BOAT FOR ANY PURPOSE OTHER THAN COMPETITION.**"

(E) Engine displacement (in cubic centimeters, cubic inches, or liters) of the individual engine upon which the engine label is affixed.

(~~d~~e) An engine label may state that such engine conforms to any other applicable state or federal emission standards for new spark-ignition marine engines, or any other information that the engine manufacturer deems necessary for, or useful to, the proper operation and satisfactory performance of the engine.

(~~e~~f) Engine identification number. Each engine must have a legible, unique engine identification number permanently affixed to or engraved on the engine.

(~~f~~g) Supplemental Engine Label Content and Location.

(1) When a final engine, equipment, or watercraft assembly that is marketed to any ultimate purchaser is manufactured and the engine label affixed by the engine manufacturer is not readily visible, the manufacturer of the final engine, equipment or watercraft assembly (i.e., original equipment manufacturer) must affix a supplemental engine label upon the engine, equipment or watercraft. The supplemental label must be made of plastic or metal, and must be welded, riveted or otherwise affixed permanently to an area of the engine, equipment or watercraft so as to be readily visible.

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

(3) The supplemental engine label must conform to the engine label requirements in Subsections (c)(3) and (4), except that the date of manufacture specified in Subsection (c)(4)(F) may be deleted from the supplemental engine label. When the date of engine manufacture does not appear on the supplemental engine label, the responsible original equipment manufacturer must display (e.g., label, stamp, etc.) the date elsewhere on the engine, equipment or watercraft so as to be readily visible. The original equipment manufacturer must also display the engine identification number elsewhere on the engine that is readily visible if the original number is obscured by the equipment manufacturer's equipment.

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

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

(~~i~~j) The engine manufacturer must obtain approval from the Executive Officer for all label and engine identification number formats and locations in conjunction with the engine family certification. Approval of specific maintenance settings on labels is not required; however, the format for all such settings and tolerances, if any, is subject to review. If the Executive Officer finds that the information on the label or engine identification number is vague or subject to misinterpretation, or that the location does not comply with these specifications, the Executive Officer may require that the label(s), engine identification number(s) or location(s) be modified accordingly.

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

(kl) The Executive Officer may approve alternate label and engine identification number locations. The Executive Officer may also, upon request, waive or modify the label content requirements provided that the intent of this section is met.

(lm)(1) If the Executive Officer finds any engine manufacturer using labels and engine identification numbers that are different from those approved or do not substantially comply with the readability or durability requirements set forth in these specifications, the engine manufacturer will be subject to revocation or suspension of Executive Orders for the applicable engine families and subject to being enjoined from any further sales, or distribution, of such noncompliant engine families, in the State of California pursuant to section 43017 of the Health and Safety Code. Additional penalties may be assessed to the extent permissible under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

(2) If the Executive Officer finds any original equipment manufacturer using labels for which it has responsibility for attaching that are different from those approved or that do not substantially comply with the readability or durability requirements set forth in these specifications, the equipment manufacturer will be subject to being enjoined from any further sales or distribution, of applicable equipment product line that uses noncompliant labels in the State of California pursuant to section 43017 of the Health and Safety Code. Additional penalties may be assessed to the extent permissible under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the equipment manufacturer, the Executive Officer will consider any information provided by the equipment manufacturer.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.2. Consumer/Environmental Label Requirements.

(a) Purpose. The purpose of this section is to require engine manufacturers to affix a single label on each production spark-ignition marine engine (or watercraft, as applicable) that provides potential engine owners, engine owners, and enforcement personnel with information on the relative cleanliness of the engine under the Air Resources Board's standards.

(b) Applicability. This section applies to:

(1) Model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition sterndrive and inboard marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013;

(2) Federally certified spark-ignition marine engines produced prior to model year 2001 that comply with the emission standards pursuant to section 2442; and

(3) Spark-ignition personal watercraft and outboard marine engines produced prior to model year 2001 and shown by the manufacturer to comply with the emission standards pursuant to section 2442.

(c) If an engine manufacturer has a certified spark-ignition marine engine family to an FEL at or below the exhaust emission standard designated in section 2442(a), Table 1, the engine manufacturer (or equipment/watercraft manufacturer who uses such engines) must label each new engine within the engine family as a compliant engine pursuant to this section. If the engine family fails in-use compliance and/or production line testing and corrective action is not taken within thirty (30) days, the engine manufacturer must cease representation of any engines within the family as compliant engines. In this case, corrective action refers to only physical changes made to bring the engine into compliance with its original FEL. Spark-ignition marine engines as described in paragraph (b)(2) may be labeled pursuant to the provisions of this section before the 2001 model year if such engines comply with Title 40, Code of Federal Regulations, Part 91 [October 4, 1996], which is incorporated herein by reference. Spark-ignition marine engines as described in paragraph (b)(3) may be labeled pursuant to the provisions of this section before the 2001 model year if such engines are tested using certification test procedures plus a thirty (30) percent deterioration factor, as applicable. Alternative demonstrations of emissions performance may be used for engine described in paragraphs (b)(2) and (b)(3) if the engine manufacturer demonstrates to the Executive Officer's satisfaction that the emissions performance is representative of actual emissions for the engine family. Any use of the label described below counter to the requirements set forth herein violates this section and may be subject the engine manufacturer to penalties as permitted by Part 5, Division 26 of the Health and Safety Code.

(1) Facsimiles of the label format are shown in Figure 1.

Figure 1

(NOTE: Labels are not to scale.)

(A) The engine manufacturer must ensure that the label has the following characteristics:

(i) Oval shape;

(ii) Dimensions of no less than three inches wide by two and a half inches high, except that it may be no less than two inches by one and two-thirds inches high for engines that have power outputs of 11.2 kW (15 hp) or less;

(iii) A watermark as shown in Figure 2 that is a clear laminate. The watermark must cover the entire label and be screened at no less than fifteen percent; and

(iv) All written information required by paragraph (c)(4)(B) must be in the English language and the font must be sans serif. The characters must be a minimum of two (2) millimeters in height except as specified in paragraph (b)(1)(B)(i)(d), and of a color that contrasts with the background on which it is displayed.

Figure 2

(B) Multiple levels of cleanliness. Progressively clean engines shall carry the following notations (as applicable):

(i) An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table ~~1~~4 of this section for Tier 1 must include the phrase "**LOW EMISSION**" and a single star symbol as shown in Figure 1.

(ii) An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table ~~1~~4 of this section for Tier 2 must include the phrase "**VERY LOW EMISSION**" and two star symbols as shown in Figure 1.

(iii) An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table ~~1~~4 of this section for Tier 3 must include the phrase "**ULTRA LOW EMISSION**" and three star symbols as shown in Figure 1.

(iv) An engine that has an FEL or that has been certified at or below the hydrocarbon plus oxides of nitrogen standard listed in Table 4 of this section for Tier 4 must include the phrase "**SUPER ULTRA LOW EMISSION**" and four star symbols as shown in Figure 1.

Table ~~1~~4.

Hydrocarbon plus Oxides of Nitrogen Standards (in g/kW-hr)		
Tier	**P < 4.3**	**P ~~>~~≥ 4.3**
1	81.00	$(0.25 \times (151+557/P^{0.9})) + 6.0$
2	64.80	$(0.20 \times (151+557/P^{0.9})) + 4.8$
3	30.00	$(0.09 \times (151+557/P^{0.9})) + 2.1$
4	5.0	5.0

Where P means the average power in kW (sales-weighted) of the subject engine family.

(iv) All phrases encircling the top portion must have block characters that are a minimum of five (5) millimeters in height except that the characters may be three (3) millimeters for labels sized as allowed pursuant to paragraph (c)(1)(A)(i) for engines that have power outputs of 11.2 kW (15 hp) or less.

(C) Language other than that specified in paragraph (b)(1)(B) must not be used unless permitted by the Executive Officer.

(D) The color of the outer oval and stars on the label must contrast with the engine cover or watercraft hull. The color of the interior oval (i.e., background for the stars) must contrast with the color of the outer oval and stars.

(2) Label location. For outboard engines, a single label must be permanently affixed to the back of the engine cover or cowling. For personal watercraft, sterndrives and inboards, a single label must be affixed two or three inches to the right of the required location of the California Assigned Vessel Number displayed on the port side of the hull. Each label must be manufactured and permanently affixed so that it cannot be removed without destroying or defacing the label, must be readily visible and must not be affixed to any location that is likely to be replaced during the engine's useful life. For the purposes of this paragraph, readily visible means that the label's shape and number of stars are discernable from a distance of 100 feet.

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

(4) (A) Labels must be affixed to new watercraft or engines by the engine manufacturer or the original equipment manufacturer. If affixed by the original equipment manufacturer, the engine manufacturer remains the ultimate party responsible for ensuring that the labels are correctly administered. Improper labeling or distributing of labels will subject the engine manufacturer to penalties as described in paragraph (h).

(B) Labels on engines or watercraft described in paragraphs (b)(2) and (b)(3) may be applied by either the engine manufacturer, the original equipment manufacturer, distributors or dealers. However, the engine manufacturer remains the ultimate party responsible for ensuring that the labels are correctly administered. Improper labeling or distributing of labels will subject the engine manufacturer to penalties as described in paragraph (h). If the labels are applied by the distributor or dealer, the engine manufacturer must include its name and a serial number on the lower portion of the label as shown in Figure 1. The format of the serial number will be two alpha characters followed by five numeric characters (e.g., AA12345). The serial numbers must be recorded by the distributor or dealer and reported to the manufacturer of the engine when installed on a pre-2001 model year watercraft or engine. These numbers must be made available to the Executive Officer upon request.

(d) If the engine or watercraft cannot be adequately labeled under the requirements of paragraph (c), the engine manufacturer may request modification of these requirements from the Executive Officer.

(e) Replacement engines installed in hulls, cowlings or watercraft that had been previously labeled in accordance with these specifications must have identical or improved emissions to that of the original certified engine.

(f) Samples of all labels produced pursuant to this section must be submitted to the Executive Officer with the applicable certification application.

(g) Engines that are labeled in accordance with this section and subsequently modified with add-on or modified parts that are not exempted by the Executive Officer, are subject to label removal by an ARB Enforcement Officer or other authorized party.

(h) If the Executive Officer finds any engine manufacturer using labels for which it has responsibility for attaching that are different from those approved or that do not substantially comply with the discernibility or durability requirements set forth in these specifications, the engine manufacturer will be subject to being enjoined from any further sales or distribution, of applicable equipment product line that uses noncompliant labels in the State of California pursuant to section 43017 of the Health and Safety Code. If the Executive Officer finds any engines or watercraft with labels that are not affixed in accordance with paragraph (c)(1)(B), the engine manufacturer must remove the labels from all affected watercraft and engines and will be subject to being enjoined from any further sales or distribution, of applicable equipment product line that uses noncompliant labels in the State of California pursuant to section 43017 of the Health and Safety Code. Additional penalties may be assessed to the extent permissible under Part 5, Division 26 of the Health and Safety Code. Before seeking remedial action against the engine or equipment manufacturer, the Executive Officer will consider any information provided by the engine or equipment manufacturer.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2443.3. Environmental Label/Consumer Notification Requirements.

(a) Applicability. This section applies to model year 2001 and later spark-ignition personal watercraft and outboard marine engines and model year 2003 and later spark-ignition sterndrive and inboard marine engines, which have been certified to the applicable emission standard pursuant to Health and Safety Code section 43013.

(b) A nonpermanent label (i.e., hang tag) must be attached to each engine or watercraft, as applicable, at time of sale that includes a copy of the following:

Front of Hang Tag:

“

The Star Label means Cleaner Marine Engines

This engine has been certified as a:

☐ ☒ ☐ ☐

(<Check appropriate box.>)

The Symbol for Cleaner Marine Engines:

Cleaner Air and Water – for a healthier lifestyle and environment.

Better Fuel Economy – burns up to 30-40 percent less gas and oil than conventional carbureted two-stroke engines, saving money and resources.

Longer Emissions Warranty – protects consumer for worry free operation.

“

Back of Hang Tag:

"

<facsimile of the one-star label>

One Star – Low Emission
The one-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2001 exhaust emission standards. Engines meeting these standards have 75% lower emissions than conventional carbureted two-stroke engines. These engines are equivalent to the U.S. EPA's 2006 standards for marine engines.

<facsimile of the two-star label>

Two Stars – Very Low Emission
The two-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2004 exhaust emission standards. Engines meeting these standards have 20% lower emissions than One Star – Low-Emission engines.

<facsimile of the three-star label>

Three Stars – Ultra Low Emission
The three-star label identifies engines that meet the Air Resources Board's Personal Watercraft and Outboard marine engine 2008 exhaust emission standards or the Sterndrive and Inboard marine engine 2003-2008 exhaust emission standards. Engines meeting these standards have 65% lower emissions than One Star – Low Emission engines.

<facsimile of the four-star label>

Four Stars – Super Ultra Low Emission
The four-star label identifies engines that meet the Air Resources Board's Sterndrive and Inboard marine engine 2009 exhaust emission standards. Personal Watercraft and Outboard marine engines may also comply with these standards. Engines meeting these standards have 90% lower emissions than One Star – Low Emission engines.

<White Space for dealer or manufacturer identification or additional information>

Cleaner Watercraft – Get the Facts
1-800-END-SMOG
www.arb.ca.gov

"

(1) Facsimiles of the ~~three~~four environmental labels, as described in section 2443.2(c)(1), with the appropriate label circled or otherwise identified as being applicable to the spark-ignition marine engine, must be displayed on the nonpermanent label. Each facsimile must have dimensions no less than one inch by four-fifths inch.

(2) For outboard engines greater than 130 horsepower, facsimiles of only the "Low Emission Engine" and "Very Low Emission Engine" labels described in sections 2443.2 (c)(1)(B)(i) and (ii) need to be displayed on the nonpermanent label until the earlier of:

(A) the 2004 model year; or

(~~b~~B) the first model year after the date the ARB certifies the first outboard engine family greater than 130 horsepower to the 2008 model year standards.

(3) For personal watercraft, facsimiles of only the "Low Emission Engine" and "Very Low Emission Engine" labels described in sections 2443.2(c)(1)(B)(i) and (ii) need to be displayed on the nonpermanent label until the earlier of:

(A) the 2004 model year; or

(~~b~~B) the first model year after the date the ARB certifies the first personal watercraft engine family to the 2008 model year standards.

(4) All textual information (i.e., characters and/or lettering) required by this section must be no smaller than two (2) millimeters in height.

(c) The information required by paragraph (b) must also be provided in the owner's manual and in the engine manufacturer's application for certification.

(d) Samples of all labels produced pursuant to this section must be submitted to the Executive Officer with the applicable certification application.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2444.1. In-Use Compliance Testing and Recall Regulations – Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) Applicability. This section applies to model year 2001 and later spark-ignition marine engines, which have been certified to the applicable emission standards pursuant to Health and Safety Code section 43013. Spark-ignition sterndrive and inboard marine engines shall comply with the in-use testing requirements found in title 13, California Code of Regulations, sections 2111, et seq.

(b) Manufacturer In-Use Compliance Test Procedures.

(1) For the purposes of this section, the Air Resources Board will accept emission data collected from the in-use testing program implemented by the United States Environmental Protection Agency as specified in Title 40, Code of Federal Regulations, section 91.803 [October 4, 1996], which is incorporated herein by reference.

(2) The Executive Officer, may, upon notice to the engine manufacturer and after review of the engine families identified by the United States Environmental Protection Agency for federal in-use testing, prescribe that a California-specific in-use testing program be conducted pursuant to paragraph (b)(3) at the engine manufacturer's expense if:

(A) The results obtained from the federal in-use test program pursuant to paragraphs (b)(1) of this section are determined not to be representative of engines sold and operated in California; or,

(B) The necessity is supported by other data or information (e.g., California-only engine families).

(3) California In-Use Testing Program.

(A) The Executive Officer shall identify engine families and those configurations within families offered for sale in California that the engine manufacturer must then subject to in-use testing for the specified model year. The number of engine families identified shall not exceed 25 percent of the engine manufacturer's families offered for sale in California. The Executive Officer may allow for reduced testing upon the engine manufacturer's demonstration of consistent compliance with the applicable emission standards.

(B) Number of Engines to be Tested. The number of engines to be tested by an engine manufacturer must be determined by the following method:

(i) A minimum of two (2) engines per family provided that no engine fails any standard. For each failing engine, two (2) more engines must be tested until the total number equals ten.

(ii) For engine families of less than 50 engines (California sales) for the identified model year or for engine manufacturers who make less than or equal to 200 engines (California sales) for that model year, a minimum of one engine per family provided that this engine does not fail any standard. If this engine fails, two (2) more engines shall be tested. For each additional engine failure, the engine manufacturer must continue testing two (2) additional engines until the total number equals eleven.

(iii) If an engine family was certified using carryover emission data and has been previously tested under paragraph (b)(3)(B) without an ordered recall, then only one engine for that family must be tested. If this engine fails any standard, testing must be conducted as outlined in paragraphs (b)(3)(B), as applicable.

(C) At the discretion of the Executive Officer, an engine manufacturer may test more engines than the minimums described in paragraph (b)(3)(B) or may concede failure before testing a total of ten engines.

(D) The Executive Officer will consider failure rates, average emission levels and the existence of any defects among other factors in determining whether to pursue remedial action under this subsection. The Executive Officer may request an ordered recall pursuant to paragraph (e)(2).

(E) The Executive Officer may approve an alternative to engine manufacturer in-use testing where:

(i) engine family production in California is less than or equal to 20 per year; or

(ii) engines cannot be obtained for testing because they are used substantially in watercraft that are not conducive to engine removal such as large watercraft where the engine cannot be removed without dismantling either the engine or the watercraft; or

(iii) other compelling circumstances associated with the structure of the industry and uniqueness of spark-ignition marine engine applications. Such alternatives shall be designed to determine whether the engine family is in compliance in-use.

(F) Collection of In-Use Engines. The engine manufacturer shall procure in-use engines that have been operated between half and three-quarters of the engine's useful life. For purposes of paragraph (b) only, "useful life" means ten (10) years or 350 hours of operation for outboard engines and five (5) years or 350 hours of operation for personal watercraft engines. The engine manufacturer may test engines from more than one model year in a given year. The engine manufacturer shall begin testing within twelve (12) months after receiving notice that the Executive Officer has identified a particular engine family for testing and shall complete testing within twelve months from the start of such testing. Test engines may be procured from sources associated with the engine manufacturer (i.e., manufacturer-established fleet engines, etc.) or from sources not associated with the engine manufacturer (i.e., consumer-owned engines, independently-owned fleet engines, etc.).

(G) Maintenance, Procurement and Testing of In-Use Engines.

(i) A test engine must have a maintenance and use history representative of actual in-use conditions.

~~(a)~~a. The engine manufacturer must obtain information from the end users regarding the accumulated usage, maintenance, operating conditions and storage of the test engines.

~~(b)~~b. Documents used in the procurement process must be maintained as required by section 30 of the Test Procedures.

(ii) The engine manufacturer may perform minimal "set-to-specification" maintenance on components of a test engine that are not subject to parameter adjustment. Maintenance may include only that which is listed in the owner's manual for test engines with the amount of service and age of the acquired engine. Documentation shall be maintained and retained as required by section 30 of the Test Procedures.

(iii) At least one valid emission test, performed according to the test procedures outlined in Part IV of the Test Procedures is required for each in-use engine.

(iv) The Executive Officer may waive portions or requirements of the test procedures, if any, that are not necessary to determine in-use compliance.

(v) If a selected in-use engine fails to comply with any applicable emission standard, the engine manufacturer must determine the reason for noncompliance. The engine manufacturer must report all such reasons of noncompliance within fifteen days of completion of testing.

(c) Reports and Evaluation.

(1) The engine manufacturer must maintain and submit sufficient records to the Executive Officer within three months of completing testing from the in-use program. These records must include, but need not be limited to, the following for each test engine:

(A) Engine family.
(B) Engine model.
(C) Engine identification (or serial) number.
(D) Date of manufacture.
(E) Estimated hours of use.
(F) Date and time of each test attempt.
(G) Results (if any) of each test attempt.
(H) Results of all emission testing.
(I) Summary of all maintenance and/or adjustments performed.
(J) Summary of all modifications and/or repairs.
(K) Determinations of noncompliance and probable causes of failure.
(L) Description of operating and storage conditions.

(2) If the results of the in-use emission tests indicate that the average emissions of the test engines for any regulated pollutant exceed the applicable emission standards specified in Title 13, California Code of Regulations, section 2442, the entire engine population so represented shall be deemed to exceed the standards. The Executive Officer shall notify the engine manufacturer of the test results and upon receipt of the notification, the engine manufacturer has 45 days to submit a plan to

make up all excess emissions resulting from in-use testing non-compliance in accordance with paragraph (c)(3). If excess emissions cannot be made up in accordance with paragraph (c)(3), the engine manufacturer must implement a voluntary recall plan in accordance with the applicable portions of paragraphs (d) and (e). If no excess emissions cannot be made up in accordance with paragraph (c)(3) and the engine manufacturer does not implement a voluntary recall plan, the Executive Officer may prescribe the implementation of an ordered recall pursuant to the applicable portions of paragraph (e)(2).

(3) All excess emissions resulting from in-use noncompliance with the California standard must be made up in the model year following the model year in which the notification of noncompliance is received. In-use noncompliance may not be remedied through implementation of the federal in-use credit program described in Title 40, Code of Federal Regulations, Part 91, Subpart N [October 4, 1996]. As an alternative to recall and with prior approval from the Executive Officer, the engine manufacturer may make up the excess emissions by any one or combination of the following options:

(A) Recertification of the noncompliant engine family to a lower emission level (or higher FEL) that makes up for the noncompliance, while maintaining compliance on a corporate average basis;

(B) Implementation of a running change and/or field fix on the noncompliant engine family;

(C) Implementation of market-based incentives, to be approved by the Executive Officer, to make up the noncompliance; or

(D) Payment of a noncompliance penalty to be determined by the Executive Officer on a per engine basis as provided by Part 5, Division 26 of the Health and Safety Code.

(d) Voluntary Emission Recalls.

(1) When an engine manufacturer initiates a voluntary emission recall campaign, the Executive Officer shall be notified of the recall at least thirty (30) days before owner notification is to begin. The engine manufacturer shall also submit a voluntary recall plan for approval, as described in paragraph (e) below. A voluntary recall plan shall be deemed approved by the Executive eOfficer within thirty (30) days after receipt of the recall plan unless objected to in the interim.

(2) (A) When any engine manufacturer, based on enforcement test results or any other information provided to or required by the ARB, proposes to initiate a voluntary emission recall program, the engine manufacturer shall submit for approval by the Executive Officer an emission recall plan as described in paragraph (e) below. The plan shall be submitted within 45 days following the receipt of a notification from the ARB that enforcement test results or other information demonstrate an engine noncompliance.

(B) The Executive Officer shall approve the recall plan in writing if it contains the information specified in paragraph (e) where specified and is designed to notify the engine/watercraft owner and correct the noncompliance in an expeditious manner. Notification of engine/watercraft owners and the implementation of recall repairs shall commence no later than the schedule specified under paragraph (e)(1)(C) and (e)(1)(D), respectively, unless the engine manufacturer can show good cause for the Executive Officer to extend the deadline. If the plan does not contain the provisions of paragraph (e), the Executive Officer shall disapprove the plan in writing and require revisions where deemed necessary. The engine manufacturer may contest such a disapproval by requesting a hearing pursuant to Subchapter 1.25, Title 17, California Code of Regulations. If no request for a hearing is made or the hearing upholds the disapproval, the engine manufacturer shall incorporate all requested revisions to the plan and begin implementation of the recall plan within sixty (60) days of receipt of the disapproval.

(C) The engine manufacturer may also request a public hearing pursuant to the procedures set forth in Subchapter 1.25, Title 17, California Code of Regulations to contest the finding of nonconformity and the need for an ordered recall. If such a hearing occurs and the nonconformity is confirmed therefrom, the engine manufacturer shall submit the recall plan required by paragraph (e)(2) within thirty (30) days after receipt of the Board's decision unless an extension is granted by the Executive Officer.

(e) Voluntary and Ordered Recall Plans.

(1) The recall plan for voluntary and ordered recalls must be submitted to the Executive Officer for review and must contain the following information unless otherwise specified:

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

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

(C) A description of the method by which the engine manufacturer will notify engine/watercraft owners;

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

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

(F) A description of the system by which the engine manufacturer will assure that an adequate supply of parts is available to perform the repair under the plan, including the date by which an adequate supply of parts will be available to initiate the repair campaign, and the method to be used to assure the supply remains both adequate and responsive to engine/watercraft owner demand.;

(G) A copy of the letter of notification to be sent to engine/watercraft owners; and

(H) A copy of all necessary instructions to be sent to those persons who are to perform the repair;.

(2) For an ordered recall, the recall plan shall include the information required for voluntary recall plans as specified in paragraphs (e)(1). Additionally, it shall include the following:

(A) A plan describing how the maximum feasible capture rate will be achieved for recalls based on either the exceedance of emission standard or on the failure of an emission-related component.

(B) The plan shall also include a schedule for implementing actions to be taken including identified increments of progress towards implementation and deadlines for completion of each increment. If, after good faith efforts, the engine manufacturer cannot reach the maximum feasible capture rate by the applicable deadline, the engine manufacturer must propose mitigation efforts to be approved by the Executive Officer that will offset the emissions of the unrepaired engines.

(3) The engine manufacturer must not condition repair of the noncomplying engine/watercraft on the proper maintenance or use of the engine except for compelling reasons approved by the Executive Officer. The engine manufacturer, however, is not obligated to repair a component which has been removed or modified.

(4) Record keeping and Reporting Requirements.

(A) The engine manufacturer shall report on the progress of the voluntary or ordered recall program by submitting a report one year from the date owner notification begins and a final report an additional year later. Such reports shall be submitted to the Chief, Mobile Source Operations Division, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA 91734-8001. For each class of engine subject to the recall program, the yearly report shall contain:

(i) Engine family and emission recall campaign number designated by the engine manufacturer.

(ii) Date engine/watercraft owner notification was begun, and date completed.

(iii) Number of engines involved in the voluntary or ordered recall campaign.

(iv) Number of engines known or estimated to be affected by the nonconformity and an explanation of how this number was determined.

(v) Number of engines inspected pursuant to the voluntary or ordered recall plan.

(vi) Number of inspected engines found to be affected by the nonconformity.

(vii) Number of engines receiving repair under the recall plan and a listing of these engines' engine identification numbers.

(viii) Number of engines determined to be ineligible for recall action due to removed or modified parts.

(ix) A copy of any service bulletins transmitted to dealers or other authorized repair facilities which pertain to the nonconformity to be corrected and that have not previously been reported.

(x) A copy of all communications transmitted to engine/watercraft owners that relate to the nonconformity and that have not previously been submitted.

(B) If the engine manufacturer determines that any of the information submitted pursuant to paragraph (5)(A) above has changed or was incorrect, revised information and an explanation must be submitted. Responses to subsections ~~(5)~~(4)(A)(v), (vi), (vii), (viii) and (ix) above shall be cumulative totals.

(C) The engine manufacturer shall maintain the names and addresses of engine/watercraft owners:

(i) To whom notification was given;

(ii) Whose engines were repaired or inspected under the recall plan; and

(iii) Whose engines were determined not to qualify for repair due to removed or modified components.

(D) All reports shall be maintained for not less than one year beyond the useful life of the engines and shall be made available to authorized personnel of the ARB upon request.

(f) Penalties. Under an ordered recall, failure of the engine manufacturer to notify engine/watercraft owners and repair the engines in the manner specified in the recall plan constitutes a violation of Health and Safety Code section 43105 and subjects the engine manufacturer to penalties pursuant to Part 5, Division 26 of the Health and Safety Code.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2444.2. On-Board Engine Malfunction Detection System Requirements – Model Year 2007 and Later Spark-Ignition Sterndrive and Inboard Marine Engines.

Beginning with 2007 model year spark-ignition sterndrive and inboard marine engines certified to the 5.0 grams per kilowatt-hour $HC+NO_x$ standard, the requirements for subsections (a) through (k) below shall be implemented as follows. For all 2009 model year and later spark-ignition sterndrive and inboard marine engines, requirements in **bold type** will also apply.

Diagnostic systems shall, at a minimum, comply with the requirements of Title 13, section1968, "Malfunction and Diagnostic System for 1988 and Subsequent Model Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles with Three-Way Catalyst Systems and Feedback Control," California Code of Regulations, except as otherwise stipulated below.

(a) General requirements.

(1) Spark-ignition sterndrive and inboard marine engines sold as new shall be equipped with an on-board diagnostics-marine (OBD-M) system to identify emission-related malfunctions by means of diagnostic trouble codes stored in non-volatile computer memory. Emission-related malfunctions are not limited to emission control components and systems only, but to any other electronic component or system that can affect emissions including the on-board computer itself. Additionally, OBD-M systems shall have the capability to activate an audio or visual alert device located on the marine vessel to inform vessel occupants in the event of emission-related malfunctions, and to transmit diagnostic information locally via a standardized data link connector.

(2) Spark-ignition sterndrive and inboard marine vessels shall be equipped with an audio alert device and/or visual alert device that is compatible with the activation function of the OBD-M system on the installed engine.

(A) If equipped, the audio alert device shall provide sufficient volume and intensity to be readily perceptible to vessel occupants during virtually any mode of vessel operation and occupant activity, but shall not exceed applicable maximum noise levels as set by authorized federal or State agencies. Further, the audio alert device shall in no way impede the function of required sound-signaling devices, or other safety-related devices, already present on the vessel. The audio alert device shall sound briefly at reduced-volume in the engine-run key position during engine cranking to indicate that the audio alert device is functional and shall, when activated, emit a periodic series of five full-volume bursts separated by no more than a two second interval between bursts and fifteen minutes between series. **Notwithstanding, the audio alert device shall emit a pulsating full-volume burst at one-second intervals during the detection of severe misfire that can cause damage to the catalytic converter.**

(B) If equipped, the visual alert device shall provide sufficient activation and be located such that it is readily visible under all lighting conditions, but shall in no way impede the function of any visual distress-signaling device, fog signal, or navigational light. The visual alert device shall activate in the engine-run key position before engine cranking to indicate that the visual alert device is functional and shall, when activated, display the phrase "Service Required." Alternatively, the International Standards Organization (ISO) engine symbol may be substituted for the phrase. **Notwithstanding, the visual alert device shall blink at one-second intervals during the detection of severe misfire that can cause damage to the catalytic converter.**

(3) Malfunction thresholds for catalyst, **misfire**, fuel system, oxygen sensor, and oxygen sensor heater diagnostics shall be determined by the engine manufacturer such that emissions do not exceed applicable emission certification standards, based on the Spark-Ignition Marine Engine test cycle, by more than 50 percent before the malfunction thresholds have been reached. Malfunction thresholds for other monitored components and systems shall not be limited to a percent increase above the standards, but shall be determined by the engine manufacturer to indicate when components or systems are no longer operating within design tolerances.

(4) Regarding diagnostic system monitoring and audio/visual alert device activation requirements, engine manufacturers are required to define monitoring conditions that are representative of typical in-use operation, and which will result in the routine execution and completion of all IMDN diagnostics in-use. With the exception of **misfire**, fuel system, and comprehensive component monitoring, these conditions shall occur within a steady-state window of operation defined by throttle position, delta throttle, engine load, and temperature. Within this window, monitors are required to execute, at least once per operating cycle, regardless of other operating conditions. A monitor must be enabled continuously while operating within the window; however, operation over the entire window shall not be permitted as a condition for monitoring completion. Further, all steady-state monitoring conditions must be designed such that they will be encountered below eighty-five percent of full throttle. Subject to Executive Officer approval, engine manufacturers may request the

inclusion of other monitoring conditions to define the window of operation in the event a suitable environment to reliably diagnose a particular monitoring strategy has not been provided. In approval of the request, the Executive Officer shall consider the extent to which the use of additional conditions provide for more effective and frequent in-use monitoring during normal operation. **Misfire,** fuel system, and comprehensive component monitors shall not be limited to steady-state windows of operation, but shall function continuously throughout the operating cycle. Upon detection of a malfunction, except as noted in paragraphs (a)(2)(A) and (a)(2)(B) above, the audio/visual alert device is to be activated and a diagnostic trouble code stored no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again detected.

(5) For model years 2007-2008, activation of the audio/visual alert device upon detection of a catalyst, fuel system, or oxygen sensor or heater malfunction shall be optional. The audio/visual alert device activation for these model years shall be mandatory for other monitoring requirements. The audio/visual alert device shall be activated during these model years for lack of function for electronic components/systems otherwise approved for audio/visual alert device suppression. Furthermore, there are no exemptions from storing diagnostic trouble codes in non-volatile computer memory during these model years for any malfunction. The OBD-M must be capable of fully communicating stored information to a generic scan tool via the standardized data link connector.

(6) Engine manufacturers may employ alternate statistical audio/visual alert device activation and diagnostic trouble code storage protocols to those specified in these requirements, subject to Executive Officer approval, based on comparable timeliness in detecting a malfunction and evaluating system performance. For strategies requiring, on average, between three and six operating cycles for audio/visual alert device activation, the engine manufacturer shall provide data and/or an engineering evaluation which adequately demonstrate that the monitoring system is equally effective and timely in detecting deterioration. Strategies requiring on average more than six operating cycles for audio/visual alert device activation shall not be accepted.

(7) Should emission control devices/strategies be introduced on the engine in addition to those identified herein as requiring monitoring (e.g., exhaust gas recirculation), engine manufacturers shall submit a plan for Executive Officer approval of the monitoring strategy and malfunction thresholds prior to its incorporation into the OBD-M system. Executive Officer approval shall be based on the effectiveness of the monitoring strategy, the malfunction criteria utilized, and the frequency at which the monitoring conditions required by the diagnostic occur while in-use.

(8) Engine manufacturers may request Executive Officer approval to disable any diagnostic strategy at ambient engine starting temperatures below twenty degrees Fahrenheit (low ambient temperature conditions may be determined based on intake air or engine coolant temperature at engine starting), and at elevations above eight thousand feet above sea level provided the engine manufacturer submits data and/or an engineering evaluation which adequately demonstrate that monitoring would be unreliable when such conditions exist. Notwithstanding, diagnostic system disablement may be requested at other ambient engine starting temperatures if the engine manufacturer adequately demonstrates with data and/or an engineering evaluation that misdiagnosis would occur due to the impact of such ambient temperatures on the performance of the component itself (e.g., component freezing).

(9) Engine manufacturers may disable monitoring systems that can be affected by running out of fuel (e.g., misfire detection) when the fuel level is low, provided disablement will not occur when the fuel level is above fifteen percent of the nominal capacity of the fuel tank.

(10) Engine manufacturers shall not be required to individually monitor the positive crankcase ventilation system or the engine thermostat unless these devices are specifically used to enable the execution of other IMDN diagnostics.

(b) Monitoring requirements.

(1) Catalyst monitoring.

(A) Purpose and scope:

(i) The diagnostic system shall monitor the catalyst system on spark-ignited marine engines for proper combined conversion efficiency of hydrocarbons and oxides of nitrogen ($HC+NO_x$).

(ii) Manufacturers of spark-ignited lean-burn marine engines may request that the Executive Officer exempt such applications from these catalyst monitoring requirements if it can be demonstrated that a reliable monitoring technology is not available. The Executive Officer shall approve such a request upon determining that all reasonable monitoring technologies have been considered to the extent possible.

(B) Malfunctioning criteria:

(i) The catalyst system shall be considered malfunctioning when its conversion efficiency decreases to the point that $HC+NO_x$ tailpipe emissions exceed the applicable $HC+NO_x$ certification standard by more than 50 percent, adjusted upward by the $HC+NO_x$ emissions from a representative 20 hour catalyst system (i.e., $[HC+NO_x]_{tailpipe} \geq 150\% \times [HC+NO_x]_{standard} + [HC+NO_x]_{20hour}$). All emissions measurements and standards are in reference to the spark-ignition marine engine test cycle.

(ii) Through the 2008 model year, as an option to setting malfunction thresholds by relating tailpipe emissions to a percent increase over applicable standards, engine manufacturers may specify relative malfunction thresholds based on a percent reduction of post-catalyst $HC+NO_x$ concentration compared to pre-catalyst $HC+NO_x$ concentration. In accordance with this provision, manufacturers may monitor the front catalyst independently of, or in combination with, the next catalyst downstream. Each monitored catalyst or catalyst combination shall be considered malfunctioning when total $HC+NO_x$ conversion efficiency falls below 60 percent while in normal closed loop operation. As a guideline, the catalyst(s) should not be considered malfunctioning when its efficiency is greater than 80 percent. The efficiency determination shall be based on a steady state test, wherein a malfunction is noted when the total $HC+NO_x$ emission concentration measured at the outlet of the monitored catalyst(s) is more than 20 to 40 percent of the cumulative total engine-out emissions measured at the inlet of the catalyst(s).

(iii) For artificially heated catalyst systems (electric, heat exchanger, etc.), the heating mechanism shall be considered malfunctioning when the catalyst does not reach its designated heating temperature within a requisite time period after engine starting. The time period is to be determined by the manufacturer subject to the conditions that it is representative of typical in-use operation and that it is sufficient to detect a heating system malfunction causing emissions to exceed the applicable $HC+NO_x$ certification standard by more than 50 percent.

(C) Monitoring conditions:

(i) The engine manufacturer shall choose a steady-state window of operation defined by throttle position, delta throttle, engine load, and temperature for monitoring the catalyst with the constraints that the check shall:

a. occur within a ± 15 percent throttle position window between 25 percent and 85 percent of full throttle, or at idle should a catalyst warm-up temperature profile strategy be employed,

b. be tolerant of throttle position fluctuations or changes less than 1 percent per second over any two second interval within the throttle position window,

c. take no more than a 40-second interval to determine both that the engine is operating in a proper window to perform the check and to actually perform the check, and

d. be conducted at the earliest acceptable opportunity encountered after the beginning of each operating cycle.

Performance of the check may be delayed after engine startup until stabilized coolant temperature is achieved and/or a suitable cumulative time interval of non-closed throttle engine operation has elapsed to ensure the catalyst is warmed-up for properly performing the monitoring check. The specified cumulative time interval shall begin from the first non-closed throttle operation either after achieving a stabilized coolant temperature or after engine starting and shall not exceed 180 seconds. These monitoring constraints and conditions may be altered, subject to Executive Officer approval. Such approval shall be granted if the engine manufacturer submits data and an engineering evaluation that, together, justify the need for the exception and demonstrate that the requested alteration would yield improved catalyst monitoring.

(ii) The monitoring system shall operate at least once per in-use operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(D) Malfunctioning notification and diagnostic trouble code storage:

(i) Upon detection of a catalyst malfunction, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again present.

(ii) The diagnostic system shall temporarily disable catalyst monitoring when a malfunction exists that could affect the proper evaluation of catalyst efficiency.

(iii) The monitoring method for the catalyst(s) shall be capable of detecting when a catalyst trouble code has been cleared (except diagnostic system self-clearing), but the catalyst has not been replaced (e.g., catalyst overtemperature approaches may not be acceptable).

(2) Misfire monitoring.

(A) Purpose and scope: The diagnostic system shall monitor for engine misfire. The diagnostic system does not have to identify the misfiring cylinder(s), however misfire must be identified regardless of whether it occurs in a single or multiple number of cylinders.

(B) Malfunctioning criteria: The diagnostic system shall identify a malfunction when the total number of misfires exceeds a percentage of the total number of firing events necessary for satisfying the conditions listed below. These threshold percentages shall be determined by the engine manufacturer and provided in the certification documentation.

(i) The percent misfire evaluated in 200 crankshaft-revolution increments for each engine speed and load condition that would result in catalyst damage. Subject to Executive Officer approval, a longer interval may be employed (but only for determining, on a given operating cycle, the first misfire exceedance in paragraph (b)(2)(D)(i)(a) below) provided the engine manufacturer submits data and/or an engineering evaluation which adequately demonstrate that catalyst damage would not occur due to unacceptably high catalyst temperatures before the interval has elapsed. The engine manufacturer shall submit in the certification documentation catalyst temperature data versus percent misfire over the full range of engine speed and load conditions. The data shall be obtained from a representative cross section of an engine manufacturer's engine offerings from small to large displacements. Up to three such engine evaluations shall be documented per engine manufacturer, though an engine manufacturer may submit more data if desired. An engineering evaluation shall be provided for establishing malfunction criteria for the remainder of engine families in the engine manufacturer's product line. The Executive Officer shall waive the evaluation requirement each year if, in the judgment of the Executive Officer, technological changes do not affect the previously determined malfunction criteria;

(ii) The percent misfire evaluated in 1000 crankshaft-revolution increments that would cause emissions from an aged engine (480 hours) to exceed any of the spark-ignition marine engine test cycle-based standards by more than 50 percent if the degree of misfire were present from the beginning of the test. Subject to Executive Officer approval, an engine manufacturer may employ other crankshaft-revolution increments if the engine manufacturer adequately demonstrates that the strategy is equally effective and timely in detecting misfire. For the purpose of establishing the percent misfire, the engine manufacturer shall conduct the demonstration test(s) with the misfire events occurring at equally spaced complete engine cycle intervals, across randomly selected cylinders throughout each 1000 crankshaft-revolution increment. However, the percent misfire established shall be applicable for any misfire condition (e.g., random, continuous, equally-spaced, etc.) for the purpose of identifying a malfunction. This criterion may be used for all engines containing the same number of cylinders as the aged engine. The number of misfires in 1000 crankshaft-revolution increments that was determined for the aged engine malfunction criterion may be used to establish the corresponding percent misfire malfunction criteria for engines with other numbers of cylinders. The malfunction criteria for an engine manufacturer's product line shall be updated when an aged engine is tested and subsequently indicates that more stringent criteria are necessary than previously established to remain within the above emission limit.

(C) Monitoring conditions:

(i) Except as provided for in paragraph (ii) below, monitoring for misfire shall be continuous from engine starting under all positive torque engine speeds and load conditions.

(ii) As an exception to monitoring misfire during all positive torque operating conditions, engine manufacturers may disable misfire monitoring in the engine operating region bound by the positive torque line (i.e., engine load with the transmission in neutral), and the two following engine operating points:

a. an engine speed of 3000 rpm with the engine load at the positive torque line; and

b. the redline engine speed (defined in section 2441) with the engine's manifold vacuum at four inches of mercury lower than that at the positive torque line.

Misfire detection systems unable to detect all misfire patterns under all required conditions shall be evaluated for compliance by the Executive Officer based on, but not limited to, the following factors:

c. the magnitude of the region(s) in which misfire detection is limited,

d. the degree to which misfire detection is limited in the region(s) (i.e., the probability of detection of misfire events),

e. the frequency with which said region(s) are expected to be encountered in-use,

f. the type of misfire patterns for which misfire detection is troublesome, and

g. demonstration that the monitoring technology employed is not inherently incapable of detecting misfire under required conditions (i.e., compliance can be achieved on other engines).

The evaluation shall be based on the following misfire patterns:

h. equally spaced misfire occurring on randomly selected cylinders,

i. single cylinder continuous misfire; and

j. paired cylinder (cylinders firing at the same crank angle) continuous misfire.

Further, with Executive Officer approval, the engine manufacturer may disable misfire monitoring or employ higher malfunction criteria when misfire cannot be distinguished from other effects (e.g., ocean bounce) when using the best available monitoring technology. The engine manufacturer shall present data and/or an engineering evaluation to the Executive Officer to justify the proposed action. Executive Officer approval shall be based on the extent to which monitoring is expected to be disabled in relation to the capabilities of the best available monitoring technologies as applied to other engines. However, any such disablement occurring within the first 5 seconds after engine starting shall not require Executive Officer approval. Additionally, for engines with greater than eight cylinders, the Executive Officer shall waive the requirements of this section provided the engine manufacturer submits data and/or an engineering evaluation which adequately demonstrates that misfire detection throughout the required operating region cannot be achieved when employing proven monitoring technology (i.e., a technology that provides for compliance with these requirements on other engines) and provided misfire is detected to the fullest extent permitted by the technology.

(D) Malfunction notification and diagnostic trouble code storage:

(i) Upon detection of the level of misfire specified in paragraph (b)(2)(B)(i), the following criteria shall apply for audio/visual alert device activation and diagnostic trouble code storage:

a. A temporary diagnostic trouble code shall be stored and the audio/visual alert device shall activate once-per-second during actual misfire conditions no later than after the third exceedance of the specified misfire level when operating in the region bound by modes 2 through 5 of the spark-ignition marine engine test cycle and no later than after the first exceedance of the specified misfire level when operating at any other engine speed and load condition during a single operating cycle. While a temporary diagnostic trouble code is stored, the audio/visual alert device shall activate during every subsequent exceedance during the operating cycle but may remain inactive when misfire is not present. If the level of misfire is exceeded again (a single exceedance) during the following operating cycle or the next operating cycle in which similar conditions are encountered (as defined in paragraph (b)(3)(D)(iii)) or while a temporary diagnostic trouble code for the level of misfire specified in paragraph (b)(2)(B)(ii) is present, the audio/visual alert device shall activate as specified above, a diagnostic trouble code shall be stored, and the audio/visual alert device shall remain continuously activated, even if the misfire ceases. The initial temporary code and stored conditions may be erased if misfire is not detected during the following operating cycle and similar conditions have been encountered without an exceedance of the specified misfire level. The code and conditions may also be erased if similar driving conditions are not encountered during 80 operating cycles subsequent to the initial detection of a malfunction.

b. Notwithstanding, in engines that provide fuel shutoff and default fuel control to prevent over fueling during misfire conditions, the audio/visual alert device need not activate at one-second intervals. Instead, the audio/visual alert device may activate continuously upon detection of misfire, in accordance with the requirements for continuous audio/visual alert device activation in paragraph (a) above, provided that the fuel shutoff and default control shall be activated as soon as misfire is detected. Fuel shutoff and default fuel control may be deactivated only to permit fueling outside of the misfire range.

(ii) Upon detection of the misfire level specified in paragraph (b)(2)(B)(ii), the following criteria shall apply for audio/visual alert device activation and diagnostic trouble code storage:

a. A temporary diagnostic trouble code shall be stored no later than after the fourth exceedance of the specified misfire level during a single operating cycle and the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the following operating cycle or the next operating cycle in which similar conditions are encountered (as defined in paragraph (b)(2)(D)(iii)) if the level of misfire is again exceeded four times. The initial temporary code and stored conditions may be erased if misfire is not detected during the following operating cycle and similar conditions have been encountered without an exceedance of the specified misfire level. The code and conditions may also be erased if similar driving conditions are not encountered during 80 operating cycles subsequent to the initial detection of a malfunction.

b. Notwithstanding, a temporary diagnostic trouble code shall be stored no later than after the first exceedance of the specified misfire level during a single operating

cycle if the exceedance occurs within the first 1000 crankshaft-revolutions from engine start (defined in the glossary) during which misfire detection is active. The audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of any subsequent operating cycle if misfire is again detected in the first 1000 crankcase revolutions. If similar conditions are encountered during a subsequent operating cycle without an exceedance of the specified misfire level, the initial temporary code and stored conditions may be erased. Furthermore, if similar driving conditions are not encountered during 80 operating cycles subsequent to the initial detection of a malfunction, the initial temporary code and stored conditions may be erased.

(iii) Upon detection of misfire, engine manufacturers shall store the engine speed, load, and warm-up status (i.e., cold or warmed-up) under which the first misfire event was detected that resulted in the storage of a temporary diagnostic trouble code. An operating cycle shall be considered to have similar conditions if the stored engine speed conditions are encountered within 375 rpm, load conditions within 20 percent, and the same warm-up status is present. With Executive Officer approval, other strategies for determining if similar conditions have been encountered may be employed. Approval shall be based on comparable timeliness and reliability in detecting similar conditions.

(3) Fuel system monitoring.

(A) Purpose and scope: The diagnostic system shall monitor the fuel delivery system for its ability to provide compliance with emission standards.

(B) Malfunction criteria: The engine manufacturer shall establish malfunction criteria to monitor the fuel delivery system such that an engine's emissions would not exceed the applicable $HC+NO_x$ certification standard by more than 50 percent before a fault is detected. If the engine is equipped with fuel trim circuitry, the engine manufacturer shall include as one of the malfunction criteria the condition where the trim circuitry has used up all of the trim adjustment allowed within the engine manufacturer's selected limit(s). Engine manufacturers may compensate the criteria limit(s) appropriately for changes in altitude or for other similar identifiable operating conditions when they occur.

(C) Monitoring conditions: The fuel system shall be monitored continuously for the presence of a malfunction.

(D) Malfunction notification and diagnostic trouble code storage:

(i) For fuel systems with short-term trim only capability, the diagnostic system shall store a diagnostic trouble code after the fuel system has attained the criteria limit for an engine manufacturer-defined time interval sufficient to determine a malfunction. If the malfunction criteria limit and time interval are exceeded, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle in which the criteria and interval are again exceeded; unless driving conditions similar to those under which the problem was originally detected have been encountered (see paragraph (iii) below) without such an exceedance, in which case the initial temporary code and stored conditions may be erased. Furthermore, if similar driving conditions are not encountered during 80 operating cycles subsequent to the initial detection of a malfunction, the initial temporary code and stored conditions may be erased.

(ii) For fuel systems with long-term fuel trim capability, upon attaining a long-term based malfunction criteria limit independent of, or in combination with, the short-term trim system status, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the end of the next operating cycle if the malfunction is again detected. If the malfunction is not detected during the second operating cycle, the audio/visual alert device shall be activated and a diagnostic trouble code stored no later than the next operating cycle in which the malfunction is again detected; unless driving conditions similar to those under which the problem was originally detected have been encountered (see paragraph (iii) below) without an indication of a malfunction, in which case the initial temporary code and stored conditions may be erased. Furthermore, if similar driving conditions are not encountered during 80 operating cycles subsequent to the initial detection of a malfunction, the initial temporary code and stored conditions may be erased.

(iii) Upon detection of a fuel system malfunction, engine manufacturers shall store the engine speed, load and warm-up status (i.e., cold or warmed-up) under which the malfunction was detected. An operating cycle shall be considered to have similar conditions if the stored engine speed is encountered within 375 rpm, load conditions within 20 percent, and the same warm-up status is present. With Executive Officer approval, other strategies for determining if similar conditions have been encountered may be employed. Approval shall be based on comparable timeliness and reliability in detecting similar conditions.

(4) Oxygen sensor monitoring.

(A) Purpose and scope:

(i) The diagnostic system shall monitor the output voltage, response rate, and any other parameter which can affect emissions, of all primary (fuel control) oxygen (lambda) sensors for malfunction. It shall also monitor all secondary oxygen sensors (fuel trim control or use as a monitoring device) for proper output voltage and/or response rate. Response rate is the time required for the oxygen sensor to switch from lean-to-rich once it is exposed to a richer than stoichiometric exhaust gas or vice versa (measuring oxygen sensor switching frequency may not be an adequate indicator of oxygen sensor response rate, particularly at low speeds).

(ii) Either the lean-to-rich or both the lean-to-rich and rich-to-lean response rates shall be checked. Response rate checks shall evaluate the portions of the sensor's dynamic signal that are most affected by sensor malfunctions such as aging or poisoning.

Engine manufacturers may observe the voltage envelope of the sensor when cycled at a frequency of 1.5 Hertz or greater, as determined by the engine manufacturer, to evaluate a slow response rate sensor (i.e., a slow sensor cannot achieve maximum and/or minimum voltage as will a good sensor, given a properly chosen switching frequency and fuel step change for the check). With Executive Officer approval, engine manufacturers may use alternative parameters to comply with this requirement such as voltage ranges and fuel-air switching frequencies based on a determination that the modifications will result in an accurate and timely evaluation of the sensor.

(iii) For sensors with different characteristics, the engine manufacturer shall submit data and an engineering evaluation to the Executive Officer for approval based on showing equivalent evaluation of the sensor.

(iv) For engines equipped with heated oxygen sensors, the heater circuit shall be monitored for proper current and voltage drop (note: a continuity check of oxygen sensors is not required). Other heater circuit monitoring strategies would require approval by the Executive Officer based on equally reliable and timely indication of malfunction as current or voltage-based monitoring.

(B) Malfunction criteria:

(i) An oxygen sensor shall be considered malfunctioning when the voltage, response rate, or other criteria are exceeded and causes emissions from an engine equipped with the sensor(s) to exceed the applicable $HC+NO_x$ standard by more than 50 percent, or when sensor output characteristics are no longer sufficient (e.g., lack of sensor switching) for use as a diagnostic system monitoring device (e.g., for catalyst efficiency monitoring).

(ii) For heated oxygen sensors, the heater circuit shall be considered malfunctioning when the current or voltage drop in the circuit is no longer within the engine manufacturer's specified limits for normal operation (i.e., within the criteria required to be met by the component vendor for heater circuit performance at high mileage). Subject to Executive Officer approval, other monitoring strategy malfunction criteria for detection of heater circuit malfunctions may be used provided the engine manufacturer submits data and/or an engineering evaluation adequately showing monitoring reliability and timeliness to be equivalent to the stated criteria in this paragraph.

(C) Monitoring conditions:

(i) For primary oxygen sensor(s) used for fuel control, the response rate and output voltage shall be monitored for malfunction after the engine has commenced closed-loop operation. If the oxygen sensor(s) is used as part of the monitoring strategy for the catalyst, the oxygen sensor(s) diagnostics should be scheduled to execute before the catalyst diagnostics begin. The engine manufacturer shall choose a steady-state window of operation defined by throttle position, delta throttle, engine load, and temperature for monitoring the oxygen sensor with the constraints that the check shall:

a. occur within a ± 10 percent throttle position window between 35 percent and 85 percent of full throttle,

b. be tolerant of throttle position fluctuations or changes less than 1 percent per second over any two second interval within the throttle position window,

c. take no more than a 30 second interval to determine both that the engine is operating in a proper window to perform the check and to actually perform the check, and

d. be conducted at the earliest such condition encountered after the beginning of closed-loop operation for each operating cycle.

Performance of the check may be delayed after engine startup until stabilized coolant temperature is achieved and/or a suitable cumulative time interval of non-closed throttle engine operation has elapsed to ensure the oxygen sensor is warmed-up for properly performing the monitoring check. The specified cumulative time interval shall begin from the first non-closed throttle operation either after achieving a stabilized coolant temperature or after engine starting and shall not exceed 180 seconds. These monitoring constraints and conditions may be altered, subject to Executive Officer approval. Such approval shall be granted if the engine manufacturer submits data and an engineering evaluation that, together, justify the need for the exception and demonstrate that the requested alteration would yield improved oxygen sensor monitoring.

(ii) The monitoring system shall operate at least once per in-use operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(iii) For secondary oxygen sensors used for catalyst monitoring and/or fuel system trim, the engine manufacturer shall define steady state operating conditions for response rate and/or output voltage malfunction monitoring that are representative of typical in-use operation, and which will result in the routine execution and completion of the diagnostics in-use. The monitoring system shall operate at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(iv) For heated oxygen sensors, the engine manufacturer shall define appropriate operating conditions for malfunction monitoring of the heater circuit that are representative of typical in-use operation, and which will result in the routine execution and completion of the diagnostic in-use. The monitoring system shall operate at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(D) Malfunction notification and diagnostic trouble code storage: Upon detection of any oxygen sensor malfunction, the diagnostic system shall store a diagnostic trouble code and the audio/visual alert device shall activate no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again present.

(E) Other (non-Lambda) oxygen sensors:

(i) For engines equipped with universal exhaust gas oxygen sensors (i.e., sensors which provide an output proportional to exhaust gas oxygen concentration), the engine manufacturer shall define steady state operating conditions as in paragraph (b)(4)(C)(i) above for the diagnostic system to perform a response rate check (the time required to respond to a specific change in fuel/air ratio) that are representative of typical in-use operation, and which will result in the routine execution and completion of all IMDN diagnostics in-use. The monitoring system shall operate at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met. The diagnostic system shall also perform an out-of-range check for which monitoring shall be continuous. For malfunctions, audio/visual alert device activation and diagnostic trouble code storage shall be as in paragraph (b)(4)(D).

(ii) If an engine manufacturer utilizes other types of oxygen sensors, the engine manufacturer shall submit a monitoring plan to the Executive Officer for approval based on equivalent monitoring with conventional sensors.

(5) Comprehensive component monitoring.

(A) Purpose and scope: The diagnostic system shall monitor for malfunction any electronic engine component/system not otherwise described above which either provides input to (directly or indirectly), or receives commands from the on-board computer, and which: (1) can affect emissions during any reasonable in-use driving condition, or (2) is used as part of the diagnostic strategy for any other monitored system or component.

(i) Input components:

a. The monitoring system shall have the capability of detecting, **at a minimum,** lack of circuit continuity **and out of range values to ensure proper operation of the input device. The determination of out of range values shall**

include logic evaluation of available information to determine if a component is operating within its normal range (e.g., a low throttle position sensor voltage would not be reasonable at a high engine speed with a high mass airflow sensor reading). To the extent feasible, said logic evaluation shall be "two-sided" (i.e., verify a sensor output is not inappropriately high or low).

b. Input components may include, but are not limited to, the engine speed sensor, crank angle sensor, knock sensor, throttle position sensor, coolant temperature sensor, cam position sensor, and other electronic components such as sensors, modules, and solenoids which provide signals to the engine control system (see paragraph (b)(5)(E)).

c. The coolant temperature sensor shall be monitored for achieving a stabilized minimum temperature level that is needed to achieve closed-loop operation within an engine manufacturer-specified time interval after starting the engine. The time interval shall be a function of starting engine coolant temperature and/or a function of intake air temperature. Engine manufacturers may suspend or delay the diagnostic if the engine is subjected to conditions which could lead to false diagnosis (e.g., engine operation at idle for more than 50 to 75 percent of the warm-up time). Engine manufacturers shall provide data to support specified times. The Executive Officer shall allow disablement of this check under extremely low ambient temperature conditions (below 20 degrees Fahrenheit) provided an engine manufacturer submits data and/or an engineering evaluation that adequately demonstrate non-attainment of a stabilized minimum temperature.

(ii) Output components:

a. The diagnostic system shall monitor output components **for proper functional response to computer commands.**

b. Components **for which functional monitoring is not feasible** shall be monitored, **at a minimum,** for proper circuit continuity and out of range values, if applicable.

c. Output components may include, but are not limited to, the automatic idle speed motor, emission-related electronic solenoids, heated fuel preparation systems, and a warm-up catalyst bypass valve (see paragraph (b)(5)(E)).

(B) Malfunction criteria:

(i) Input components: Input components/systems shall be considered malfunctioning when, **at a minimum**, lack of circuit continuity **or engine manufacturer-specified out-of-range values** occur.

(ii) Output components:

a. **Output components/systems shall be considered malfunctioning when proper functional response to computer commands does not occur. Should a functional check for malfunction not be feasible, then** an output component/system shall be considered malfunctioning when, **at a minimum**, lack of circuit continuity **or engine manufacturer-specified out-of-range values** occurs.

b. **The idle speed control motor/valve shall be monitored for proper functional response to computer commands. For strategies based on deviation from target idle speed, a fault shall be indicated when the idle speed control system cannot achieve the target idle speed within an engine manufacturer specified time and engine speed tolerance. In general, the engine speed tolerances shall not exceed 200 rpm above the target speed or 100 rpm below the target speed. The Executive Officer shall allow larger engine speed tolerances provided an engine manufacturer submits data and/or an engineering evaluation which adequately demonstrate that the tolerances can be exceeded without a malfunction present.**

(C) Monitoring conditions:

(i) Input components: Input components shall be monitored continuously for **proper range of values and** circuit continuity. **For rationality monitoring (where applicable), engine manufacturers shall define appropriate operating conditions that are representative of typical in-use operation and will result in the routine execution and completion of all**

diagnostics in-use. Rationality monitoring shall occur at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met.

(ii) Output components: Monitoring for circuit continuity **and proper range of values (if applicable)** shall be conducted continuously. **For functional monitoring, engine manufacturers shall define appropriate operating conditions that are representative of typical in-use operation and will result in the routine execution and completion of all diagnostics in-use. Functional monitoring shall occur at least once per operating cycle during which the engine manufacturer-defined monitoring conditions are met.**

(D) Malfunction notification and diagnostic trouble code storage:

(i) Upon detecting a malfunction, the diagnostic system shall store a diagnostic trouble code no later than the end of the next operating cycle during which monitoring occurs provided the malfunction is again detected.

(ii) In conjunction with storing a diagnostic trouble code, engine manufacturers shall activate the audio/visual alert device for malfunctions of components/systems for which either of the following occurs:

a. when malfunctioning, the component or system could cause engine emissions to increase by 15 percent or more of the $HC+NO_x$ standard, or

b. the component/system is used as part of the diagnostic strategy for any other monitored system or component.

(E) Component determination: The engine manufacturer shall determine whether an engine input or output component not otherwise covered can affect emissions. If the Executive Officer reasonably believes that an engine manufacturer has incorrectly determined that a component cannot affect emissions, the Executive Officer shall require the engine manufacturer to provide emission data showing that such a component, when faulty and installed in a suitable test engine, does not have an emission effect. Emission data may be requested for any reasonable driving condition.

(c) Additional audio/visual alert device activation and diagnostic trouble code storage protocol.

(1) Audio/visual alert device activation: For all emission-related components/systems, upon final determination of malfunction, the audio/visual alert device shall remain continuously activated **(except that it shall activate at one-second intervals as indicated previously for misfire detection). If any malfunctions are identified in addition to misfire, the misfire condition shall take precedence, and the audio/visual alert device shall activate at one-second intervals accordingly.** The diagnostic system shall store a diagnostic trouble code whenever the audio/visual alert device is activated. The diagnostic system shall activate the audio/visual alert device and shall store a diagnostic trouble code whenever the engine enters a default or "limp home" mode of operation. The diagnostic system shall activate the audio/visual alert device and shall store a diagnostic trouble code whenever the engine control system fails to enter closed-loop operation (if employed) within an engine manufacturer specified minimum time interval.

(2) Audio/visual alert device deactivation:

(A) **Misfire and** Fuel System Malfunctions: For **misfire or** fuel system malfunctions, the audio/visual alert device may be deactivated if the fault does not recur when monitored during three subsequent sequential operating cycles in which conditions are similar to those under which the malfunction was first determined (see paragraphs (b)(2)(D)(iii) and (b)(3)(D)(iii)).

(B) All Other Malfunctions: For all other faults, the audio/visual alert device may be deactivated after three subsequent sequential operating cycles during which the monitoring system responsible for activating the audio/visual alert device functions without detecting the malfunction and if no other malfunction has been identified that would independently activate the audio/visual alert device according to the requirements outlined above.

(3) Erasing a diagnostic trouble code: The diagnostic system may erase a diagnostic trouble code if the same fault is not re-registered in at least 40 engine warm-up cycles, and the audio/visual alert device is not activated for that diagnostic trouble code.

(d) Tampering protection: Computer-coded engine operating parameters shall not be changeable without the use of specialized tools and procedures (e.g. soldered or potted computer components or sealed (or soldered) computer enclosures). Subject to Executive Officer approval, engine manufacturers may exempt from this requirement those product lines that are unlikely to require protection. Criteria to be evaluated in making an exemption include, but are not limited to, current availability of performance chips, high performance capability of the engine, and sales volume.

(e) Readiness/Function code: The on-board computer shall store a code upon first completing a full diagnostic check (i.e., the minimum number of checks necessary for audio/visual alert device activation) of all monitored components and systems (except as noted below) since the computer memory was last cleared (i.e., through the use of a scan tool or battery disconnect). The code shall be stored in the format specified by SAE J1979, September 1997, or alternatively as specified in ISO 15765-4, November 1999, and ISO 15031-5, December 1999. These documents are incorporated by reference in paragraphs (i)(2) and (i)(5). The diagnostic system check for comprehensive component monitoring and continuous monitoring of **misfire and** fuel system faults shall be considered complete for purposes of determining the readiness indication if malfunctions are not detected in these areas by the time all other diagnostic system checks are complete. Subject to Executive Officer approval, if monitoring is disabled for a multiple number of operating cycles due to the continued presence of extreme operating conditions (e.g., cold ambient temperatures, high altitudes, etc.), readiness for the subject monitoring system may be set without monitoring having been completed. Executive Officer approval shall be based on the conditions for monitoring system disablement and the number of operating cycles specified without completion of monitoring before readiness is indicated.

(f) Stored engine conditions: Upon detection of the first malfunction of any component or system, "freeze frame" engine conditions present at the time shall be stored in computer memory. Should a subsequent fuel system or misfire malfunction occur, any previously stored freeze frame conditions shall be replaced by the fuel system or misfire conditions (whichever occurs first). Stored engine conditions shall include, but are not limited to, calculated load value, engine rpm, fuel trim value(s) (if available), fuel pressure (if available), engine speed (if available), coolant temperature, intake manifold pressure (if available), closed- or open-loop operation (if available), and the diagnostic trouble code which caused the data to be stored. The engine manufacturer shall choose the most appropriate set of conditions facilitating effective repairs for freeze frame storage. Only one frame of data is required. Engine manufacturers may at their discretion choose to store additional frames provided that at least the required frame can be read by a generic scan tool meeting SAE specifications established in SAE J1978, Recommended Practices on "OBD II Scan Tool," February 1998, and SAE J1979, "E/E Diagnostic Test Modes," September 1997, which are incorporated by reference herein. If the diagnostic trouble code causing the conditions to be stored is erased in accordance with paragraph (c)(3), the stored engine conditions may be cleared as well.

(g) Certification documentation: The engine manufacturer shall submit the following documentation for each engine family at the time of certification. With Executive Officer approval, one or more of the documentation requirements specified in this section may be waived or altered if the information required would be redundant or unnecessarily burdensome to generate:

(1) A written description of the functional operation of each monitoring strategy within the diagnostic system.

(2) A table providing the following information for each monitored component or system (either computer-sensed or -controlled) of the emission control system:

(A) corresponding diagnostic trouble code

(B) monitoring method or procedure for malfunction detection

(C) primary malfunction detection parameter and its type of output signal

(D) fault criteria limits used to evaluate output signal of primary parameter

(E) other monitored secondary parameters and conditions (in engineering units) necessary for malfunction detection.

(F) monitoring time length and frequency of checks.

(G) criteria for storing diagnostic trouble code

(H) criteria for activating the audio/visual alert device

(I) criteria used for determining out of range values and input component rationality checks

(3) A logic flowchart describing the general method of detecting malfunctions for each monitored emission-related component or system. To the extent possible, abbreviations in SAE J1930 "Electrical/Electronic

Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms," May 1998, shall be used. J1930 is incorporated by reference herein. The information required in the chart under (2) above may instead be included in this flow chart, provided all of the information required in (2) is included.

(4) A listing and block diagram of the input parameters used to calculate or determine calculated load values and the input parameters used to calculate or determine fuel trim values.

(5) A scale drawing of the audio/visual alert device specifying location in the instrument panel, wording, color, and intensity.

(6) Data supporting the selected degree of misfire which can be tolerated without damaging the catalyst. Representative data demonstrating the capability of the misfire monitoring system (i.e., probability of detection of misfire events) to detect misfire over the full engine speed and load operating range for selected misfire patterns (i.e., random cylinders, one cylinder out, paired cylinders out).

(7) Data supporting the limit for the time between engine starting and attaining the designated heating temperature for artificially heated catalyst systems.

(8) Data supporting the criteria used to indicate a malfunction when catalyst deterioration causes emissions to exceed the applicable $HC+NO_x$ threshold specified in paragraph (b)(1)(B)(i).

(9) If applicable, data supporting the criteria used by the diagnostic system for establishing a 60 to 80 percent catalyst efficiency level to determine a malfunction in accordance with paragraph (b)(1)(B)(ii).

(10) A listing of all electronic engine input and output signals.

(11) Any other information determined by the Executive Officer to be necessary to demonstrate compliance with the requirements of this section.

(h) Confirmatory testing: The ARB may perform confirmatory testing of engine manufacturers' diagnostic systems for compliance with requirements of this section in accordance with malfunction criteria submitted in the engine manufacturer's approved certification documentation. The ARB or its designee may install appropriately deteriorated or malfunctioning components in an otherwise properly functioning test engine (or simulate a deteriorated or malfunctioning component response) in order to test the fuel system, **misfire detection system**, oxygen sensor, and catalyst efficiency system monitors for compliance with the applicable emission constraints in this section. Diagnostic systems of a representative sample of engines that uniformly fail to meet the requirements of this section may be recalled for correction.

(i) Standardization: Standardized access to emission-related diagnostic trouble codes, emission-related engine test information (i.e., parameter values) as outlined in subsection (j), emission related diagnostic procedures, and stored freeze frame data shall be incorporated based on the industry specifications referenced in this regulation.

(1) Either SAE Recommended Practice J1850, "Class B Data Communication Network Interface", March 1998, or ISO 9141-2, "Road engines - Diagnostic Systems - CARB Requirements for Interchange of Digital Information," February 1994, or ISO 14230-4, "Road engines - Diagnostic systems - KWP 2000 requirements for Emission-related systems," April 1996, which are incorporated by reference, shall be used as the on-board to off-board network communications protocol. All SAE J1979 emission related messages sent to the J1978 scan tool over a J1850 data link shall use the Cyclic Redundancy Check and the three-byte header, and shall not use inter-byte separation or checksums.

(2) (A) J1978 & J1979: Standardization of the message content (including test modes and test messages) as well as standardization of the downloading protocol for diagnostic trouble codes, parameter values and their units, and freeze frame data are set forth in SAE J1978, Recommended Practices on "OBD II Scan Tool," February 1998, and SAE J1979, "E/E Diagnostic Test Modes," September 1997, which have been incorporated by reference. Diagnostic trouble codes, parameter values, and freeze frame data shall be capable of being downloaded to a generic scan tool meeting these SAE specifications.

(B) The J1978 scan tool shall be capable of notifying the user when one or more of the required monitoring systems are not included as part of the IMDN system.

(3) J2012 Part C: Uniform diagnostic trouble codes based on SAE specifications shall be employed. SAE J 2012, "Recommended Format and Messages for Diagnostic Trouble Codes," October 1996, is incorporated by reference.

(4) J1962: A standard data link connector in each engine shall be incorporated. The location of the connector shall be easily identified by a technician viewing the engine from above. Any pins in the standard connector that provide any electrical power shall be properly fused to protect the integrity and usefulness of the diagnostic connector for diagnostic purposes. The SAE J1962 Recommended Practice "Diagnostic Connector," February 1998, is incorporated by reference.

(j) Signal access.

(1)The following signals in addition to the required freeze frame information shall be made available on demand through the serial port on the standardized data link connector: calculated load value, diagnostic trouble codes, engine coolant temperature (if available), fuel control system status (open loop, closed loop, other; if equipped with closed loop fuel control), fuel trim (if equipped), fuel pressure (if available), ignition timing advance (if equipped), intake air temperature (if equipped), manifold air pressure (if equipped), air flow rate from mass air flow meter (if equipped), engine rpm, throttle position sensor output value (if equipped), and engine speed (if equipped). The signals shall be provided in standard units based on the SAE specifications incorporated by reference in this regulation, and actual signals shall be clearly identified separately from default value or limp home signals.

(2) Oxygen sensor data (including current oxygen sensor output voltages) allowing the diagnosis of malfunctioning oxygen sensors shall be provided through serial data port on the standardized data link. In addition, for all monitored components and systems, except misfire detection, fuel system monitoring, and comprehensive component monitoring, results of the most recent test performed by the engine, and the limits to which the system is compared shall be available through the data link. For the monitored components and systems excepted above, a pass/fail indication for the most recent test results shall be available through the data link. Such data shall be transmitted in accordance with SAE J1979 (or SAE J1939, whichever applies). Engine manufacturers shall report the test results such that properly functioning systems do not indicate a failure (e.g., a test value that is outside of the test limits). Alternative methods shall be approved by the Executive Officer if, in the judgment of the Executive Officer, they provide for equivalent off-board evaluation.

(3) Calibration Verification Number: Engine manufacturers shall provide for verification of the on-board computer software integrity in electronically reprogrammable control units through the standardized engine data connector in a standardized format to be adopted by SAE. Such verification shall be capable of being used to determine if the emission-related software and/or calibration data are valid and applicable for that engine.

(k) Implementation schedule.

(1) These OBD-M requirements, unless otherwise specified, shall be implemented beginning with the 2007 model year.

(2) All engine manufacturers shall meet these requirements by the 2009 model year.

(3) The Executive Officer, upon receipt of an application from the engine manufacturer, may certify the engines in question even though said engines may not comply with one or more of the requirements of these subsections. Such certification is contingent upon the extent to which these requirements are satisfied overall on the engine applications in question and a demonstrated good-faith effort to meet these requirements in full by evaluating and considering the best available monitoring technology. Each incident of non-compliance will be recorded as a deficiency.

(A) Engine manufacturers of non-complying systems shall be subject to fines pursuant to section 43016 of the California Health and Safety Code for each deficiency identified subject to the following limitations:

(i) The specified fines shall apply to the second and subsequently identified deficiencies, with the exception that fines shall apply to all monitoring system deficiencies wherein a required monitoring strategy is completely absent from the IMDN system; and

(ii) Engine manufacturers may not carry over monitoring system deficiencies for more than two model years unless it can be adequately demonstrated that substantial engine hardware modifications and additional lead time beyond two years would be necessary to correct the deficiency, in which case the deficiency may be carried over for three model years.

(B) For the second deficiency and every deficiency thereafter identified in an engine model, the fines shall be in the amount of $50 per deficiency per engine for non-compliance with any of the monitoring requirements specified in subsections (b)(1) through (b)(4), and $25 per deficiency per engine for non-compliance with any other requirement. In determining the identified order of deficiencies, deficiencies of subsections (b)(1) through (b)(4) shall be identified first. Total fines per engine under this section shall not exceed $500 per engine and shall be payable to the State Treasurer for deposit in the Air Pollution Control Fund.

NOTE: Authority cited: Sections 39515, 39600, 39601, 43006, 43013, 43018, 43104, and 44036.2, Health and Safety Code; Sections 27156 and 38395 Engine Code.
Reference: Sections 39002, 39003, 39667, 43000, 43004, 43006, 43008.6, 43013, 43018, 43100, 43101, 43101.5, 43102, 43104, 43105, 43106, 43204, and 44036.2, Health and Safety Code; Sections 27156, 38391, and 38395, Engine Code.

§ 2445.1. Defects Warranty Requirements for Model Year 2001 and Later Spark-Ignition Marine Engines.

(a) Applicability. This section applies to model year 2001 and later spark-ignition personal watercraft and outboard marine engines, and to model year 2003 and later spark-ignition inboard and sterndrive marine engines. The warranty period begins on the date the engine or equipment is delivered to an ultimate purchaser or first placed into service (e.g., a demonstration engine or watercraft).

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

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

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

(c) Warranty Period. In the case of all new, spark-ignition marine engines, the warranty period will be:

(1) For model year 2001 and later spark-ignition personal watercraft and outboard marine engines, a period of 4 years or 250 hours of use, whichever occurs first.

(2) For model year 2003-2008 spark-ignition inboard and sterndrive marine engines, a period of 2 years.

(3) For model year 2009 and later spark-ignition inboard and sterndrive marine engines, a period of 3 years.

(d) Subject to the conditions and exclusions of Subsection (g), the warranty on emission-related parts is as follows:

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

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

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

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

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

(6) The engine owner must not be charged for diagnostic labor that is directly associated with diagnosis of a defective, emission-related warranted part, provided that such diagnostic work is performed at a warranty station.

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

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

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

(10) Add-on or modified parts, as defined in Section 1900(b)(1) and (b)(10), Title 13, that are not exempted by the Air Resources Board may not be used. The use of any non-exempted add-on or modified parts by the ultimate purchaser will be grounds for disallowing a warranty claim made in accordance with this article. The engine manufacturer will not be liable under this article to warrant failures of warranted parts caused by the use of a non-exempted add-on or modified part.

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

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

(1) Fuel Metering System
- (A) Carburetor and internal parts (and/or pressure regulator or fuel injection system)
- (B) Air/fuel ratio feedback and control system
- (C) Cold start enrichment system
- (D) Intake valve(s)

(2) Air Induction System
- (A) Controlled hot air intake system
- (B) Intake manifold
- (C) Air filter
- (D) Turbocharger systems
- (E) Heat riser valve and assembly

(3) Ignition System
- (A) Spark plugs
- (B) Magneto or electronic ignition system
- (C) Spark advance/retard system
- (D) Ignition coil and/or control module
- (E) Ignition wires

(4) Lubrication System
- (A) Oil pump and internal parts
- (B) Oil injector(s)
- (C) Oil meter

(5) Positive Crankcase Ventilation (PCV) System
- (A) PCV valve
- (B) Oil filler cap

(6) Exhaust Gas Recirculation (EGR) System
- (A) EGR valve body, and carburetor spacer if applicable
- (B) EGR rate feedback and control system

(7) Air Injection System
- (A) Air pump or pulse valve
- (B) Valves affecting distribution of flow
- (C) Distribution manifold

(8) Exhaust System

(9) Catalyst or Thermal Reactor System
- (A) Catalytic converter
- (B) Thermal reactor
- (C) Exhaust manifold
- (D) Exhaust valve(s)

(10) Miscellaneous Items Used in Above Systems
(A) Hoses, clamps, fittings, tubing, sealing gaskets or devices, and mounting hardware
(B) Pulleys, belts and idlers
(C) Vacuum, temperature, check, and time sensitive valves and switches
(D) Electronic Controls

(f) Each engine manufacturer must provide with each new engine written instructions for the maintenance and use of the engine by the owner. The instructions must be consistent with this Article. A copy of the instructions for each engine family must be provided to the Executive Officer upon commencement of its production.

(g) Exclusions.

(1) The repair or replacement of any warranted part otherwise eligible for warranty coverage under Subsection (d) may be excluded from such warranty coverage if the engine manufacturer demonstrates that the engine has been abused, neglected, or improperly maintained, and that such abuse, neglect, or improper maintenance was the direct cause of the need for repair or replacement of the part.

(2) Engine manufacturers must warrant engines for the yearly warranty period specified in paragraph (c). For Outboard and Personal Watercraft engines, manufacturers may warrant engines for the hour warranty period if ~~unless~~ the engines:

(A) are equipped with hour meters;

(B) are equipped with devices similar to hour meters that are approved by the Executive Officer; or

(C) are or will be accompanied by other evidence or methods that the Executive Officer determines reliable for determining engine usage in hours.

(3) Except as provided in Subsection (1) above, any adjustment of a component that has a factory installed, and properly operating, adjustment limiting device (such as an idle limiter cap or plug) is eligible for warranty coverage under Subsection (d).

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2445.2. Emission Control Warranty Statements.

(a) Each engine manufacturer must provide a verbatim copy of the following statement with each new 2001 model year and later spark-ignition personal watercraft and outboard marine engine and with each new 2003 model year and later spark-ignition inboard and sterndrive marine engine, using those portions of the statement applicable to the engine.

CALIFORNIA EMISSION CONTROL WARRANTY STATEMENT
YOUR WARRANTY RIGHTS AND OBLIGATIONS

The California Air Resources Board (and engine manufacturer's name, optional) is (are) pleased to explain the emission control system warranty on your (model year) (inboard, sterndrive, outboard or personal watercraft) engine. In California, new (inboard, sterndrive, outboard, or personal watercraft) engines must be designed, built and equipped to meet the State's stringent anti-smog standards. (Engine manufacturer's name) must warrant the emission control system on your (inboard, sterndrive, outboard, or personal watercraft) engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your (inboard, sterndrive, outboard, or personal watercraft) engine.

Your emission control system may include parts such as the carburetor or fuel injection system, the ignition system, and catalytic converter. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, (engine manufacturer's name) will repair your (inboard, sterndrive, outboard, or personal watercraft) engine at no cost to you, including diagnosis, parts and labor.

MANUFACTURER'S WARRANTY COVERAGE:

(For spark-ignition personal watercraft and outboard marine engines:) Select emission control parts from model year 2001 and later (outboard, or personal watercraft) engines are warranted for 4 years, or for 250 hours of use, whichever occurs first.

(For 2003-2008 spark-ignition inboard and sterndrive marine engines:) Select emission control parts from model year 2003-2008 (inboard or sterndrive) engines are warranted for 2 years.

(For 2009 and later spark-ignition inboard and sterndrive marine engines:) Select emission control parts from model year 2009 and later (inboard or sterndrive) engines are warranted for 3 years.

However, warranty coverage based on the hourly period is only permitted for outboard engines and personal watercraft equipped with appropriate hour meters or their equivalent. If any emission-related part on your engine is defective under warranty, the part will be repaired or replaced by (engine manufacturer's name).

OWNER'S WARRANTY RESPONSIBILITIES:

– As the (inboard, sterndrive, outboard, or personal watercraft) engine owner, you are responsible for the performance of the required maintenance listed in your owner's manual. (Engine manufacturer's name) recommends that you retain all receipts covering maintenance on your (inboard, sterndrive, outboard, or personal watercraft) engine, but (engine manufacturer's name) cannot deny warranty solely for the lack of receipts or your failure to ensure the performance of all scheduled maintenance.

– As the (inboard, sterndrive, outboard, or personal watercraft) engine owner, you should however be aware that (engine manufacturer's name) may deny you warranty coverage if your (inboard, sterndrive, outboard, or personal watercraft) engine or a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.

– You are responsible for presenting your (inboard, sterndrive, outboard, or personal watercraft) engine to a (engine manufacturer's name) distribution center as soon as a problem exists. The warranty repairs will be completed in a reasonable amount of time, not to exceed 30 days.

If you have any questions regarding your warranty rights and responsibilities, you should contact (Insert chosen contact of engine manufacturer) at 1-XXX-XXX-XXXX.

(b) Commencing with the 2001 model year, each engine manufacturer must also provide with each new engine a warranty statement in accordance with section 2445.1, Title 13, California Code of Regulations, that generally describes the obligations and rights of the engine manufacturer and engine owner under this article. Engine manufacturers must also include in the warranty statement a phone number the consumer may use to obtain their nearest franchised service center.

(c) Each engine manufacturer must submit the documents required by Subsections (a) and (b) with the engine manufacturer's application for new engine certification for approval by the Executive Officer. The Executive Officer may reject or require modifications of the documents to the extent the submitted documents do not satisfy the requirements of Subsections (a) and (b). Approval by the Executive Officer of the documents required by Subsections (a) and (b) is a condition of certification. The Executive Officer will approve or disapprove the documents required by Subsections (a) and (b) within ninety (90) days of the date such documents are received from the engine manufacturer. Any disapproval must be accompanied by a statement of reasons therefore. In the event of disapproval, the engine manufacturer may petition the Board to review the decision of the Executive Officer pursuant to Subchapter 1.25 of Title 17, California Code of Regulations.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

§ 2446. 2001 and ~~Subsequent~~ Later Model Year Production-Line Test Procedures and Selective Enforcement Auditing Regulations for Spark-Ignition Marine Engines.

(a) Applicability. This section applies to 2001 and ~~subsequent~~ later spark-ignition marine engines. The allowable methods of production-line testing are specified in paragraphs (b) and (c), unless the engine manufacturer can satisfactorily provide an alternate method that shows an equivalent assurance of compliance to that of paragraph (b). The engine manufacturer must choose only one method for each model year and submit its method of production-line testing to the Executive Officer for approval no later than 90 days prior to the start of the subject model year production. Only subsections (d) and (e) apply to 2003 and later spark-ignition inboard and sterndrive marine engines.

(b) 2001 and ~~Subsequent~~ Later Model Year Quality-Audit Production Line Test Procedures.

(1) Engine Sample Selection.

(A) Except as provided in subsection (b)(2), the engine manufacturer must randomly select one percent of the California sales volume of engines from each engine family for quality-audit testing.

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

(2) Alternate Quality-Audit Engine Selection Criteria ~~F~~for 2001 and ~~Subsequent~~ Later Model Years.

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

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

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

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

$$\frac{(\text{emission standard} - \text{mean})\,(N)^{0.5}}{(\text{standard deviation})}$$

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

Table 1

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

Table 2

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

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

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

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

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

(3) Compliance Evaluation.

(A) Each engine manufacturer must review the test results of the first 10 test engines or equipment of each engine family, from each calendar quarter of production or from the start of calendar year production. It must also review the quarter's cumulative test results of each engine family at the end of each month. If 10 or more engines or units of equipment have been tested, the engine manufacturer must notify the Chief of the Mobile Source Operations Division and the Manager of the New Vehicle Audit Section, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA, 91734-8001, in writing within ten working days whenever an engine family exceeds an emission standard.

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

(C) When the average value of any pollutant that is rounded off to the same number of significant digits as is the standard, in accordance with ASTM E 29-93a, exceeds the applicable family emission level or emission standard, whichever is applicable; or, when the engine manufacturer's submitted data reveal that the production line tests were performed improperly, the engine family may be determined to be in noncompliance. The Executive Officer will follow the manufacturer notification procedures in section (d)(4).

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

(4) Reports.

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

(B) The quarterly report shall include the following:

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

(ii) eEngine identification numbers and explanation of the identification code.

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

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

(v) The exhaust emission data for $HC+NO_x$ for each test engine or equipment. The data reported shall provide two significant figures beyond the number of significant figures in the applicable emission standard.

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

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

1. Number of engines or units of equipment tested.

2. Average emissions and standard deviations of the sample for $HC+NO_x$.

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

(ix) The applicable quarterly report shall include the date of the end of the engine manufacturer's model year production for an engine family.

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

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

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

(c) 2001 and Later Model Year Cumulative Sum Production-Line Test Procedures.

(1) Engine Sample Section.

(A) At the start of each model year, the engine manufacturer will begin to randomly select engines from each engine family with California sales greater than 20 units for production line testing, according to the criteria specified herein.

(i) For newly certified engine families: After two (2) engines are tested, the engine manufacturer will calculate the required sample size for the model year according to the Sample Size Equation in paragraph (c)(1)(B) of this section.

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

(iii) The engines must be representative of the engine manufacturer's California sales. Each engine will be selected from the end of the assembly line. All engine models within the engine family must be included in the sample pool. Each selected engine for quality-audit testing must pass the inspection test, by being equipped with the appropriate emission control systems certified by the ARB. The procedure for randomly selecting engines or units of equipment must be submitted to the Chief, Mobile Source Operations Division, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA, 91734-8001, before the start of production for the first year of production.

(iv) ~~(a)~~a. Prior to the beginning of the 2001 model year, if an engine manufacturer cannot provide actual California sales data, it must provide its total production and an estimate of California sales at the end of the model year. The engine manufacturer must also provide supporting material for its estimate.

~~(b)~~b. For the 2001 and later model years, engine manufacturers must provide actual California sales, or other information acceptable to the Executive Officer, including, but not limited to, an estimate based on market analysis and federal production or sales.

(B)(i) Engine manufacturers must calculate the required sample size for the model year for each engine family using the Sample Size Equation below. N is calculated from each test result. The number N indicates the number of tests required for the model year for an engine family. N is recalculated after each test. Test results used to calculate the variables in the Sample Size Equation must be final deteriorated test results as specified in paragraph (c)(3)(C).

$$N = \left[\frac{(t_{95} * \sigma)}{(x - FEL_{jx})} \right]^2 + 1$$

where:

N	= ~~r~~Required sample size for the model year.
T_{95}	= 95% confidence coefficient. It is dependent on the actual number of tests completed, n, as specified in the table in paragraph (c)(1)(B)(ii) of this section. It defines one-tail, 95% confidence intervals.
FEL_{jx}	= Family Emission Limit
σ	= ~~a~~Actual test sample standard deviation calculated from the following equation:

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

where:

X_i = eEmission test results for an individual engine
x = mMean of emission test results of the actual sample
n = The actual number of tests completed in an engine family

(ii) Actual Number of Tests (n) and 1-tail Confidence Coefficients (t_{95}) are listed in Table 3 below:

Table 3

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

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

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

(v) An engine manufacturer must continue testing and updating each engine family's sample size calculations according to paragraphs (c)(1)(B)(i) through (c)(1)(B)(iv) of this section until a decision is made to stop testing as described in paragraph (c)(1)(B)(vi) of this section or a noncompliance decision is made pursuant to paragraph (c)(2)(A)(v) of this section.

(vi) If, at any time throughout the model year, the calculated required sample size, N, for an engine family is less than or equal to the actual sample size, n, and the sample mean, x, for each regulated pollutant is less than or equal to the FEL for that pollutant, the engine manufacturer may stop testing that engine family except as required by paragraph (c)(2)(A)(vi).

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

(viii) The maximum required sample size for an engine family (regardless of the required sample size, N, as calculated in paragraph (c)(1)(B)(i) of this section) is thirty (30) tests per model year.

(ix) Engine manufacturers may elect to test additional randomly chosen engines. All additional randomly chosen engines tested in accordance with the testing procedures specified in the Test Procedures must be included in the Sample Size and Cumulative Sum equation calculations as defined in paragraphs (c)(1)(B)(i) and (c)(2)(A)(i) of this section, respectively.

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

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

(2) Calculation of the Cumulative Sum Statistic.

(A) Each engine manufacturer must review the test results obtained in paragraph (c)(1) using the following procedure:

(i) Engine manufacturers must construct the following Cumulative Sum Equation for each regulated pollutant for each engine family. Test results used to calculate the variables in the Cumulative Sum Equation must be final deteriorated test results as defined in paragraph (c)(3)(C).

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

where:

C_i	= The current Cumulative Sum statistic
C_{i-1}	= The previous Cumulative Sum statistic. Prior to any testing, the Cumulative Sum statistic = 0 (i.e., $C_0 = 0$)
X_i	= The current emission test result for an individual engine
FEL_{jx}	= Family Emission Limit
F	= $0.25 \times \sigma$

After each test, C_i is compared to the action limit, H, the quantity that the Cumulative Sum statistic must exceed, in two (2) consecutive tests, before the engine family may be determined to be in noncompliance for purposes of paragraphs (a)(2)(A)(iv) and (a)(2)(A)(v).

H	= The Action Limit. It is $5.0 \times \sigma$ and is a function of the standard deviation, σ.
σ	= ~~is t~~The sample standard deviation and is recalculated after each test.

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

(iii) If, at any time during the model year, an engine manufacturer amends the application for certification for an engine family as specified in Part I, section 28 or 29 of the Test Procedures by performing an engine family modification (i.e., a change such as a running change involving a physical modification to an engine, a change in specification or setting, the addition of a new configuration, or the use of a different deterioration factor), all previous sample size and Cumulative Sum statistic calculations for the model year will remain unchanged.

(iv) A failed engine is one whose final deteriorated test results pursuant to paragraph (c)(3)(C), for a regulated pollutant exceeds the FEL for that pollutant.

(v) An engine family may be determined to be in noncompliance~~,~~ if, at any time throughout the model year, the Cumulative Sum statistic, C_i, for~~,~~ a regulated pollutant is greater than the action limit, H, for two (2) consecutive tests.

(vi) The engine manufacturer must perform a minimum of two tests per engine family per quarter, regardless of whether the conditions of paragraph (c)(1)(B)(vi) have been met. The Executive Officer may waive the requirement of this paragraph if the engine manufacturer does not have a failing engine family in the prior two model years of testing.

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

(viii) If the Cumulative Sum analysis indicates that an engine family has failed, the engine manufacturer must notify the Chief of the Mobile Source Operations Division, in writing and by telephone, within ten working days. Corrective action will be taken as noted in paragraph (c)(4)(E).

(ix) If an engine manufacturer performs corrective action on a failed engine family and then resumes production, all previous tests will be void, and Cumulative Sum analysis will begin again with the next test.

(B) Within 45 days after the end of the quarter, or when the Cumulative Sum analysis indicates that a decision has been made, the engine manufacturer must provide all the data accumulated during the quarter.

(3) Calculation and Reporting of Test Results.

(A) Initial test results are calculated following the applicable test procedure specified in the Test Procedures.

(B) Final test results are calculated by summing the initial test results derived in paragraph (A) for each test engine and dividing by the number of tests conducted on the engine.

(C) The final deteriorated test results for each test engine are calculated by applying the appropriate deterioration factors, derived in the certification process for the engine family, to the final test results, and rounding in accordance with ASTM E29-93a, incorporated by reference herein, to the same number of decimal places contained in the applicable standard expressed to one additional significant figure.

(D) If, at any time during the model year, the Cumulative Sum statistic exceeds the applicable action limit, H, in two (2) consecutive tests, the engine family may be determined to be in noncompliance and the engine manufacturer must notify the Chief of the Mobile Source Operations Division and the Manager of the New Vehicle Audit Section, P.O. Box 8001, 9528 Telstar Avenue, El Monte, CA, 91734-8001, within ten working days of such exceedance by the Cumulative Sum statistic.

(E) Within 45 calendar days of the end of each quarter, each engine manufacturer must submit to the Executive Officer a report that includes the following information:

(i) The location and description of the engine manufacturer's or other's exhaust emission test facilities that were utilized to conduct testing reported pursuant to this section;

(ii) Total production and sample sizes, N and n, for each engine family~~.~~;

(iii) The applicable emission standards for each engine family~~.~~;

(iv) A description of the process to obtain engines on a random basis;

(v) A description of the test engines or equipment (i.e., date of test, engine family, engine size, engine or equipment identification number, fuel system, dynamometer power absorber setting in horsepower or kilowatts, engine code or calibration number, and test location);

(vi) The date of the end of the engine manufacturer's model year production for each engine family;

(vii) For each test conducted,

~~(a)~~a. A description of the test engine, including:
~~(1)~~1. Configuration and engine family identification,
~~(2)~~2. Year, make, and build date,
~~(3)~~3. Engine identification number and explanation of the identification code, and
~~(4)~~4. Number of hours of service accumulated on engine prior to testing.

~~(b)~~b. Location where service accumulation was conducted and description of accumulation procedure and schedule;

(c)c. Test number, date, test procedure used, initial test results before and after rounding, and final test results for all exhaust emission tests, whether valid or invalid, and the reason for invalidation, if applicable;

(d)d. The exhaust emission data for CO, NO_x and HC for each test engine or watercraft. The data reported must provide two (2) significant figures beyond the number of significant figures in the applicable emission standard.

(e)e. The retest emissions data, as described in paragraph (a)(4)(b)(4)(B)(vi) of this section, for any engine or watercraft failing the initial test, and description of the corrective measures taken, including specific components replaced or adjusted.

(f)f. A complete description of any adjustment, modification, repair, preparation, maintenance, and/or testing that was performed on the test engine, was not reported pursuant to any other part of this article, and will not be performed on all other production engines;

(g)g. A Cumulative Sum analysis, as required in paragraph (a)(2)(c)(2)(A)(i) of this section, of the production line test results for each engine family;

(h)h. Any other information the Executive Officer may request relevant to the determination whether the new engines being manufactured by the engine manufacturer do in fact conform with the regulations with respect to which the Executive Order was issued;

(viii) For each failed engine as defined in paragraph (vii)(d)d., above, a description of the remedy and test results for all retests;

(ix) Every aborted test data and reason for the aborted test.;

(x) The start and stop dates of batch-produced engine family production; and

(xi) The required information for all engine families in production during the quarter regardless of sample size; and.

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

(d) Test Procedures Applicable to All Production-Line and Selective Enforcement Audit Testing.

(1) Standards and Test Procedures. The emission standards, exhaust sampling and analytical procedures are those specified in Section 2442. The exhaust sampling and analytical procedures are those described in the Test Procedures. An engine is in compliance with the production-line or selective enforcement audit standards and test procedures only when all portions of the production-line or selective enforcement audit test procedures and requirements specified in Part IV of the Test Procedures are fulfilled, except that any adjustable engine parameters must be set to any value or position that is within the range available to the ultimate purchaser.

(2) Air Resources Board (ARB) personnel and mobile laboratories must have access to engine or equipment assembly plants, distribution facilities, and test facilities for the purpose of engine selection, testing, and observation. Scheduling of access must be arranged with the designated engine manufacturer's representative and must not unreasonably disturb normal operations (See section 31 of the Test Procedures).

(3) Engine Preparation and Preconditioning.

(A) No emissions tests may be performed on an engine before the first production line test on that engine.

(B) The engine or watercraft must be tested after the engine manufacturer's recommended break-in period. The engine manufacturer must submit to the Executive Officer the schedule for engine break-in and any changes to the schedule with each quarterly report. This schedule must be adhered to for all production-line or selective enforcement audit testing within an engine family and subgroup or engine family and assembly plant as appropriate.

(C) If an engine or watercraft is shipped to a remote facility for production-line or selective enforcement audit testing, and adjustment or repair is necessary because of such shipment, the engine manufacturer must perform the necessary adjustments or repairs only after the initial test of the engine or watercraft. Engine manufacturers must report to the Executive Officer in the quarterly report, all adjustments or repairs performed on engines or watercraft prior to each test. In the event a retest is performed, a request may be made to the Executive Officer, within ten days of the production quarter, for permission to substitute the after-repair test results for the original test results. The Executive Officer will either affirm or deny the request by the engine manufacturer within ten working days from receipt of the request.

(D) If an engine manufacturer determines that the emission test results of an engine or watercraft are invalid, the engine or equipment must be retested. Emission results from all tests must be reported. The engine manufacturer must include a detailed report on the reasons for each invalidated test in the quarterly report.

(4) Manufacturer Notification of Failure.

(A) The Executive Officer will notify the engine manufacturer that the engine manufacturer may be subject to revocation or suspension of the Executive Order authorizing sales and distribution of the noncompliant engines in the State of California of the noncompliant engines in the State of California pursuant to section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or seeking to enjoin an engine manufacturer, the Executive Officer will consider all information provided by the engine manufacturer, and other interested parties, including, but not limited to corrective actions applied to the noncompliant engine family.

(B) The Executive Officer will notify the equipment manufacturer that the equipment manufacturer may be subject to revocation or suspension of the Executive Order or penalized pursuant to section 43017 of the Health and Safety Code. Prior to revoking or suspending the Executive Order, or penalizing an equipment manufacturer, the Executive Officer will consider all information provided by interested parties, including, but not limited to corrective actions applied to the noncompliant engine family.

(5) Suspension and Revocation of Executive Orders.

(A) The Executive Order is automatically suspended with respect to any engine failing pursuant to paragraph (b)(3)(D) or (c)(2)(A)(iv) effective from the time that testing of that engine is completed.

(B) The Executive Officer may suspend the Executive Order for an engine family that is determined to be in noncompliance pursuant to paragraph (b)(3)(C) or (c)(2)(A)(v). This suspension will not occur before fifteen (15) days after the engine family is determined to be in noncompliance.

(C) If the results of testing pursuant to these regulations indicate that engines of a particular family produced at one plant of an engine manufacturer do not conform to the regulations with respect to which the Executive Order was issued, the Executive Officer may suspend the Executive Order with respect to that family for engines manufactured by the engine manufacturer at all other plants.

(D) Notwithstanding the fact that engines described in the application for certification may be covered by an Executive Order, the Executive Officer may suspend such Executive Order immediately in whole or in part if the Executive Officer finds any one of the following infractions to be substantial:

(i) The engine manufacturer refuses to comply with any of the requirements of this section.

(ii) The engine manufacturer submits false or incomplete information in any report or information provided to the Executive Officer under this section.

(iii) The engine manufacturer renders inaccurate any test data submitted under this section.

(iv) An ARB enforcement officer is denied the opportunity to conduct activities authorized in this section.

(v) An ARB enforcement officer is unable to conduct activities authorized in paragraph (d)(2) of this section because an engine manufacturer has located its facility in a foreign jurisdiction where local law prohibits those activities.

(E) The Executive Officer will notify the engine manufacturer in writing of any suspension or revocation of an Executive Order in whole or in part. A suspension or revocation is effective upon receipt of the notification or fifteen (15) days from the time an engine family is determined to be in noncompliance pursuant to paragraph (d)(1), except that the Executive Order is immediately suspended with respect to any failed engines as provided for in paragraphs (b)(3)(D) or (c)(2)(iv) of this section.

(F) The Executive Officer may revoke an Executive Order for an engine family after the Executive Order has been suspended pursuant to paragraphs (d)(5)(B) or (C) of this section if the proposed remedy for the nonconformity, as reported by the engine manufacturer to the Executive Officer, is one requiring a design change or changes to the engine and/or emission control system as described in the application for certification of the affected engine family.

(G) Once an Executive Order has been suspended for a failed engine, as provided for in paragraph (d)(5)(A) of this section, the engine manufacturer must take the following actions before the Executive Order is reinstated for that failed engine:

(i) Remedy the nonconformity;

(ii) Demonstrate that the engine conforms to its applicable FEL by retesting the engine in accordance with these regulations; and

(iii) Submit a written report to the Executive Officer, after successful completion of testing on the failed engine, that contains a description of the remedy and test results for each engine in addition to other information that may be required by this part.

(H) Once an Executive Order for a failed engine family has been suspended pursuant to paragraphs (d)(5)(B), (C) or (D) of this section, the engine manufacturer must take the following actions before the Executive Officer will consider reinstating the Executive Order:

(i) Submit a written report to the Executive Officer that identifies the reason for the noncompliance of the engines, describes the proposed remedy, including a description of any proposed quality control and/or quality assurance measures to be taken by the engine manufacturer to prevent future occurrences of the problem, and states the date on which the remedies will be implemented.

(ii) Demonstrate that the engine family for which the Executive Order has been suspended does in fact comply with the regulations of paragraphs (b) or (c), as applicable, by testing as many engines as needed so that the Cumulative Sum statistic, as calculated in paragraph (c)(2)(A)(i), falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(3)(A) remains below the FEL, as applicable. Such testing must comply with the provisions of paragraphs (b) or (c), as applicable. If the engine manufacturer elects to continue testing individual engines after suspension of an Executive Order, the Executive Order is reinstated for any engine actually determined to be in conformance with the emission standards through testing in accordance with the applicable test procedures, provided that the Executive Officer has not revoked the Executive Order pursuant to paragraph (d)(5)(F) of this section.

(I) Once the Executive Order has been revoked for an engine family, if the engine manufacturer wants to introduce into commerce a modified version of that family, the following actions must be taken before the Executive Officer may issue an Executive Order for that modified family:

(i) If the Executive Officer determines that the proposed change(s) in engine design may have an effect on emission performance deterioration, the Executive Officer will notify the engine manufacturer, within five (5) working days after receipt of the report in paragraph (d)(5)(H)(i) of this section, whether subsequent testing under this section will be sufficient to evaluate the proposed change or changes or whether additional testing will be required; and

(ii) After implementing the change or changes intended to remedy the nonconformity, the engine manufacturer must demonstrate that the modified engine family does in fact conform with the regulations of paragraphs (b) or (c), as applicable, by testing as many engines as needed from the modified engine family so that the Cumulative Sum statistic, as calculated in paragraph (c)(2)(A)(i), falls below the action limit, or the average emissions from the Quality-Audit testing as calculated in paragraph (b)(3)(A) remains below the FEL, as applicable. When this requirement is met, the Executive Officer will reissue the Executive Order or issue a new Executive Order, as the case may be, to include that family. The revocation of engine family executive orders issued based on Cumulative Sum testing results remains in effect as long as the Cumulative Sum statistic remains above the action limit.

(J) At any time after the suspension of an Executive Order for a test engine under to paragraph (d)(5)(A)_of this section, but not later than fifteen (15) days (or such longer period as may be allowed by the Executive Officer) after notification of the Executive Officer's decision to suspend or revoke an Executive Order in whole or in part pursuant to paragraphs (d)(5)(B), (C) or (F) of this section, an engine manufacturer may request a hearing pursuant to subchapter 1.25, Title 17, California Code of Regulations, as to whether the tests have been properly conducted or any sampling methods have been properly applied.

(K) Any suspension of an Executive Order under paragraph (d)(5)(D) of this section:

(i) must be made only after the engine manufacturer concerned has been offered an opportunity for a hearing pursuant to subchapter 1.25, Title 17, California Code of Regulations, and;

(ii) does not apply to engines no longer in the possession of the engine manufacturer.

(L) After the Executive Officer suspends or revokes an Executive Order pursuant to this section and before the commencement of a hearing, if the engine manufacturer demonstrates to the Executive Officer's satisfaction that the decision to suspend or revoke the Executive Order was based on erroneous information, the Executive Officer will reinstate the Executive Order.

(M) To permit an engine manufacturer to avoid storing non-test engines while conducting subsequent testing of the noncomplying family, an engine manufacturer may request that the Executive Officer conditionally reinstate the Executive Order for that family. The Executive Officer may reinstate the Executive Order subject to the following condition: the engine manufacturer must commit to recall all engines of that family produced from the time the Executive Order is conditionally reinstated, and must commit to remedy any nonconformity at no expense to the owner.

(e) Selective Enforcement Auditing Regulations.

(1) Test eOrders.

(A) A test order addressed to the engine manufacturer is required for any testing under paragraph (e).

(B) The test order is signed by the Executive Officer or his or her designee. The test order must be delivered in person by an ARB enforcement officer or ARB authorized representative to a company representative or sent by registered mail, return receipt requested, to the engine manufacturer's representative who signed the application for certification submitted by the engine manufacturer, pursuant to the requirements of the applicable portions of Title 13, California Code of Regulations, section 2447. Upon receipt of a test order, the engine manufacturer must comply with all of the provisions of this subsection and instructions in the test order.

(C) Information included in test order.

(i) The test order will specify the engine family to be selected for testing, the engine manufacturer's engine assembly plant or associated storage facility or port facility (for imported engines) from which the engines must be selected, the time and location at which engines must be selected, and the procedure by which engines of the specified family must be selected. The test order may specify the configuration to be audited and/or the number of engines to be selected per day. Engine manufacturers are required to select a minimum of four engines per day unless an alternate selection procedure is approved pursuant to paragraph (e)(2)(A), or unless total production of the specified configuration is less than four engines per day. If total production of the specified configuration is less than four engines per day, the engine manufacturer selects the actual number of engines produced per day.

(ii) The test order may include alternate families to be selected for testing at the Executive Officer's discretion in the event that engines of the specified family are not available for testing because those engines are not being manufactured during the specified time or are not being stored at the specified assembly plant, associated storage facilities, or port of entry.

(iii) If the specified family is not being manufactured at a rate of at least two (2) engines per day in the case of engine manufacturers specified in paragraph (e)(4)(G)(i) of this section, or one engine per day in the case of engine manufacturers specified in paragraph (e)(4)(G)(ii) of this section, over the expected duration of the audit, the Executive Officer or her or his designated representative may select engines of the alternate family for testing.

(iv) In addition, the test order may include other directions or information essential to the administration of the required testing.

(D) An engine manufacturer may submit a list of engine families and the corresponding assembly plants, associated storage facilities, or (in the case of imported engines) port facilities from which the engine manufacturer prefers to have engines selected for testing in response to a test order. In order that an engine manufacturer's preferred location be considered for inclusion in a test order for a particular engine family, the list must be submitted prior to issuance of the test order. Notwithstanding the fact that an engine manufacturer has submitted the list, the Executive Officer may order selection at other than a preferred location.

(E) Upon receipt of a test order, an engine manufacturer must proceed in accordance with the provisions of paragraph (e).

(2) Testing by the Executive Officer.

(A) The Executive Officer may require by test order under paragraph (e)(1) that engines of a specified family be selected in a manner consistent with the requirements of paragraph (e)(3) and submitted to the Executive Officer at the place designated for the purpose of conducting emission tests. These tests will be conducted in accordance with paragraph (e)(4) to determine whether engines manufactured by the engine manufacturer conform with the regulations with respect to which the certificate of conformity was issued.

(B) Designating official data.

(i) Whenever the Executive Officer conducts a test on a test engine or the Executive Officer and engine manufacturer each conduct a test on the same test engine, the results of the Executive Officer's test are the official data for that engine.

(ii) Whenever the engine manufacturer conducts all tests on a test engine, the engine manufacturer's test data are accepted as the official data, provided that if the Executive Officer makes a determination based on testing conducted under paragraph (e)(2)(A) of this section that there is a substantial lack of agreement between the engine manufacturer's test results and the Executive Officer's test results, no engine manufacturer's test data from the engine manufacturer's test facility will be accepted for purposes of this subsection.

(C) If testing conducted under paragraph (e)(1) is unacceptable under paragraph (B)(ii) of this subsection, the Executive Officer must:

(i) Notify the engine manufacturer in writing of the Executive Officer's determination that the test facility is inappropriate for conducting the tests required by this subsection and the reasons therefor; and

(ii) Reinstate any engine manufacturer's data upon a showing by the engine manufacturer that the data acquired under paragraph (e)(2) were erroneous and the engine manufacturer's data was correct.

(D) The engine manufacturer may request in writing that the Executive Officer reconsider the determination in paragraph (B)(ii) of this section based on data or information indicating that changes have been made to the test facility and these changes have resolved the reasons for disqualification.

(3) Sample selection.

(A) Engines comprising a test sample will be selected at the location and in the manner specified in the test order. If an engine manufacturer determines that the test engines cannot be selected in the manner specified in the test order, an alternative selection procedure may be employed, provided the engine manufacturer requests approval of the alternative procedure before starting test sample selection, and the Executive Officer approves the procedure.

(B) The engine manufacturer must produce and assemble the test engines of the family selected for testing using its normal production and assembly process for engines to be distributed into commerce. If, between the time the engine manufacturer is notified of a test order and the time the engine manufacturer finishes selecting test engines, the engine manufacturer implements any change(s) in its production or assembly processes, including quality control, which may reasonably be expected to affect the emissions of the engines selected, then the engine manufacturer must, during the audit, inform the Executive Officer of such changes. If the test engines are selected at a location where they do not have their operational and emission control systems installed, the test order will specify the manner and location for selection of components to complete assembly of the engines. _The engine manufacturer must assemble these components onto the test engines using normal assembly and quality control procedures as documented by the engine manufacturer.

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

(D) The test order may specify that an ARB enforcement officer(s) or authorized representative(s), rather than the engine manufacturer, select the test engines according to the method specified in the test order.

(E) The order in which test engines are selected determines the order in which test results are to be used in applying the sampling plan in accordance with paragraph (e)(5).

(F) The engine manufacturer must keep on hand all untested engines, if any, comprising the test sample until a pass or fail decision is reached in accordance with paragraph (e)(5)(E). The engine manufacturer may ship any tested engine which has not failed the requirements as set forth in paragraph (e)(5)(B). However, once the engine manufacturer ships any test engine, it may not conduct retests as provided in paragraph (e)(4)(I).

(4) Test procedures.

(A)(i) For spark-ignition marine engines subject to the provisions of this subsection, the prescribed test procedures are the test procedures as specified in Part IV of the Test Procedures.

(ii) The Executive Officer may, on the basis of a written application by an engine manufacturer, prescribe test procedures other than those specified in paragraph (i) for any spark-ignition marine engine he or she determines is not susceptible to satisfactory testing using the procedures specified in paragraph (i).

(B)(i) The engine manufacturer may not adjust, repair, prepare, or modify the engines selected for testing and may not perform any emission tests on engines selected for testing pursuant to the test order unless this adjustment, repair, preparation, modification, and/or tests are documented in the engine manufacturer's engine assembly and inspection procedures and are actually performed or unless these adjustments and/ or tests are required or permitted under this subsection or are approved in advance by the Executive Officer.

(ii) The Executive Officer may adjust or cause to be adjusted any engine parameter that the Executive Officer determines subject to adjustment for certification and Selective Enforcement Audit testing in accordance with Part I, section 18 of the Test Procedures, ~~adopted October 21, 1999, and incorporated by reference herein,~~ to any setting within the physically adjustable range of that parameter, as determined by the Executive Officer in accordance with section

18, prior to the performance of any tests. However, if the idle speed parameter is one which the Executive Officer has determined to be subject to adjustment, the Executive Officer may not adjust it to any setting that causes a lower engine idle speed than would have been possible within the physically adjustable range of the idle speed parameter if the engine manufacturer had accumulated 12 hours of service on the engine under paragraph (C) of this section, all other parameters being identically adjusted for the purpose of the comparison. The engine manufacturer may be requested to supply information needed to establish an alternate minimum idle speed. The Executive Officer, in making or specifying these adjustments, may consider the effect of the deviation from the engine manufacturer's recommended setting on emission performance characteristics as well as the likelihood that similar settings will occur on in-use engines. In determining likelihood, the Executive Officer may consider factors such as, but not limited to, the effect of the adjustment on engine performance characteristics and information from similar in-use engines.

(C) Service Accumulation. Before performing exhaust emission testing on a selective enforcement audit test engine, the engine manufacturer may accumulate on each engine a number of hours of service equal to the greater of 12 hours or the number of hours the engine manufacturer accumulated during certification on the emission data engine corresponding to the family specified in the test order.

(i) Service accumulation must be performed in a manner using good engineering judgment to obtain emission results representative of normal production engines. This service accumulation must be consistent with the new engine break-in instructions contained in the applicable owner's manual.

(ii) The engine manufacturer must accumulate service at a minimum rate of 6 hours per engine during each 24-hour period, unless otherwise approved by the Executive Officer.

~~(a)~~a. The first 24-hour period for service begins as soon as authorized checks, inspections, and preparations are completed on each engine.

~~(b)~~b. The minimum service accumulation rate does not apply on weekends or holidays.

~~(c)~~c. If the engine manufacturer's service or target is less than the minimum rate specified (6 hours per day), then the minimum daily accumulation rate is equal to the engine manufacturer's service target.

(iii) Service accumulation must be completed on a sufficient number of test engines during consecutive 24-hour periods to assure that the number of engines tested per day fulfills the requirements of paragraphs (G)(i) and (G)(ii) ~~of this section~~below.

(D) The engine manufacturer may not perform any maintenance on test engines after selection for testing, nor may the Executive Officer allow deletion of any engine from the test sequence, unless requested by the engine manufacturer and approved by the Executive Officer before any engine maintenance or deletion.

(E) The engine manufacturer must expeditiously ship test engines from the point of selection to the test facility. If the test facility is not located at or in close proximity to the point of selection, the engine manufacturer must assure that test engines arrive at the test facility within 24 hours of selection. The Executive Officer may approve more time for shipment based upon a request by the engine manufacturer accompanied by a satisfactory justification.

(F) If an engine cannot complete the service accumulation or an emission test because of a malfunction, the engine manufacturer may request that the Executive Officer authorize either the repair of that engine or its deletion from the test sequence.

(G) Whenever an engine manufacturer conducts testing pursuant to a test order issued under this subsection, the engine manufacturer must notify the Executive Officer within one working day of receipt of the test order as to which test facility will be used to comply with the test order. If no test cells are available at a desired facility, the engine manufacturer must provide alternate testing capability satisfactory to the Executive Officer.

(i) An engine manufacturer with projected spark-ignition marine engine sales for the California market for the applicable year of 20 or greater must complete emission testing at a minimum rate of two (2) engines per 24-hour period, including each voided test.

(ii) An engine manufacturer with projected spark-ignition marine engine sales for the California market for the applicable year of less than 20 must complete emission testing at a minimum rate of one engine per 24-hour period, including each voided test.

(iii) The Executive Officer may approve a lower daily rate of emission testing based upon a request by an engine manufacturer accompanied by a satisfactory justification.

(H) The engine manufacturer must perform test engine selection, shipping, preparation, service accumulation, and testing in such a manner as to assure that the audit is performed in an expeditious manner.

(I) Retesting.

(i) The engine manufacturer may retest any engines tested during a Selective Enforcement Audit once a fail decision for the audit has been reached in accordance with paragraph (e)(5)(E).

(ii) The Executive Officer may approve retesting at other times based upon a request by the engine manufacturer accompanied by a satisfactory justification.

(iii) The engine manufacturer may retest each engine a total of three times. The engine manufacturer must test each engine or vehicle the same number of times. The engine manufacturer may accumulate additional service before conducting a retest, subject to the provisions of paragraph (C) of this paragraph (4).

(J) An engine manufacturer must test engines with the test procedure specified in Part IV of the Test Procedures to demonstrate compliance with the exhaust emission standard (or applicable FEL) for $HC+NO_x$. If alternate procedures were used in certification pursuant to Part 1, section 20(c) of the Test Procedures, ~~adopted October 21, 1999 and incorporated by reference herein,~~ then those alternate procedures must be used.

(5) Compliance with acceptable quality level and passing and failing criteria for selective enforcement audits.

(A) The prescribed acceptable quality level is 40 percent.

(B) A failed engine is one whose final test results for $HC+NO_x$ pursuant to paragraph (b)(3)(D) or (c)(2)(iv), as applicable, exceed the applicable family emission level.

(C) The engine manufacturer must test engines comprising the test sample until a pass or fail decision is reached for $HC+NO_x$. A pass decision is reached when the cumulative number of failed engines, as defined in paragraph (B), for $HC+NO_x$, is less than or equal to the pass decision number, as defined in paragraph (D), appropriate to the cumulative number of engines tested. A fail decision is reached when the cumulative number of failed engines for $HC+NO_x$ is greater than or equal to the fail decision number, as defined in paragraph (D), appropriate to the cumulative number of engines tested.

(D) The pass and fail decision numbers associated with the cumulative number of engines tested are determined by using the tables in Appendix A to this subsection (e), "ASampling Plans for Selective Enforcement Auditing of Spark-Ignition Marine Engines," appropriate to the projected sales as made by the engine manufacturer in its report to ARB under paragraph (b)(4) or (c)(3)(A). In the tables in Appendix A to this subsection, sampling plan "Astage" refers to the cumulative number of engines tested. Once a pass or fail decision has been made for $HC+NO_x$, the number of engines with final test results exceeding the emission standard for $HC+NO_x$ shall not be considered any further for the purposes of the audit.

(E) Passing or failing a selective enforcement audit occurs when the decision is made on the last engine required to make a decision under paragraph (C).

(F) The Executive Officer may terminate testing earlier than required in paragraph (C) upon either a manufacturers'= or Executive Officer's admission that further testing would not change the pass/fail decision.

NOTE: Authority cited: Sections 39600, 39601, 43013, 43018, 43101, 43102 and 43104, Health and Safety Code.
Reference: Sections 43013, 43017, 43018, 43101, 43102, 43104, 43105, 43150-43154, 43205.5 and 43210-43212, Health and Safety Code.

ATTACHMENT B

TEST PROCEDURES

State of California
AIR RESOURCES BOARD

CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2001 MODEL YEAR AND LATER SPARK-IGNITION MARINE ENGINES

Adopted: October 21, 1999
Amended: (insert date of amendment)

[Note: The proposed amendments for this rulemaking action are shown in ~~strikethrough~~ to indicate proposed deletions and underline to indicate proposed additions.]

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CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2001 MODEL YEAR AND LATER SPARK-IGNITION MARINE ENGINES

Part I. Emission Regulations for 2001 and Later New Spark-Ignition Marine Engines, General Provisions.

1. General Applicability.

(a) (1) This rule applies to model year 2001 and ~~subsequent~~later ~~model year~~ spark-ignition (SI) marine engines ~~used to propel marine vessels as defined in the General Provisions of the United States Code, 1 U.S.C.3 (1992)~~, unless otherwise indicated.

~~(2) Sterndrive and inboard engines are exempt from this rule.~~

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

(3) Spark-ignition inboard and sterndrive marine engines produced by the engine manufacturer specifically for competition are exempt from the requirements of this document, provided that the marine watercraft in which the engine is installed is designed, built, and used solely for competition. Marine watercraft used for amateur or occasional competition do not meet the competition exemption criteria.

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

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

(2) This article shall not apply to engines used in off-road military tactical vehicles or equipment which have been exempted from regulations under the federal national security exemption, 40 CFR, subpart J, section 90.908, which is incorporated by reference herein. It shall also not apply to those vehicles and equipment covered by the definition of military tactical vehicle that are commercially available and for which a federal certificate of conformity has been issued under 40 CFR Part 91-, subpart B, which is incorporated by reference herein.

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

2. Definitions.

The definitions in section 2441, Chapter 9, Title 13 of the California Code of Regulations apply with the following additions:

"Engine Family" is a subclass of a basic engine based on similar emission characteristics. The engine family is the grouping of engines that is used for the purposes of certification, and is determined in accordance with section 17.

"Engine-Displacement-System Combination" or "Engine Family-Displacement-Emission Control System Combination" is a subclass of an engine family based on engine displacement and specific emission control system components, and is used for purposes of test engine selection.

"Engine Model" or "Engine Code" is a subclass of an engine-displacement-system combination on the basis of the engine calibration (e.g., carburetor jet size, valve timing, etc.), and other parameters that may be designated by the Executive Officer.

"Gross Power" means the power measured at the engine crankshaft (or equivalent) and produced by an engine that is equipped with only the accessories that are necessary for engine operation.

"Hang-up" means the situation whereby hydrocarbon molecules are absorbed, condensed, or otherwise removed from the sample flow prior to the instrument detector; and any subsequent desorption of the molecules into the sample flow when such molecules are assumed to be absent.

"Incomplete Engine Assembly" is a basic engine assembly that does not include all of the components necessary for designation as a complete engine assembly, and is marketed in order to be a part of, and assembled into, a new unit of equipment.

"Oxides of Nitrogen" means the sum of the nitric oxide and nitrogen dioxide contained in a gas sample as if the nitric oxide were in the form of nitrogen dioxide.

"Rated Power" means the maximum brake power output (in kilowatts) of an engine as specified by an engine manufacturer.

"Rated Speed" means the engine speed (revolutions per minute [rpm]) at which the manufacturer specifies the maximum rated power of an engine.

"Span gas" means a gas of known concentration that is used routinely to set the output level of any analyzer.

"Special Tool" means a tool or fixture specified by an engine manufacturer that is intended to perform only a specific function with respect to an engine; and the effective usage of the tool or fixture requires special expertise.

3. **Abbreviations.**

ARB – California Air Resources Board.
AECD – Auxiliary emission control device
ASME – American Society of Mechanical Engineers
ASTM – American Society for Testing and Materials
C – Carbon.
C – Celsius.
C_3H_8 – Propane.
cc – Cubic centimeter(s).
cfm – Cubic feet per minute.
cfh – Cubic feet per hour.
CLD – chemiluminescent detector
cm – Centimeter(s).
CO – Carbon monoxide.

CO_2 – Carbon Dioxide.
Conc – Concentration.
cu. – Cubic.
CVS – Constant Volume Sample.
EGR – Exhaust gas recirculation.
EP – End point.
F – Fahrenheit.
FEL – Family Emission Limit
g – Gram(s).
g/kW-hr – gram(s) per kilowatt hour
h – hour.
HC – Hydrocarbon(s.)
HCLD – heated chemiluminescent detector.
HFID – heated flame ionization detector.
Hg – Mercury.
hp – Horsepower.
HSC – Health and Safety Code
H_2O – Water.
in. – Inch(es)
K – Kelvin.
kg – Kilogram(s).
km – Kilometer(s).
kPa – Kilopascals.
kW – kilowatt
lb – Pound(s).
m – meter(s).
mph – Miles per hour.
mm – Millimeter(s).
N – Newton.
~~N – Nitrogen.~~
N_2 – Nitrogen.
NDIR – non-dispersive infrared analyzer
NGPA – Natural Gas Processors Association
NIST – National Institute of Standards and Testing.
NO – Nitric Oxide.
NO_2 – Nitrogen Oxide.
NO_x – Oxides of nitrogen.
No. – Number.
O_2 – Oxygen.
OB – Outboard engine(s).
Pa – Pascals.
Pb – Lead.
PMD – Paramagnetic detector.
ppm – Parts per million by volume.
psi – Pounds per square inch.
psig – Pounds per square inch gauge.

PWC – Personal watercraft.
R – Rankine.
rpm – Revolutions per minute.
SI – Spark-ignition.
U.S.C. – United States Code.
VOC – Volatile organic compounds
wt – Weight.
ZROD – Zirconium dioxide sensor
° – Degree(s).
% – Percent.

4. Measurement System.

These provisions utilize the International System of Units.

5. General Standards; Increase in Emissions; Unsafe Conditions.

(a) Any emission control system installed on or incorporated in a new spark-ignition marine engine to enable such an engine to conform to standards imposed by these provisions:
  (1) Must not in its operation or function cause the emission into the ambient air of any noxious or toxic substances that would not be emitted in the operation of such engine without such emission control system, except as specifically permitted by regulation; and,
  (2) Must not in its operation, function, malfunction result in any unsafe condition endangering the equipment, its user(s), or persons or property in close proximity to the equipment.

(b) Every manufacturer of new spark-ignition marine engines subject to any of the standards imposed by these provisions must test, or cause to be tested, engines in accordance with good engineering practice to ascertain that such test engines will meet the requirements of this section for the useful life of the engine.

6. Defeat Devices, Prohibition.

(a) No spark-ignition marine engine may be equipped with a defeat device.

(b) Defeat device means any element of design that:
  (1) Senses temperature, engine RPM, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying or deactivating the operation of any part of the emission control system; and,
  (2) Reduces the effectiveness of the emission control system under conditions that may reasonably be expected to be encountered in normal equipment operation and use, unless:

(i) Such conditions are substantially included in the test procedure; or,
(ii) The need for the device is justified in terms of protecting the spark-ignition marine engine against damage or accident; or,
(iii) The device does not go beyond the requirements of engine starting or warm-up.

7. **[Reserved].**

8. **Replacement Engines.**

No new spark-ignition marine engines may be produced for sale to replace spark-ignition marine engines in pre-2001 model year equipment after the 2004 model year, unless those engines comply with the 2001 model year emission standards.

9. **Exhaust Emission Standards for 2001 and Later Spark-Ignition Marine Engines.**

(a) Model year 2001 and later model year spark-ignition personal watercraft and outboard marine engines:

~~(a)~~(1) Exhaust emissions from new spark-ignition marine engines manufactured for sale, sold, or offered for sale in California, or that are introduced, delivered or imported into California for introduction into commerce, must not exceed the following standards:

Table 1. Corporate Average Emission Standards by Implementation Date $HC+NO_x$ (in g/kW-hr)

Corporate Average Emission Standards by Implementation Date $HC+NO_x$ (g/kW-hr)			
Model Year	**Max. Family Emission Limit (FEL)**	**P_{tx} < 4.3 kW**	**$P_{tx} \geq$ 4.3 kW**
2001-2003	Not Applicable	81.00	$(0.25 \times (151+557/P_{tx}^{0.9})) + 6.0$
2004-2007	80	64.80	$(0.20 \times (151+557/P_{tx}^{0.9})) + 4.8$
2008 and Later	44	30.00	$(0.09 \times (151+557/P_{tx}^{0.9})) + 2.1$

where:

P_{tx} is the average power in kilowatts (kW) (sales-weighted) of the total number of spark-ignition marine engines produced for sale in California in model year x. Engine power must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference. Engine manufacturers must not determine P_{tx} by combining the power outputs of personal watercraft engines.

~~(b)~~(2) An engine manufacturer may comply with the standards directly on an individual engine family basis. Consequently in Table 1, FELs are not applicable for any model year and P_{tx} means the average power in kW (sales-weighted) of the subject engine family produced for sale in California in model year x.

Compliance with the standards on a corporate average basis is determined as follows:

$$\frac{\sum_{j=1}^{n}(PROD_{jx})(FEL_{jx})(P_{jx})}{\sum_{j=1}^{n}(PROD_{jx})(P_{jx})} = STD_{ca}$$

where:

n = total number of engine families (by category)

$PROD_{jx}$ = number of units each engine family j produced for sale in California in model year x.

FEL_{jx} = the Family Emission Limit (FEL) for engine family j in model year x, which must be determined by the engine manufacturer subject to the following conditions: (1) no individual engine family FEL shall exceed the maximum allowed value as specified in Table 1; (2) no engine family designation or FEL shall be amended in a model year unless the engine family is recertified; and (3) prior to sale or offering for sale in California, each engine family must be certified in accordance with the test procedures referenced in section 2447 and must meet the engine manufacturer's FEL as a condition of the Executive Order. Before certification, the engine manufacturer must also submit estimated production volumes for each engine family to be offered for sale in California.

P_{jx} = The average power in kW (sales-weighted) of engine family j produced for sale in California in model year x. Engine power must be calculated using SAE standard J1228, November 1991, incorporated herein by reference.

STD_{ca} = An engine manufacturer's calculated corporate average $HC+NO_x$ exhaust emissions from those California spark-ignition marine engines subject to the California corporate average $HC+NO_x$ exhaust emission standard determined from Table 1, as established by an Executive Order certifying the California production for the model year. This Executive Order must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

~~(1)~~(A) For purposes of compliance under this paragraph, engine manufacturers must not corporate average outboard engine families in combination with personal watercraft engine families.

~~(2)~~(B) During engine manufacturer's production year, for each engine family, the manufacturer shall provide to the Executive Officer within 45 days after the last day in each calendar quarter: The total number of spark-ignition marine engines produced for sale in California and their applicable FEL.

~~(3)~~(C) The Executive Order certifying the California production for a model year must be obtained prior to the issuance of certification Executive Orders for individual engine families for the model year.

~~(4)~~(D) The engine manufacturer's average pollutant exhaust emissions must meet the corporate average standard at the end of the manufacturer's production for the model year. No later than 90 days after the end of the model year, the manufacturer must calculate a corrected corporate average using actual rather than projected sales.

~~(5)~~(E) Production and sale of spark-ignition marine engines which result in non-compliance with the California standard for the model year shall cause an engine manufacturer to be subject to civil penalties, per engine, pursuant to section 43017 of the Health and Safety Code, and subject to all other remedies available under Part 5, Division 26 of the Health and Safety Code. All excess emissions resulting from non-compliance with the California standard must be made up in the following model year.

~~(6)~~(F) For each model the engine manufacturer shall submit California sales data.

(b) Exhaust emissions from new model year 2003 and later spark-ignition inboard and sterndrive marine engines must not exceed the exhaust emission standards listed in Table 2 or Table 3, as applicable, for the designated emission durability test period.

Table 2.

Inboard and Sterndrive Exhaust Emission Standards (by Implementation Date)		
Model Year	**$HC+NO_x$** (grams per kilowatt-hour)	**Durability Test Period** (hours)
2003-2008[1]	15.0[2]	—
2007 and Later[3, 4]	5.0	480

1. Engines with a maximum rated power exceeding 373 kilowatts (500 horsepower) are not required to comply with these standards.
2. Compliance to the $HC+NO_x$ standard may be averaged on a sales-weighted basis, across the engine manufacturers' California production.
3. For model year 2007, engine manufacturers shall certify a minimum of 10% of their California production to the 2009 model year emission standards and other requirements.
4. For model year 2008, engine manufacturers shall certify a minimum of 50% of their California production to the 2009 model year emission standards and other requirements.

Table 3.

Small Volume Manufacturers Inboard and Sterndrive Exhaust Emission Standards		
Model Year	**$HC+NO_x$** (grams per kilowatt-hour)	**Durability Test Period** (hours)
2009 and Later	5.0	480

(c) In 2001 and subsequent model years, fire and police departments, and other entities that specialize in emergency response may purchase emergency equipment powered by a non-California-certified spark-ignition marine engine only when such equipment with a California-certified spark-ignition marine engine is not available. For purposes of this section, a request to purchase emergency equipment powered by a non-California-certified engine must be submitted for approval to the Executive Officer.

10. Maintenance and Warranty Instructions.

Maintenance and warranty instructions must conform with the requirements pursuant to sections 2445.1 and 2445.2, Title 13, California Code of Regulations.

11. Labeling.

Labeling required pursuant to sections 2443.1, 2443.2 and 2443.3, Title 13 of the California Code of Regulations must conform with the requirements specified therein.

12. Submission of Engine Identification Number.

(a) The manufacturer of any spark-ignition marine engine covered by an Executive Order must furnish to the Executive Officer, at the beginning of each model year, information and an explanation about the engine identification number system pursuant to section 2443.1(e), Title 13 of the California Code of Regulations that identifies production engines that are covered by an Executive Order.

(b) Within 30 days of receiving a request by the Executive Officer, the manufacturer of any spark-ignition marine engine covered by an Executive Order must identify such engines by their identification number system provided under the requirements of paragraph (a) above.

13. [Reserved].

14. Application for Certification.

(a) The Executive Officer may request notification, sixty (60) days prior to the initial model year submission of an engine manufacturer's certification application(s), of the engine manufacturer's intent to seek engine family certification (i.e., a letter of intent) so that the Executive Officer can adequately allocate resources required for reviewing such certification applications in a timely manner. Such letters of intent must provide the engine manufacturer's best estimate of general information for the applicable model-year certification, such as identification of each engine family, date of expected submission, etc.

(b) New spark-ignition marine engines are covered by the following:

(1) Manufacturers of new spark-ignition marine engines must complete and submit to the Executive Officer a written application, in the English language, requesting an Executive Order that certifies such engines be issued. The engine manufacturer must update and correct by amendment such applications whenever changes are made to engines that are delineated in the certification application (see section 28). An engine manufacturer must include within a single application for certification all engine models within an engine family (see section 17 to determine what is an engine family). The application must describe each applicable engine model in the engine family. An engine manufacturer may, however, choose to apply separately for certification of part of its engine product line. The selection of test engines and the computation of emission test results must be determined by the Executive Officer for each separate and individual engine family certification application.

(2) The certification application must be signed by an authorized representative of the engine manufacturer. The certification application must include the following:

(i) Identification and description of the engines covered by the engine family certification application; descriptions of the engine designs (e.g., combustion chamber, valves, etc.); and, identifications (i.e., part numbers) and descriptions of the emission control system and components, auxiliary emission control devices, fuel system and components, air inlet system and components, exhaust system and components, and any optional equipment. For purposes of this section, "auxiliary emission control device" means any element of design that senses temperature, engine RPM, manifold vacuum, or any other parameter for the purpose of activating, modulating, delaying, or deactivating the operation of any part of the emission control system.

(ii) Emission control warranty information as set forth in section 10.

(iii) Emission control and consumer/environmental label information as set forth in section 11, including actual production labels and descriptions of all applicable label attachment locations.

(iv) Identification and description (i.e., range, value, etc.) of any adjustable engine parameters (e.g., idle fuel/air, ignition timing, etc.); and a description of the method used to ensure that the emission characteristics of the certification test engines remain representative of those of the production engines with respect to any adjustments of such engine parameters.

(v) Projected California sales data of the engine family for which certification is requested. Where applicable, the sales for each engine model within the engine family should be provided. Such estimated sales data must include an explanation of the method used to make the estimate.

(vi) A description of the facility and equipment used to test the engines for certification including (as applicable) specifications about the dynamometers, gas analyzers, data collection devices, etc.

(vii) Information about the certification test fuels and lubricants, and information about the commercially available fuels and lubricants recommended for use in the production engines.

(viii) A description of the proposed certification test engine service accumulation (e.g., break-in) procedure and the certification test engine maintenance schedule.

(ix) A statement of recommended periodic and anticipated procedures for maintenance necessary to assure that the engine covered by an Executive Order conforms to the regulations. The statement must include a listing of the fuels and lubricants recommended for use by the ultimate purchaser and a description of the training program for personnel who will perform such maintenance, and the equipment required to perform such maintenance.

(x) The engine family's FEL and an estimate of the overall corporate average emissions for that model year.

(xi) Information about high-altitude adjustments, and an engineering evaluation of one engine family within the manufacturer's line that demonstrates emissions compliance at high altitudes.

(3) Completed copies of the engine family certification application and of any amendments thereto, and all notifications under sections 28 and 29 must be submitted in such multiple copies as the Executive Officer requires.

15. Approval of Application For Certification.

(a) After a review of the complete engine family application for certification and any other information that the Executive Officer requires, the Executive Officer will approve the application if all the foregoing conditions are satisfied.

(b) The Executive Officer may disapprove an engine family application for certification, in whole or in part, for reasons including, but not limited to, being incomplete, inaccurate, or providing inappropriate information regarding proposed break-in procedures, maintenance, test equipment, label content or locations, test fuel or lubricant. It may also be disapproved if the described engines incorporate any defeat devices. If an engine family certification application or part thereof is rejected, the Executive Officer will notify the engine manufacturer in writing and set forth the reasons for such rejection.

16. Engine Displacement of Spark-Ignition Marine engines.

Engine displacements must be calculated using nominal engine values and rounded to the nearest tenth of a cubic centimeter, in accordance with ASTM E 29-93a, (May 1993), incorporated by reference herein.

17. Engine Families and Engine Family Groups.

(a) Certification applications submitted by engine manufacturers must divide engines covered therein into groupings that are expected to have similar emission characteristics throughout their useful life. Each group of engines with similar emission characteristics must be defined as a separate engine family.

(b) In order to be included within the same engine family, engines must be identical in all of the following specifications:

(1) The combustion cycle.
(2) The cooling mechanism.
(3) The cylinder block configuration (i.e., inline, vee, opposed, bore spacings, etc.).
(4) The number of cylinders.
(5) The method of air aspiration.
(6) The number, location, volume, and composition of any catalytic converters.
(7) The thermal reactor characteristics.
(8) The number of carburetors, as applicable.
(9) The prechamber characteristics.
(10) The exhaust port(s) and cylinder design of two-stroke engines.

(c) At the engine manufacturer's option, reciprocating engines identical in all the specifications listed in paragraph (b) of this section may be further divided into different engine families if the Executive Officer determines that they may be expected to have different emission characteristics. This determination will be based upon consideration of factors such as:
(1) The bore and stroke.
(2) The combustion chamber configuration.
(3) The intake and exhaust timing method of actuation (i.e., poppet valve, reed valve, rotary valve, etc.).
(4) The intake and exhaust valve or port sizes, as applicable.
(5) The fuel system.
(6) The exhaust system.

18. Test Engines.

(a) Test engines will be selected by the engine manufacturer to represent each engine-displacement-system combination. The engine manufacturer will select the engine configuration (i.e., air inlet system, exhaust system, engine calibration, etc.) of each engine-displacement-system combination in the engine family that is expected to have the greatest probability of exceeding the emission standards. The Executive Officer will make the final determination whether the test engines selected by the engine manufacturer may be used for certification testing. At the manufacturer's option, the criterion for selecting the worst case engine may be that engine configuration which has the highest weighted brake-specific fuel consumption over the engine test cycle described in section 20(b)(5).

(b) A test engine must be a complete engine assembly with all emission control systems and components that are specified in the certification application installed and functional for test purposes.

(c) Concurrent with the selection of an engine family test engine, the Executive Officer will determine the engine parameters subject to adjustment for certification, assembly-line quality-audit and compliance tests. The Executive Officer will also evaluate the adequacy of the limits, stops, seals, or other methods utilized to control, restrict or inhibit adjustment, and will evaluate resultant adjustable ranges of each parameter. The Executive Officer will notify the engine manufacturer of each determination.
(1) The Executive Officer will consider an engine parameter to be subject to adjustment if the parameter is capable of adjustment and the adjustment may significantly affect emissions.
(2) In order to determine if an engine parameter is subject to adjustment, the Executive Officer will consider the in-use probability

that the parameter may be changed from the values, or beyond the positions, specified in the engine family certification application (i.e., misadjustment). The Executive Officer may evaluate this probability on the basis of factors such as: ease of access to the parameter, damage to the engine or equipment that may result from an attempt to misadjust the parameter, consequence with respect to emissions of a misadjustment, information provided in the preliminary engine family application, and information obtained from any compliance-related activities that are, or may be, required.

(3) The Executive Officer will determine an adjustable parameter to be adequately inaccessible when either or both of the following applies:
   (i) The physical device that controls the adjustable parameter can be accessed only by the disassembly of the engine or equipment, and this disassembly requires the use of special tools.
   (ii) Adequate deterrence to restrict access to an adjustable parameter will not be demonstrated by the necessity to remove an engine component that is routinely removed in maintenance, or that is required to be removed in order to perform an adjustment.

(4) The Executive Officer shall determine an adjustable parameter to be adequately controlled or restricted when one or more of the following apply:
   (i) The device that controls the adjustable parameter is restricted from adjustment beyond the range or values specified in the engine family certification application.
   (ii) The restriction may be circumvented only through the use of special tools.
   (iii) Attempts to misadjust the parameter would result in breakage of the restrictive device and/or the parameter and thereby result in unsatisfactory engine operation.

(5) The Executive Officer may also determine an adjustable parameter to be adequately controlled or restricted when either one or both of the following apply:
   (i) Attempts to misadjust the parameter are ineffective. For example, an adjustment beyond the values or positions specified in the engine family certification application would not alter significantly the engine performance; hence, the emission levels as projected in certification are representative of in-use engine family emissions.
   (ii) Any solid-state memory devices that control or monitor emission control systems or components are protected adequately against unauthorized or inappropriate changes.

(f) [Reserved].

(g) In lieu of testing an engine and submitting data thereon, an engine manufacturer may, with the prior written approval of the Executive Officer, submit exhaust emission data on a similar engine for which certification has previously been obtained or for which all applicable data have previously been submitted (i.e., carryover).

(h) All engines must have closed crankcases. For purposes of this section, "crankcase" means the housing for the crankshaft and other related internal parts.

19. Executive Officer's Engines.

The Executive Officer may require additional tests on the engines selected in accordance with section 18 and tested in accordance with section 20.

20. Test Procedures, General Requirements.

(a) For each engine family, engine manufacturers must determine a deterioration factor for each regulated pollutant pursuant to Part II.

(b) Certification testing of exhaust emissions.

(1) Manufacturers of spark-ignition marine engines must use the test procedures outlined in Part IV.

(2) The exhaust emission test consists of prescribed sequences of engine operating conditions to be conducted on an engine dynamometer. The exhaust gases generated during engine operation are sampled either raw or dilute (as required), and specific components are analyzed through the exhaust gas analytical system. The test is designed to measure (as applicable) the concentration of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), oxides of nitrogen (NO_x), exhaust volume, temperature, fuel flow, and the gross power output. The measured values are weighted and used to calculate the brake-specific emissions of each pollutant (in g/kW-hr).

~~(4)~~(3) For engines with adjustable parameters, the Executive Officer may adjust or require to be adjusted those adjustable parameters to any specification within the adjustable range during testing to determine compliance with the requirements of this Part.

~~(5)~~(4) The exhaust emission test uses prescribed sequences of engine operation as indicated in Table 20-1.

TABLE 20-1. Spark-Ignition, Marine Engine Test Cycle

Mode Number	1	2	3	4	5
Speed (%)	100	80	60	40	Idle
Torque (%)	100	71.6	46.5	25.3	0
Weighting Factor	0.06	0.14	0.15	0.25	0.40

(6)(5) Engine power (in kilowatts) must be calculated using the Society of Automotive Engineers (SAE) standard J1228, November 1991, incorporated herein by reference.

(c) The Executive Officer will prescribe emission test procedures for any spark-ignition marine engine that the Executive Officer determines is not susceptible to satisfactory testing by the methods set forth in the test procedures.

(e)(d) The Executive Officer may revise these test procedures on a case-by-case basis when a request to do so is supported by data and results, or other information, showing the necessity for the revision.

21. Service Accumulation Procedures; Test Engines.

(a) The service accumulation (i.e., break-in) procedure for an emission test engine must be the procedure specified by the engine manufacturer, and must be approved by the Executive Officer before the accumulation of hours.

(b) During the service accumulation period, engine manufacturers must not operate engines for a total of more than 12 hours unless an allowance to do so is approved by the Executive Officer. Engine shutdowns are permitted during the operating sequence; however, the periods of shutdown must not be included in the 12 hour total.

22. Scheduled Maintenance; Test Engines.

(a) Engine manufacturers may schedule and perform break-in maintenance on the emission test engine and its emission control and fuel systems only at the same time intervals specified in the engine manufacturer's break-in maintenance instructions furnished to the ultimate purchaser.

(b) During service accumulation, an engine manufacturer must be restricted to inspecting, replacing, cleaning, adjusting and servicing of the following items: (1) idle speed and idle air/fuel mixture; and, (2) spark plugs. Such procedures must be conducted in a manner consistent with service instructions and specifications provided by the engine manufacturer for use by the ultimate purchaser. Such procedures must not render the certification test engines unrepresentative of the emission characteristics of the engine family production engines.

(c) The Executive Officer may specify, within the physically available range, the ignition timing, idle air/fuel mixture and other fuel system adjustments to be used at each tune-up.

(d) Engine manufacturers may perform periodic changes of engine oil, and may change or service oil, air and fuel filters at the time intervals specified in the engine manufacturer's break-in maintenance instructions that are furnished to the ultimate purchaser.

(e) Engine manufacturers may request from the Executive Officer authorization to perform service accumulation maintenance of emission control related components not specifically authorized by this section, and for anticipated maintenance, before to the beginning of the service accumulation period. The Executive Officer will approve the performance of such maintenance, if the engine manufacturer makes a satisfactory showing that the maintenance will be performed by and/or for the ultimate purchaser on engines in use and that the maintenance is reasonable and necessary.

23. Unscheduled Maintenance; Test Engines.

(a) Engine manufacturers must not perform any unscheduled engine, emission control system, or fuel system adjustment, repair, removal, disassembly, cleaning, or replacement on engines without the advance approval of the Executive Officer.
   (1) In the case of unscheduled maintenance the Executive Officer will approve such maintenance if the Executive Officer:
      (i) Has made a preliminary determination that part failure or system malfunction, or the repair of such failure or malfunction, does not render the engine unrepresentative of engines in use, and does not require direct access to the combustion chamber, except for spark plug, fuel injection component, or removable prechamber removal or replacement; and
      (ii) Has made a determination that the need for maintenance or repairs is indicated by an overt indication of malfunction such as persistent misfire, engine stall, overheating, fluid leakage, loss of oil pressure, or charge indicator warning.

(2) Emission measurements must not be used as a means of determining the need for unscheduled maintenance under paragraph (a)(1)(i) of this section.

(b) Engine manufacturers may perform repairs of engine components of test engines, other than the engine, emission control system, or fuel system, only as a result of part failure or with the prior approval of the Executive Officer.

(c) The Executive Officer must be given the opportunity to verify the extent of any overt indication of part failure (e.g., misfire, stall), or an activation of an audible and/or visual signal, before the engine manufacturer performing any maintenance related to such overt indication or signal.

(d) Unless approved by the Executive Officer before use, engine manufacturers must not use any equipment, instruments, or tools to identify malfunctioning, maladjusted, or defective engine components unless the same or equivalent equipment, instruments, or tools will be available at dealerships and other service outlets; and:
   (1) Are used in conjunction with scheduled maintenance on such components; and,
   (2) Are used subsequent to the identification of an engine malfunction, as provided in paragraph (a)(1) of this section for emission data engines.

(e) If the Executive Officer determines that part failure or system malfunction occurrence and/or repair rendered the engine unrepresentative of engines in use, the engine must not be used as a test engine.

(f) Unless waived by the Executive Officer, complete emission tests are required before and after any engine maintenance that may reasonably be expected to affect emissions.

24. Engine Failure.

Engine manufacturers must not use as a test engine any test engine that incurs major mechanical failure requiring disassembly of the engine. This prohibition does not apply to failures that occur after completing the service accumulation period.

25. Data Submission.

(a) Engine manufacturers must submit the test engine emission data and results for all emission data tests (including voided tests) that were conducted on the test engines.

(b) The engine manufacturer must furnish to the Executive Officer, with the submission of the information required by paragraph (a), explanations of the cause for any voided emission tests. The Executive Officer will determine if voiding the test was appropriate based upon the explanation given by the engine manufacturer.

(c) When unscheduled or unanticipated maintenance is performed, the engine manufacturer must furnish to the Executive Officer a complete record of all pertinent maintenance, including the malfunction diagnosis, the corrective action taken, and the test data obtained.

(d) A complete record of all maintenance that was performed on any test engines must be furnished to the Executive Officer as part of the certification application.

26. Testing by the Executive Officer.

(a) At the conclusion of the service accumulation procedure and emission tests, the engine manufacturer must submit the test engine data and results to the Executive Officer in accordance with the requirements of section 25. After reviewing the test data and results, the Executive Officer may conduct emission testing on the test engine(s) (i.e., confirmatory testing) to verify the engine manufacturer's test results, and to determine that the test engine emission characteristics are representative of production engines.

(b) As part of the test data and results submission, an engine manufacturer may request that the Executive Officer not conduct confirmatory testing of the test engine(s) (i.e., test-waiver request), and that the engine manufacturer's test data and results be accepted as officially representative of production engines (i.e., projected emission levels).

(c) The Executive Officer will consider an engine manufacturer's test-waiver request by evaluating information submitted under the requirements of section 25, information contained in the engine family application, and other certification-related information. The Executive Officer will determine whether or not to conduct confirmatory emission testing on the basis of, but not limited to, such factors as:

(1) Marginal compliance with the applicable emission standards;
(2) Demonstrated capability of the engine manufacturer's prior certification-related activities;
(3) Use of new or different technologies that may affect engine emission characteristics, or that may not be compatible with existing procedures; and,
(4) Reasonableness of emission test data and results.

(d) Whenever the Executive Officer determines that confirmatory testing is not warranted, the engine manufacturer's test data and results will be accepted as the official test data and results for purposes of the certification review specified in section 27(a)(2)(i).

(e) Whenever the Executive Officer determines that confirmatory testing is warranted, the Executive Officer will notify the engine manufacturer to submit one or more of the test engines, at such a place or places as the Executive Officer may designate, for purposes of conducting confirmatory testing. The data and results from that test will, unless subsequently invalidated by the Executive Officer, comprise the official test engine(s) data and results for purposes of the certification review specified in section 27(a)(2)(i).

(f) The engine manufacturer may request a retest. The results of the retest will be used to determine compliance with the applicable emission standards.

(g) If any emission test result exceeds the applicable standard, the Executive Officer will deny certification.

27. Certification.

(a) New spark-ignition marine engines produced by a manufacturer are covered by the following certification requirements:

(1) The engine manufacturer must submit to the Executive Officer a statement that the test engine for which data have been submitted has been tested in accordance with the applicable test procedures, that it meets the requirements of such tests, and that, on the basis of such tests, it conforms to the requirements of this Part. If such statements cannot be made with respect to any engine tested, the engine must be identified, and all pertinent test data relating thereto must be supplied.

(2) (i) If, after review of the test reports and data submitted by the engine manufacturer, data derived from any inspection carried out under section 31, and any other pertinent data or information, the Executive Officer determines that a test engine(s) meets the requirements of section 43013 of the California Clean Air Act and of these provisions, the Executive Officer will issue an Executive Order certifying such engine(s) except for engines covered by section 32.

(ii) The engine family certification will be granted only for the model-year engine production as specified by the Executive Officer in the Executive Order; and upon such terms as the Executive Officer may deem necessary to assure that any new spark-ignition marine engine covered by the Executive Order will meet the requirements of these provisions.

(iii) The Executive Order will apply to all engines within the engine family represented by the test engine and will certify compliance with no more than one set of applicable standards.

(iv) The engine manufacturer may, at its option, proceed with any of the following alternatives with respect to engines represented by a test engine(s) determined not to be in compliance with applicable standards:

(A) Delete from the application for certification engines that were represented by the failed test engine. The Executive Officer will then select in place of each failed engine an alternate engine chosen in accordance with the selection criteria that were employed in selecting the engine that failed; or,

(B) Repair and retest the failed engine to demonstrate that it meets the applicable standards. The engine manufacturer must then test a second engine that is in all material respects the same as the first engine (as repaired) in accordance with the applicable test procedures.

(v) If the engine manufacturer does not submit the data required under paragraphs (2)(i), (ii) and (iii) of this section, the Executive Officer will deny certification.

28. Amendments to the Application.

(a) The engine manufacturer must inform the Executive Officer by written amendment to the certification application of any proposed changes to engines that are in production or will be produced. The Executive Officer will, if appropriate, select a new test engine. Except as provided in section 29, the engine manufacturer must not institute any changes until approved by the Executive Officer.

(b) The Executive Officer may allow reduced testing with respect to the requirements of this section.

29. Alternative Procedure For Notification of Additions and Changes.

(a) (1) If the engine manufacturer determines that a change in an engine family model will not result in failure of the subject engines to continue to meet applicable emission standards, an engine manufacturer may elect to notify the Executive Officer at the time such a change is made rather than in advance as required by section 28.

(2) Such notification must include a full description of the addition or change and any supporting documentation provided by the engine manufacturer to support its determination that the addition or change does not cause noncompliance.
(3) The engine manufacturer's determination that the addition or change does not cause noncompliance must be based on an engineering evaluation of the addition or change and/or testing.

(b) (1) The Executive Officer may require that additional emission testing be performed to support the engine manufacturer's original determination submitted in accordance with paragraph (a) of this section.
(2) If additional testing is required, the Executive Officer will proceed as in section 28.
(3) If the Executive Officer requests additional test data, the engine manufacturer must provide such data within 30 days of the request or the engine manufacturer must rescind the addition or change immediately after the expiration of the 30 day period.
(4) The Executive Officer may grant additional time to complete testing if additional testing is required.
(5) If based on this additional testing or any other information, the Executive Officer determines that the engines affected by the addition or change do not meet the applicable standards, the Executive Officer will notify the engine manufacturer to rescind the addition or change immediately upon receipt of the notification, and to cease selling engines affected by such addition or change.

(c) If an engine manufacturer elects to produce engines under this section, the engine manufacturer, upon notification from the ARB that engines that it has produced do not meet the standards set forth herein, will be subject to being enjoined from any further sales of such products in the State of California pursuant to section 43017 of the Health and Safety Code. Prior to seeking to enjoin an engine manufacturer, the Executive Officer will consider any information provided by the engine manufacturer.

30. Maintenance of Records.

(a) The manufacturer of any spark-ignition marine engine subject to any of the standards or procedures prescribed in these provisions must establish, maintain and retain the following adequately organized and indexed records;
(1) General records.
(i) (A) Identification and description of all certification engines for which testing is required under this Part.

(B) A description of all emission control systems that are installed on or incorporated in each certification engine.

(C) A description of all procedures used to test each certification engine.

(ii) A properly completed application, following the format prescribed by the California Air Resources Board for the appropriate year of production, must fulfill each of the requirements set forth in paragraph (a)(1)(i) of this section.

(2) Individual records.

(i) A brief history of each spark-ignition marine engine used for certification under these provisions including:

(A) (1) In the case where a current production engine is modified for use as a certification engine, a description of the process by which the engine was selected and of the modification made.

(2) In the case where the certification engine is not derived from a current production engine, a general description of the build-up of the engine (e.g., experimental heads were cast and machined according to supplied drawings, etc.).

(3) In both of the above cases, a description (as applicable) of the origin and selection process for the carburetor, fuel system, emission control system components, and exhaust aftertreatment device must be included. The required description must specify the steps taken to assure that the certification engine is representative of production engines with respect to its fuel system, emission control system components, exhaust aftertreatment device, or any other device or component that can reasonably be expected to influence exhaust emissions. The description must also state that all components and/or engine construction processes, component inspection and selection techniques, and assembly techniques employed in constructing such engines are reasonably likely to be implemented for production engines, or that they are as closely analogous as practicable to planned construction and assembly processes.

(B) A complete record of all certification emission tests performed (except tests performed by ARB directly) including test results, and the date and purpose of each test, and the hours accumulated on the engine.

(C) The date of each service accumulation procedure.

(D) [Reserved].

(E) A record and description of all maintenance and other service performed, including the date of the maintenance or service and the reason for it.

(F) A record and description of each test performed to diagnose engine or emissions control system performance, giving the date and time of the test and the reason for it.

(G) [Reserved].

(H) A brief description of any significant events affecting the engine during the period covered by the history, including such extraordinary events as engine accidents or dynamometer runaway.

(ii) Each such history must state the date that any of the selection or build-up activities in paragraph (a)(2)(i)(A) of this section occurred with respect to the certification engine. The history must be updated each time the operation status of the engine changes or additional work is performed on it.

(3) All records, other than routine emission test records, required to be maintained under these provisions must be retained by the engine manufacturer for a period of six (6) years after the issuance of all Executive Orders to which they relate. Routine emission test records must be retained by the manufacturer for a period of one (1) year after issuance of all Executive Orders to which they relate. Records may be retained as hard copy or reduced to rewritable compact disc, microfilm, punch cards, etc., depending on the record retention procedures of the engine manufacturer, provided, in every case, all the information contained in the hard copy must be retained.

31. Right of Entry.

(a) Any engine manufacturer subject to these emission standards and test procedures, upon receipt of prior notice must admit or cause to be admitted during operating hours any ARB Enforcement Officer that has presented proper credentials to any of the following:

(1) Any facility where tests or procedures or activities connected with such tests or procedures are or were performed.

(2) Any facility where any new spark-ignition marine engine is present and is being, has been, or will be tested.

(3) Any facility where a manufacturer constructs, assembles, modifies, or builds-up an engine into a certification engine that will be tested for certification.

(4) Any facility where any record or other document relating to any of the above is located.

(b) Upon admission to any facility referred to in paragraph (c)(1) of this section, any ARB Enforcement Officer must be allowed:
   (1) To inspect and monitor any part or aspect of such procedures, activities, and testing facilities, including, but not limited to, monitoring engine preconditioning, emissions tests and break-in, maintenance, and engine storage procedures.
   (2) To verify correlation or calibration of test equipment; and,
   (3) To inspect and make copies of any such records, designs, or other documents; and,
   (4) To inspect and/or photograph any part or aspect of any such certification engine and any components to be used in the construction thereof.

(c) To permit an ARB determination whether production spark-ignition marine engines conform in all material respects to the design specifications that apply to those engines described in the Executive Order certifying such engines and to standards prescribed herein, engine manufacturers must, upon receipt of prior notice, admit any ARB Enforcement Officer, upon presentation of credentials, to:
   (1) Any facility where any document design, or procedure relating to the translation of the design and construction of engines and emission related components described in the application for certification or used for certification testing into production engines is located or carried on; and,
   (2) Any facility where any spark-ignition marine engines to be introduced into commerce are manufactured or assembled.
   (3) Any California retail outlet where any spark-ignition marine engine is sold.

(d) On admission to any such facility referred to in this section, any ARB Enforcement Officer must be allowed:
   (1) To inspect and monitor any aspects of such manufacture or assembly and other procedures;
   (2) To inspect and make copies of any such records, documents or designs; and,
   (3) To inspect and photograph any part or aspect of any such new spark-ignition marine engine and any component used in the assembly thereof that are reasonably related to the purpose of the ARB Enforcement Officer's entry.

(e) Any ARB Enforcement Officer must be furnished by those in charge of a facility being inspected with such reasonable assistance as may be necessary to discharge any function listed in this section. Each applicant for or recipient of certification is required to cause those in charge of a facility operated for its benefit to furnish such reasonable assistance without charge to the ARB irrespective of whether or not the applicant controls the facility.

(f) The duty to admit or cause to be admitted any ARB Enforcement Officer applies whether or not the applicant owns or controls the facility in question and applies both to domestic and foreign engine manufacturers and facilities. The ARB will not attempt to make any inspections that it has been informed that local law forbids. However, if local law makes it impossible to insure the accuracy of data generated at a facility, no informed judgment that an engine is certifiable or is covered by an Executive Order can properly be based on the data. It is the responsibility of the engine manufacturer to locate its testing and manufacturing facilities in jurisdictions where this situation will not arise.

(g) For purposes of this section:
   (1) "Presentation of credentials" means a display of a document designating a person to be an ARB Enforcement Officer.
   (2) Where engine, component, or engine storage areas or facilities are concerned, "operating hours" means all times during which personnel are at work in the vicinity of the area or facility and have access to it.
   (3) Where facilities or areas other than those covered by paragraph (g)(2) of this section are concerned, "operating hours" means all times during which an assembly line is in operation or during which testing, maintenance, break-in procedure, production or compilation of records, or any other procedure or activity is being conducted related to certification testing, translation of designs from the test stage to the production stage, or engine manufacture or assembly.
   (4) "Reasonable assistance" includes, but is not limited to, providing clerical, copying, interpretation and translation services; making personnel available upon request to inform the ARB Enforcement Officer of how the facility operates and to answer questions; and performing requested emissions tests on any engine that is being, has been, or will be used for certification testing. Such tests must be nondestructive, but may require appropriate break-in. Upon written request from the Executive Officer for the appearance of any employee of a facility, and service of such request upon the engine manufacturer, the ARB may compel an engine manufacturer to cause the personal appearance of any employee at such a facility before an ARB Enforcement Officer. Any such employee who has been instructed by the engine manufacturer to appear will be entitled to be accompanied, represented, and advised by counsel.

32. Denial, Revocation, or Suspension of Certification.

(a) Notwithstanding the fact that any engine(s) tested for certification may comply with the provisions set forth herein, the Executive Officer may withhold or deny the issuance of an Executive Order (or suspend or revoke any such Executive Order that has been issued) with respect to any such engine(s) if:

(1) The engine manufacturer submits false or incomplete information in its application for certification; or,

(2) The engine manufacturer renders inaccurate or invalid any test data that it submits pertaining to the certification or otherwise circumvents the intent of section 43013 of the California Clean Air Act or of these provisions with respect to such engine; or,

(3) Any ARB Enforcement Officer is denied access on the terms specified in section 31 to any facility that contains any of the following:

(i) The engine;

(ii) Any components used or considered for use in its modification or build-up into a certification engine;

(iii) Any production engine that is or will be claimed by the engine manufacturer to be covered by the certificate;

(iv) Any step in the construction of an engine described in paragraph (c) of this section;

(v) Any records, documents, reports, or histories required by this Part to be kept concerning any of the above.

(4) Any ARB Enforcement Officer is denied "reasonable assistance" in examining any of the items listed in paragraph (a)(3) of this section.

(b) The sanctions of withholding, denying, revoking, or suspending of an Executive Order may be imposed for the reasons in paragraph (a) of this section only when the infraction is substantial.

(c) In any case in which an engine manufacturer knowingly submits false or inaccurate information, or knowingly renders inaccurate or in valid any test data, or commits any fraudulent acts and such acts contribute substantially to the Executive Officer decision to issue an order, the Executive Officer may deem such Executive Order void ab initio.

(d) In any case in which certification of an engine is proposed to be withheld, denied, revoked, or suspended under paragraph (a)(3) or (4) of this section, and in which the Executive Officer has presented to the engine manufacturer involved reasonable evidence that a violation of section 31 has occurred, the engine manufacturer, will have the burden of establishing any contention to the satisfaction of the Executive Officer, that even though the violation occurred, the engine in question was not involved to such a degree that would warrant withholding, denial, revocation, or suspension of certification under either paragraph (a)(3) or (4) of this section.

(e) Any revocation or suspension of certification under paragraph (a) of this section may also subject the manufacturer to penalties to the extent permissible under Part 5, Division 26 of the Health and Safety Code.

33. Adjudicatory Hearing.

Parties affected by an Executive Officer's determination may file for an adjudicatory hearing pursuant to Subchapter 1.25, Title 17, California Code of Regulations. The provisions of Subchapter 1.25, Title 17, California Code of Regulations, apply fully to filings made under these provisions.

Part II. Spark-Ignition Marine Engines - Determination of Deterioration Factors.

1. Definitions.

The definitions in Part I, section 2 apply to this Part.

2. Acronyms and Abbreviations.

The acronyms and abbreviations in Part I, section 3 apply to this Part.

3. Deterioration Factor.

(a) The manufacturer must determine the deterioration factor for each engine family and pollutant based on good engineering judgment and/or test data. For personal watercraft and outboard spark-ignition marine engines, ~~T~~this deterioration factor must be based on the designated useful life of the engine family. For inboard and sterndrive spark-ignition marine engines, the deterioration factor must be based on a designated test period of 480 hours.

(b) For SI marine engines not utilizing aftertreatment technology (e.g., catalytic converters, exhaust gas recirculation), the sum of the exhaust emission results from each test engine added to the deterioration factor is the emissions certification value for that engine family and pollutant. If the deterioration factor is less than zero, it is considered zero for the purposes of this Part.

(c) For SI marine engines utilizing aftertreatment technology (e.g., catalytic converters, exhaust gas recirculation), the product of the exhaust emission results from each test engine multiplied by the deterioration factor is the emissions certification value for that engine family and pollutant. If the deterioration factor is less than one, it is considered to be one for the purposes of this Part.

Part III. Emission Test Equipment Provisions.

1. Scope; Applicability.

(a) This Part describes the equipment required to perform exhaust emission tests on new spark-ignition marine engines subject to the provisions of Part I, section 1.

(b) Exhaust gases are sampled while the test engine is operated using a steady state test cycle on an engine dynamometer. Exhaust gas sampling may be performed using either the raw gas sampling method or the constant volume sampling (CVS) method. The exhaust gases receive specific component analysis determining concentration of pollutants, exhaust volume, temperature, the fuel flow, and the power output during each mode. Emissions are reported on a gram per brake-kilowatt hour (g/kW-hr). See Part IV for a complete description of the test procedure.

2. Definitions.

The definitions in Part I, section 2 apply to this Part.

3. Acronyms and Abbreviations.

The acronyms and abbreviations in Part I, section 3 apply to this Part.

4. Test Equipment Overview.

(a) All engines subject to this Part are tested for exhaust emissions. Engines are operated on dynamometers meeting the specification given in section 5.

(b) The exhaust is tested for gaseous emissions using either a constant volume sampling (CVS) system as described in Part IV, section 14, or using the raw gas sampling system as described in Part IV, section 21.

Both systems require analyzers (see paragraph (c) of this section) specific to the pollutant being measured.

(c) Analyzers used are a non-dispersive infrared detector (NDIR) absorption type for carbon monoxide and carbon dioxide analysis; paramagnetic detector (PMD), zirconia (ZRDO), or electrochemical type (ECS) for oxygen analysis; a flame ionization detector (FID) or heated flame ionization detector (HFID) type for hydrocarbon analysis; and a chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) for oxides of nitrogen analysis.

5. Dynamometer Specifications and Calibration Accuracy.

(a) Dynamometer specifications.

(1) The dynamometer test stand and other instruments for measurement of engine speed and torque must meet the accuracy requirements shown in Table 1 in Appendix A to this Part. The dynamometer must be capable of performing the test cycle described in Part I, section 20.

(b) Dynamometer calibration accuracy.

(1) The dynamometer test stand and other instruments for measurement of engine torque and speed must meet the calibration frequency shown in Table 1 in Appendix A to this Part.

(2) A minimum of three calibration weights for each range used is required. The weights must be equally spaced and traceable to within 0.5 percent of National Institute of Standards and Testing (NIST) weights. Laboratories located in foreign countries may certify calibration weights to local government bureau standards.

6. Dynamometer Torque Cell Calibration.

(a) (1) Any lever arm used to convert a weight or a force through a distance into a torque must be used in a horizontal position for horizontal shaft dynamometers (± five degrees). For vertical shaft dynamometers, a pulley system may be used to convert the dynamometer's horizontal loading into the vertical plane.

(2) Calculate the indicated torque (IT) for each calibration weight to be used by:

IT = Moment Arm (meters) X Calibration Weight (Newtons)

(3) Attach each calibration weight specified in Part III, section 5(b)(2) to the moment arm at the calibration distance determined in paragraph (a)(2) of this section. Record the power measurement equipment response (N-m) to each weight.

(4) Compare the torque value measured to the calculated torque.

(5) The measured torque must be within two percent of the calculated torque.

(6) If the measured torque is not within two percent of the calculated torque, adjust or repair the system. Repeat steps in paragraphs (a)(1) through (a)(6) of this section with the adjusted or repaired system.

(b) Option. A master load-cell or transfer standard may be used to verify the torque measurement system.

(1) The master load-cell and read out system must be calibrated with weights specified in Part III, section 5(b)(2).

(2) Attach the master load-cell and loading system.

(3) Load the dynamometer to a minimum of three equally spaced torque values as indicated by the master load-cell for each in-use range used.

(3) The in-use torque measurement must be within two percent of the torque measured by the master system for each load used.

(4) If the in-use torque is not within two percent of the master torque, adjust or repair the system. Repeat steps in paragraphs (b)(2) through (b)(4) of this section with the adjusted or repaired system.

(c) Calibrated resistors may not be used for dynamometer torque transducer calibration, but may be used to span the transducer before engine testing.

(d) Other engine dynamometer system calibrations such as speed are performed as specified by the dynamometer manufacturer or as dictated by good engineering practice.

7. Engine Cooling System.

An engine cooling system is required with sufficient capacity to maintain the engine at normal operating temperatures as prescribed by the engine manufacturer. Auxiliary fan(s) may be used to maintain sufficient engine cooling during dynamometer operation.

8. Lubricating Oil and Test Fuel.

(a) Lubricating oil.

(1) Use the engine lubricating oil which meets the engine manufacturer's requirements for a particular engine and intended usage. Record the specifications of the lubricating oil used for service accumulation and the certification test.

(2) For two-stroke engines, the fuel/oil mixture ratio must be that which is recommended by the manufacturer. If the flow rate of the oil in the engine is greater than two percent of the fuel flow rate, then the oil supplied to the engine must be added to the fuel flow in the emission calculations described in Part IV, section 19 and section 26. Good engineering judgment may be used to estimate oil flow when oil injection is used.

(b) Test fuels – certification.

(1) Petroleum-based fuels. The manufacturer must use gasoline having the specifications or substantially equivalent specifications approved by the Executive Officer, as specified in Table 8-1 below for exhaust emission testing of gasoline fueled engines. As an alternative, the manufacturer may use the fuel specifications as outlined in the California Code of Regulations, Title 13, section 1960.1, and the latest amendment of the "California Exhaust Emission Standards and Test Procedures for 1988 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles," incorporated herein by reference. The test fuel specification in either case should remain consistent from batch to batch. The specification range of the fuel to be used under this paragraph must be reported in accordance with Part I, section 14(b)(2)(vi).

Table 8-1 -- Test Fuel Specifications

Item	Property	Tolerance	Procedure (ASTM)[1]
Sulfur, ppm max.	1000	—	D 2622
Benzene, max. percent	1.5	—	D 3606
RVP, psi	8.6	±0.6	D 323
Octane, R+M/2	89.9	±3.1	D 2699 D 2700
IBP, °C	32.8	±11.0	D 86
10% point, °C	53.3	±5.5	D 86
50% point, °C	101.7	±8.3	D 86
90% point, °C	160.0	±11.1	D 86
End Point, max. °C	212.8	—	D 86
Phosphorus, g/l, max.	0.02	—	D 3231
Lead, g/l, max.	0.02	—	—
Manganese, g/l, max.	0.004	—	—
Aromatics, max. percent	35	—	D 1319
Olefins, max. percent	10	—	D 1319
Saturates, percent	remainder	—	D 1319

[1] All ASTM Procedures in this table have been incorporated by reference.

(2) Alcohol-based fuels. Alcohol-based fuels must be allowed for emission test purposes when the appropriate emission standards with respect to such fuels are a part of these provisions. Such fuels must be as specified in paragraph (b)(1) above.

(c) Test fuels – service accumulation.

(1) (A) Gasoline. Unleaded gasoline representative of commercial gasoline which will be generally available through retail outlets must be used in service accumulation for spark-ignition marine engines. As an alternative, the certification test fuels specified under paragraph (b) of this section for engine service accumulation. Leaded fuel may not be used during service accumulation.

(B) The octane rating of the gasoline used may not be higher than 4.0 research octane numbers above the minimum recommended by the manufacturer and have a minimum sensitivity of 7.5 octane numbers, where sensitivity is defined as research octane number minus motor octane number.

(C) The Reid Vapor Pressure of a gasoline must be characteristic of the engine fuel during the season in which the service accumulation takes place in the outdoors, or must be characteristic of the engine fuel appropriately suited to the ambient conditions of an indoor test cell in which the entire service accumulation takes place.

(2) Alternative fuels.

(A) Liquefied petroleum gas meeting the ASTM D1835 or NGPA HD-5 specifications must be used for service accumulation.

(B) Natural gas representative of commercial natural gas that will be generally available through retail outlets must be used in service accumulation.

(d) Other fuels may be used for testing provided:

(1) They are commercially viable,

(2) Information, acceptable to the Executive Officer, is provided to show that only the designated fuel would be used in customer service;

(3) Use of a fuel listed under paragraph (b) of this section would have a detrimental effect on emissions or durability; and

(4) The Executive Officer provides written approval of the fuel specifications before the start of testing.

9. Engine Intake Air Temperature Measurement.

(a) Engine intake air temperature measurement must be made within 100 cm of the air-intake of the engine. The measurement location must be either in the supply system or in the air stream entering the engine.

(b) The temperature measurements must be accurate to within ± 2 deg.C.

10. Engine Intake Air Humidity Measurement.

This section refers to engines which are supplied with intake air other than the ambient air in the test cell (i.e., air which has been plumbed directly to the engine air intake system). For engines which use ambient test cell air for the engine intake air, the ambient test cell humidity measurement may be used.

(a) Humidity conditioned air supply. Air that has had its absolute humidity altered is considered humidity-conditioned air. For this type of intake air supply, the humidity measurements must be made within the intake air supply system, and after the humidity conditioning has taken place.

(b) Unconditioned air supply. Humidity measurements in unconditioned intake air supply must be made in the intake air stream entering the engine. Alternatively, the humidity measurements can be measured within the intake air stream entering the supply system.

11. Test Conditions.

(a) General requirements.

(1) Ambient temperature levels encountered by the test engine throughout the test sequence may not be less than 20 deg.C nor more than 30 deg.C.

(2) Calculate all volumes and volumetric flow rates at standard conditions for temperature and pressure. Use these conditions consistently throughout all calculations. Standard conditions for temperature and pressure are 25 deg.C and 101.3 kPa.

(b) Engine test conditions. Measure the absolute temperature (designated as T and expressed in Kelvin) of the engine air at the inlet to the engine and the dry atmospheric pressure (designated as p_s and expressed in kPa. Determine the parameter *f* according to the following provisions:

(1) Naturally aspirated and mechanically supercharged engines:

$$f = \frac{99}{P_s} x \left(\frac{T}{298} \right)^{0.7}$$

(2) Turbocharged engine with or without cooling of inlet air:

$$f = \left(\frac{99}{P_s} \right)^{0.7} x \left(\frac{T}{298} \right)^{1.5}$$

(3) For a test to be recognized as valid, the parameter *f* must be between the limits as shown below:

$$0.96 < f < 1.04$$

12. Analytical Gases.

(a) The shelf life of a calibration gas may not be exceeded. Record the expiration date stated by the gas supplier for each calibration gas.

(b) Pure gases. The required purity of the gases is defined by the contamination limits given in parenthesis. The following gases must be available for operation.

(1) Purified nitrogen, also referred to as "zero-grade nitrogen" (Contamination $\leq$ 1 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.1 ppm NO)

(2) Purified oxygen (Purity 99.5 percent vol O_2)

(3) Hydrogen-helium mixture (40 ± 2 percent hydrogen, balance helium) (Contamination $\leq$ 1 ppm C, $\leq$ 400 ppm CO)

(4) Purified synthetic air, also referred to as "zero gas" (Contamination $\leq$ 1 ppm C, $\leq$ 1 ppm CO, $\leq$ 400 ppm CO_2, $\leq$ 0.1 ppm NO) (Oxygen content between 18-21 percent vol.)

(c) Calibration and span gases.

(1) Calibration gas values are to be derived from NIST "Standard Reference Materials" (SRM's) or other local gas standards and are to be single blends as specified in this subsection.

(2) Mixtures of gases having the following chemical compositions must be available:

C_3H_8 and purified synthetic air (dilute measurements); C_3H_8 and purified nitrogen (raw measurements); CO and purified nitrogen; NO_x and purified nitrogen (the amount of NO_2 contained in this calibration gas must not exceed five percent of the NO content); CO_2 and purified nitrogen.

Note: For the HFID or FID, the manufacturer may choose to use as a diluent span gas and the calibration gas either purified synthetic air or purified nitrogen. Any mixture of C_3H_8 and purified synthetic air which contains a concentration of propane higher than what a gas supplier considers to be safe may be substituted with a mixture of 8 C_3H_8 and purified nitrogen. However, the manufacturer must be consistent in the choice of diluent (zero air or purified nitrogen) between the calibration and span gases. If a manufacturer chooses to use C_3H_8 and purified nitrogen for the calibration gases, then purified nitrogen must be the diluent for the span gases.

(3) The true concentration of a span gas must be within ± two percent of the NIST gas standard. The true concentration of a calibration gas must be within ± one percent of the NIST gas standard. The use of precision blending devices (gas dividers) to obtain the

required calibration gas concentrations is acceptable. Give all concentrations of calibration gas on a volume basis (volume percent or volume ppm).

(4) The gas concentrations used for calibration and span may also be obtained by means of a gas divider, diluting with purified N_2 or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted gases may be determined to within ± two percent.

(d) Oxygen interference check gases must contain propane with 350 ppmC ± 75 ppmC hydrocarbon. Determine the concentration value to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. Use nitrogen as the predominant diluent with the balance oxygen.

(e) Fuel for the hydrocarbon flame ionization detector (HC-FID) must be a blend of 40 ± 2 percent hydrogen with the balance being helium. The mixture shall contain less than one ppm equivalent carbon response; 98 to 100 percent hydrogen fuel may be used with advance approval of the Executive Officer.

(f) Hydrocarbon analyzer burner air. The concentration of oxygen must be within one mole percent of the oxygen concentration of the burner air used in the latest oxygen interference check (percent O_2I), see Part III, section 16(d). If the difference in oxygen concentration is greater than one mole percent, then the oxygen interference must be checked and the analyzer adjusted if necessary, to meet the percent O_2I requirements. The burner air must contain less than two ppmC hydrocarbon.

13. Analyzers Required.

(a) Analyzers. Analyze measured gases with the following instruments:

(1) Carbon monoxide (CO) analysis.

(i) The carbon monoxide analyzer must be of the non-dispersive infrared (NDIR) absorption type.

(ii) The use of linearizing circuits is permitted.

(2) Carbon dioxide (CO_2) analysis.

(i) The carbon dioxide analyzer must be of the non-dispersive infrared (NDIR) absorption type.

(ii) The use of linearizing circuits is permitted.

(3) Oxygen (O_2) analysis. Oxygen (O_2) analyzers may be of the paramagnetic (PMD), zirconia (ZRDO) or electrochemical type (ECS).

(4) Hydrocarbon (HC) analysis.

(i) For Raw Gas Sampling, the hydrocarbon analyzer must be of the heated flame ionization (HFID) type. For constant volume sampling, the hydrocarbon analyzer may be of the flame ionization (FID) type or of the heated flame ionization (HFID) type.

(ii) For the HFID system, if the temperature of the exhaust gas at the sample probe is below 190 deg. C, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature of 190 deg. C ± 11 deg. C. If the temperature of the exhaust gas at the sample probe is above 190 deg. C, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature greater than 180 deg. C.

(iii) For the HFID analyzer, the detector, oven, and sample handling components within the oven must be suitable for continuous operation at temperatures to 200 deg. C. It must by capable of maintaining temperature within ± 5.5 deg. C of the set point.

(iv) Fuel and burner air must conform to the specifications in Part III, section 12.

(v) The percent of oxygen interference must be less than three percent, as specified in Part III, section 16(d).

(5) Oxides of nitrogen (NO_X) analysis.

(i) This analysis device consists of the following items:

(A) A NO_2 to NO converter. The NO_2 to NO converter efficiency must be at least 90 percent.

(B) An ice bath located after the NO_X converter (optional).

(C) A chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD).

(ii) The quench interference must be less than three percent as measured in Part III, section 25.

(b) Other gas analyzers yielding equivalent results may be used with advance approval of the Executive Officer.

(c) The following requirements must be incorporated as indicated in systems used for testing under this Part.

(1) Carbon monoxide and carbon dioxide measurements must be made on a dry basis (for raw exhaust measurement only). Specific

requirements for the means of drying the sample can be found in section 13(e).

(2) Calibration or span gases for the NO_X measurement system must pass through the NO_2 to NO converter.

(d) The electromagnetic compatibility (EMC) of the equipment must be on a level as to minimize additional errors.

(e) Gas drying. Chemical dryers are not an acceptable method of removing water from the sample. Water removal by condensation is acceptable. If water is removed by condensation, the sample gas temperature or sample dew point must be monitored either within the water trap or downstream and its temperature must not exceed 7 deg. C. A water trap performing this function is an acceptable method. Means other than condensation may be used only with prior approval from the Executive Officer.

14. Analyzer Accuracy and Specifications.

(a) Measurement accuracy – general. The analyzers must have a measuring range which allows them to measure the concentrations of the exhaust gas sample pollutants with the accuracies shown in Table 1 in Appendix A to this Part.

(1) Precision. The precision of the analyzer must be, at worst, ± one percent of full-scale concentration for each range used. The precision is defined as 2.5 times the standard deviation(s) of 10 repetitive responses to a given calibration or span gas.

(2) Noise. The analyzer peak-to-peak response to zero and calibration or span gases over any 10-second period may not exceed two percent of full-scale chart deflection on all ranges used.

(3) Zero drift. The analyzer zero-response drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The zero-response is defined as the mean response including noise to a zero-gas during a 30-second time interval.

(4) Span drift. The analyzer span drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The analyzer span is defined as the difference between the span-response and the zero-response. The span-response is defined as the mean response including noise to a span gas during a 30-second time interval.

(b) Operating procedure for analyzers and sampling system. Follow the start-up and operating instructions of the instrument manufacturer. Adhere to the minimum requirements given in Part III, sections 16 through 25 and Part IV, section 9.

(c) Emission measurement accuracy – Bag sampling.

(1) Good engineering practice dictates that exhaust emission sample analyzer readings below 15 percent of full scale chart deflection should generally not be used.

(2) Some high resolution read-out systems, such as computers, data loggers, and so forth, can provide sufficient accuracy and resolution below 15 percent of full scale. Such systems may be used provided that additional calibrations are made to ensure the accuracy of the calibration curves. The following procedure for calibration below 15 percent of full scale may be used:

Note: If a gas divider is used, the gas divider must conform to the accuracy requirements as follows: The use of precision blending devices (gas dividers) to obtain the required calibration gas concentrations is acceptable, provided that the blended gases are accurate to within ± 1.5 percent of NIST gas standards or other gas standards which have been approved by the Executive Officer. This accuracy implies that primary gases used for blending must be "named" to an accuracy of at least ± 1 percent, traceable to NIST or other approved gas standards.

(i) Span the full analyzer range using a top range calibration gas. The span gases must be accurate to within ± 2 percent of NIST gas standards or other gas standards which have been approved by the Executive Officer.

(ii) Generate a calibration curve according to, and meeting the requirements of the sections describing analyzer calibrations which are found in sections 16, 17, 18, and 20 of this Part.

(iii) Select a calibration gas (a span gas may be used for calibrating the CO_2 analyzer) with a concentration between the two lowest non-zero gas divider increments. This gas must be "named" to an accuracy of ± 2 percent of NIST gas standards, or other standards approved by the Executive Officer.

(iv) Using the calibration curve fitted to the points generated in paragraphs (c)(2)(i) and (ii) of this section, check the concentration of the gas selected in paragraph (c)(2)(iii) of this section. The concentration derived from the curve must be within ± 2.3 percent (± 2.8 percent for CO_2 span gas) of the gas' original named concentration.

(v) Provided the requirements of paragraph (c)(2)(iv) of this section are met, use the gas divider with the gas selected in paragraph (c)(2)(iii) of this section and determine the remainder of the calibration points. Fit a calibration curve per sections 16, 17, 18, and 20 of this chapter for the entire analyzer range.

(d) Emission measurement accuracy – continuous sampling. Analyzers used for continuous analysis must be operated such that the measured concentration falls between 15 and 100 percent of full scale chart deflection. Exceptions to these limits are:

(1) The analyzer's response may be less than 15 percent or more than 100 percent of full scale if automatic range change circuitry is used and the limits for range changes are between 15 and 100 percent of full scale chart deflection;

(2) The analyzer's response may be less than 15 percent of full scale if:

(i) Alternative in paragraph (c)(2) of this section is used to ensure that the accuracy of the calibration curve is maintained below 15 percent; or

(ii) The full scale value of the range is 155 ppmC or less; or

(iii) The emissions from the engine are erratic and the integrated chart deflection value for the cycle is greater than 15 percent of full scale; or

(iv) The contribution of all data read below the 15 percent level is less than 10 percent by mass of the final test results.

15. Analyzer Initial Calibration.

(a) Warming-up time. Follow the warm-up time according to the recommendations of the manufacturer. If not specified, a minimum of two hours should be allowed for warming up the analyzers.

(b) NDIR and HFID analyzer. Tune and maintain the NDIR analyzer per the instrument manufacturer recommendations. The combustion flame of the HFID analyzer must be optimized in order to meet the specifications in Part III, section 16(b).

(c) Zero setting and calibration. Using purified synthetic air (or nitrogen), set the CO, CO_2, NO_X and HC analyzers at zero. Connect the appropriate calibrating gases to the analyzers and record the values. The same gas flow rates shall be used as when sampling exhaust.

(d) Rechecking of zero setting. Recheck the zero setting and, if necessary, repeat the procedure described in paragraph (c) of this section.

16. Hydrocarbon Analyzer Calibration.

(a) Calibrate the FID and HFID hydrocarbon analyzer as described in this section. Operate the HFID to a set point ± 5.5 deg.C between 185 and 197 deg.C.

(b) Initial and periodic optimization of detector response. Prior to introduction into service and at least annually thereafter, adjust the FID and HFID hydrocarbon analyzer for optimum hydrocarbon response as specified by this paragraph. Alternative methods yielding equivalent results may be used, if approved in advance by the Executive Officer.

(1) Follow good engineering practices for initial instrument startup and basic operating adjustment using the appropriate fuel (see Part III, section 12) and purified synthetic air or zero-grade nitrogen.

(2) One of the following procedures is required for FID or HFID optimization:

(i) The procedure outlined in Society of Automotive Engineers (SAE) paper No. 770141, "Optimization of Flame Ionization Detector for Determination of Hydrocarbons in Diluted Automobile Exhaust"; author, Glenn D. Reschke. This procedure has been incorporated by reference.

(ii) The HFID optimization procedures outlined in Title 40, Code of Federal Regulations, section 86.331-79 [July 1, 1997], incorporated herein by reference.

(iii) Alternative procedures may be used if approved in advance by the Executive Officer.

(3) After the optimum flow rates have been determined, they are recorded for future reference.

(c) Initial and periodic calibration. Prior to introduction into service and monthly thereafter, or within one month before the certification test, calibrate the FID or HFID hydrocarbon analyzer on all normally used instrument ranges, using the steps in this paragraph. Use the same flow rate and pressures as when analyzing samples. Introduce calibration gases directly at the analyzer.

(1) Adjust analyzer to optimize performance.

(2) Zero the hydrocarbon analyzer with purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each used operating range with calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) For each range calibrated, if the deviation from a least squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

(d) Oxygen interference optimization. Choose a range where the oxygen interference check gases will fall in the upper 50 percent. Conduct the test, as outlined in this paragraph, with the oven temperature set as required by the instrument manufacturer. Oxygen interference check gas specifications are found in Part III, section 12(d).

(1) Zero the analyzer.
(2) Span the analyzer with the 21 percent oxygen blend.
(3) Recheck zero response. If it has changed more than 0.5 percent of full scale repeat paragraphs (d)(1) and (d)(2) of this section to correct the problem.
(4) Introduce the five percent and 10 percent oxygen interference check gases.
(5) Recheck the zero response. If it has changed more than ± one percent of full scale, repeat the test.
(6) Calculate the percent of oxygen interference (designated as percent O_2I) for each mixture in paragraph (d)(4) of this section according to the following equation:

$$percent\ O_2I = \frac{B\ Analyzer\ response\ (ppmC)}{B} x(100)$$

Where:

$$analyzer\ response = \left(\frac{A}{\%\ of\ fullscale\ analyzer\ response\ (A)}\right) x\ (\%\ of\ fullscale\ analyzer\ response\ (B))$$

A = hydrocarbon concentration (ppmC) of the span gas used in paragraph (d)(2) of this section.

B = hydrocarbon concentration (ppmC) of the oxygen interference check gases used in paragraph (d)(4) of this section.

(7) The percent of oxygen interference (designated as percent O_2I) must be less than ± three percent for all required oxygen interference check gases before testing.

(8) If the oxygen interference is greater than the specifications, incrementally adjust the air flow above and below the manufacturer's specifications, repeating paragraphs (d)(1) through (d)(7) of this section for each flow.

(9) If the oxygen interference is greater than the specification after adjusting the air flow, vary the fuel flow and thereafter the sample flow, repeating paragraphs (d)(1) through (d)(7) of this section for each new setting.

(10) If the oxygen interference is still greater than the specifications, repair or replace the analyzer, FID fuel, or burner air before testing. Repeat this section with the repaired or replaced equipment or gases.

17. Carbon Monoxide Analyzer Calibration.

(a) Calibrate the NDIR carbon monoxide analyzer described in this section.

(b) Initial and periodic interference check. Prior to its introduction into service and annually thereafter, check the NDIR carbon monoxide analyzer for response to water vapor and CO_2:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance on the most sensitive range to be used.

(2) Zero the carbon monoxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Bubble a mixture of three percent CO_2 in N_2 through water at room temperature and record analyzer response.

(4) An analyzer response of more than one percent of full scale for ranges above 300 ppm full scale or more than three ppm on ranges below 300 ppm full scale requires corrective action. (Use of conditioning columns is one form of corrective action which may be taken.)

(c) Initial and periodic calibration. Calibrate the NDIR carbon monoxide analyzer before its introduction into service and monthly thereafter.

(1) Adjust the analyzer to optimize performance.

(2) Zero the carbon monoxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with carbon monoxide-in-N_2 calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

18. Oxides of Nitrogen Analyzer Calibration.

(a) Calibrate the chemiluminescent oxides of nitrogen analyzer as described in this section.

(b) Initial and periodic interference. Prior to its introduction into service, and monthly thereafter, check the chemiluminescent oxides of nitrogen analyzer for NO_2 to NO converter efficiency. Figure 2 in Appendix B of this Part is a reference for the following paragraphs:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

(2) Zero the oxides of nitrogen analyzer with purified synthetic air or zero-grade nitrogen.

(3) Connect the outlet of the NO_X generator to the sample inlet of the oxides of nitrogen analyzer which has been set to the most common operating range.

(4) Introduce into the NO_X generator analyzer-system an NO-in-nitrogen (N_2) mixture with an NO concentration equal to approximately 80 percent of the most common operating range. The NO_2 content of the gas mixture must be less than 5 percent of the NO concentration.

(5) With the oxides of nitrogen analyzer in the NO mode, record the concentration of NO indicated by the analyzer.

(6) Turn on the NO_X generator O_2 (or air) supply and adjust the O_2 (or air) flow rate so that the NO indicated by the analyzer is about 10 percent less than indicated in paragraph (b)(5) of this section. Record the concentration of NO in this $NO+O_2$ mixture as value Ac."

(7) Switch the NO_X generator to the generation mode and adjust the generation rate so that the NO measured on the analyzer is 20 percent of that measured in paragraph (b)(5) of this section. There must be at least 10 percent unreacted NO at this point. Record the concentration of residual NO as value Ad.≅

(8) Switch the oxides of nitrogen analyzer to the NO_X mode and measure total NO_X. Record this value as "a."

(9) Switch off the NO_X generator but maintain gas flow through the system. The oxides of nitrogen analyzer will indicate the NO_X in the $NO+O_2$ mixture. Record this value as "b."

(10) Turn off the NO_X generator O_2 (or air) supply. The analyzer will now indicate the NO_X in the original NO-in-N_2 mixture. This value should be no more than 5 percent above the value indicated in paragraph (b)(4) of this section.

(11) Calculate the efficiency of the NO_X converter by substituting the concentrations obtained into the following equation:

$$percent\ efficiency = \left(1+\frac{ab}{cd}\right)x100$$

Where:

a = concentration obtained in paragraph (b)(8) of this section,

b = concentration obtained in paragraph (b)(9) of this section,

c = concentration obtained in paragraph (b)(6) of this section,

d = concentration obtained in paragraph (b)(7) of this section.

(c) Initial and periodic calibration. Prior to its introduction into service, and monthly thereafter, calibrate the chemiluminescent oxides of nitrogen analyzer on all normally used instrument ranges. Use the same flow rate as when analyzing samples. Proceed as follows:

(1) Adjust analyzer to optimize performance.

(2) Zero the oxides of nitrogen analyzer with zero-grade air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with NO-in-N_2 calibration gases with nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

19. NO_X Converter Check.

(a) The efficiency of the converter used for the conversion of NO_2 to NO is tested as given in paragraphs (a)(1) through (a)(8) of this section (see Figure 2 in Appendix B to this Part).

(1) Using the test setup as shown in Figure 2 in Appendix B to this Part (see also Part III, section 18 of this chapter) and the procedures described in paragraphs (a)(2) through (a)(8) of this section, test the efficiency of converters by means of an ozonator.

(2) Calibrate the HCLD in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80 percent of the operating range and the NO_2 concentration of the gas mixture less than five percent of the NO concentration). The NO_X analyzer must be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

(3) Calculate the efficiency of the NO_X converter as described in Part III, section 18(b).

(4) Via a T-fitting, add oxygen continuously to the gas flow until the concentration indicated is about 20 percent less than the indicated calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration as Ac.≅ The ozonator is kept deactivated throughout the process.

(5) Activate the ozonator to generate enough ozone to bring the NO concentration down to about 20 percent (minimum 10 percent) of the calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration as "d." Note that if, with the analyzer in the most common range the NO_X converter cannot give a reduction from 80 percent to 20 percent, then use the highest range which will give the reduction.

(6) Switch the NO analyzer to the NO_X mode, which means that the gas mixture (consisting of NO, NO_2, O_2 and N_2) now passes through the converter. Record the indicated concentration as "a."

(7) Deactivate the ozonator. The mixture of gases described in paragraph (a)(6) of this section passes through the converter into the detector. Record the indicated concentration as "b."

(8) Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO_X reading of the analyzer may not deviate by more than ± five percent of the theoretical value of the figure given in paragraph (a)(2) of this section.

(b) The efficiency of the converter must be tested before each calibration of the NO_X analyzer.

(c) The efficiency of the converter may not be less than 90 percent.

20. Carbon Dioxide Analyzer Calibration.

(a) Prior to its introduction into service, and monthly thereafter, or within one month before the certification test, calibrate the NDIR carbon dioxide analyzer as follows:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

(2) Zero the carbon dioxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with carbon dioxide-in-N_2 calibration or span gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of

the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(4) Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

21. NDIR Analyzer Calibration.

(a) Detector optimization. If necessary, follow the manufacturer's instructions for initial start-up and basic operating adjustments.

(b) Calibration curve. Develop a calibration curve for each range used as follows:

(1) Zero the analyzer.

(2) Span the analyzer to give a response of approximately 90 percent of full-scale chart deflection.

(3) Recheck the zero response. If it has changed more than 0.5 percent of full scale, repeat the steps given in paragraphs (b)(1) and (b)(2) of this section.

(4) Record the response of calibration gases having nominal concentrations between 10 and 90 percent of full-scale concentration. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 percent range (64 percent) is required (see following table).

Example calibration points	Acceptable for calibration?
20, 30, 40, 50, 60, 70	No, range covered is 50 percent, not 64 percent.
20, 30, 40, 50, 60, 70, 80, 90	Yes.
10, 25, 40, 55, 70, 85	Yes.
10, 30, 50, 70, 90	No, though equally spaced and entire range covered, a minimum of six points is needed.

(5) Generate a calibration curve. The calibration curve must be of fourth order or less, have five or fewer coefficients, and be of the form of equation (1) or (2). Include zero as a data point. Compensation for known impurities in the zero gas can be made to the zero-data point. The calibration curve must fit the data points within two percent of point or one percent of full scale, whichever is less.

$$y = Ax^4 + Bx^3 + Cx^2 + Dx + E \qquad (1)$$

$$y = \frac{x}{Ax^4 + Bx^3 + Cx^2 + Dx + E} \qquad (2)$$

y = concentration

x = chart deflection

(6) Option. A new calibration curve need not be generated if:

(i) A calibration curve conforming to paragraph (b)(5) of this section exists;

(ii) The responses generated in paragraph (b)(4) of this section are within one percent of full scale or two percent of point, whichever is less, of the responses predicted by the calibration curve for the gases used in paragraph (b)(4) of this section.

(7) If multiple range analyzers are used, the lowest range used must meet the curve fit requirements below 15 percent of full scale.

(c) Linear calibration criteria. If any range is within two percent of being linear, a linear calibration may be used. To determine if this criterion is met:

(1) Perform a linear least-square regression on the data generated. Use an equation of the form y = mx, where x is the actual chart deflection and y is the concentration.

(2) Use the equation $z = y/m$ to find the linear chart deflection (designated as z) for each calibration gas concentration (designated as y).

(3) Determine the linearity (designated as percent L) for each calibration gas by:

$$percent\ L = \frac{(zx)}{Full\ scale\ linear\ chart\ deflection}(100)$$

(4) The linearity criterion is met if the percent L is less than ± two percent for each data point generated. For each emission test, use a calibration curve of the form $y = mx$. The slope (designated as m) is defined for each range by the spanning process.

22. Calibration of Other Equipment.

Calibrate other test equipment as often as required by the test equipment manufacturer or as necessary according to good engineering practice.

23. Analyzer Bench Checks.

(a) Prior to initial use and after major repairs, verify that each analyzer complies with the specifications given in Table 1 to this Part.

(b) If a stainless steel NO_2 to NO converter is used, condition all new or replacement converters. The conditioning consists of either purging the converter with air for a minimum of four hours or until the converter efficiency is greater than 90 percent. The converter must be at operational temperature while purging. Do not use this procedure before checking converter efficiency on in-use converters.

24. Analyzer Leakage Check.

(a) Vacuum side leak check.

(1) Check any location within the analysis system where a vacuum leak could affect the test results.

(2) The maximum allowable leakage rate on the vacuum side is 0.5 percent of the in-use flow rate for the portion of the system being

checked. The analyzer flows and bypass flows may be used to estimate the in-use flow rates.

(3) The sample probe and the connection between the sample probe and valve V2 (see Figure 1 in Appendix A of this Part) may be excluded from the leak check.

(b) Pressure side leak check. Substantial leaks of the sample on the pressure side of the system may impact sample integrity if the leaks are of sufficient magnitude. As a safety precaution, it is good engineering practice to perform periodic pressure side leak checks on the sampling system.

25. Analyzer Interference Checks.

(a) Gases present in the exhaust other than the one being analyzed can interfere with the reading in several ways. Positive interference occurs in NDIR and PMD instruments when the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks described in this section are to be made initially and after any major repairs that could affect analyzer performance.

(b) CO analyzer water and CO_2 interference checks. Bubble through water at room temperature a CO_2 span gas having a concentration of between 80 percent and 100 percent inclusive of full scale of the maximum operating range used during testing and record the analyzer response. For dry measurements, this mixture may be introduced into the sample system before the water trap. The analyzer response must not be more than one percent of full scale for ranges equal to or above 300 ppm or more than three ppm for ranges below 300 ppm.

(c) NO_X analyzer quench check. The two gases of concern for CLD (and HCLD) analyzers are CO_2 and water vapor. Quench responses to these two gases are proportional to their concentrations and, therefore, require test techniques to determine quench at the highest expected concentrations experienced during testing.

(1) NO_X analyzer CO_2 quench check.

(i) Pass a CO_2 span gas having a concentration of 80 percent to 100 percent of full scale of the maximum operating range used during testing through the CO_2 NDIR analyzer and record the value as "a."

(ii) Dilute the CO_2 span gas approximately 50 percent with NO span gas and pass through the CO_2 NDIR and CLD (or HCLD). Record the CO_2 and NO values as "b" and "c," respectively.

(iii) Shut off the CO_2 and pass only the NO span gas through the CLD (or HCLD). Record the NO value recorded as "d."

(iv) Calculate the percent CO_2 quench as follows, which may not exceed three percent:

$$percent\ CO_2\ quench = 100\,x\left(1\frac{(c\,x\,a)}{(d\,x\,a)(d\,x\,b)}\right)x\left(a/b\right)$$

Where:

a = Undiluted CO_2 concentration (percent)

b = Diluted CO_2 concentration (percent)

c = Diluted NO concentration (ppm)

d = Undiluted NO concentration (ppm)

(2) NO_X analyzer water quench check.

(i) This check applies to wet measurements only. Pass an NO span gas having a concentration of 80 percent to 100 percent of full scale of a normal operating range through the CLD (or HCLD). Record the response as AD.≅ Bubble through water at room temperature the NO span gas and pass it through the CLD (or HCLD). Record the analyzers response as AAR.≅ Determine and record the analyzers absolute operating pressure and the bubbler water temperature. (It is important that the NO span gas contains minimal NO_2 concentration for this check. No allowance for absorption of NO_2 in water has been made in the following quench calculations.)

(ii) Calculations for water quench must consider dilution of the NO span gas with water vapor and scaling of the water vapor concentration of the mixture to that expected during testing. Determine the mixture's saturated vapor pressure (designated as APwb≅) that corresponds to the bubbler water temperature. Calculate the water concentration (AZ1", percent) in the mixture by the following equation:

$$Z1 = 100\,x\left(Pwb/GP\right)$$

Where:

GP = the analyzer's standard operating pressure (pascals)

(iii) Calculate the expected dilute NO span gas and water vapor mixture concentration (designated as AD1") by the following equation:

$$D1 = D\,x\left(1Z1/_{100}\right)$$

26. Pre- and Post-test Analyzer Calibration.

Calibrate the operating range of each analyzer used during the test before and after each test in accordance with the following procedure (A chronic need for parameter adjustment can indicate a need for instrument maintenance.):

(a) Make the calibration using a zero gas and a span gas whose nominal value is between 80 percent and 100 percent of full scale, inclusive, of the measuring range.

(b) Use the same analyzer(s) flow rate and pressure as that used during exhaust emission test sampling.

(c) Warm-up and stabilize the analyzer(s) before the calibration is made.

(d) If necessary, clean and/or replace filter elements before calibration is made.

(e) Calibrate analyzer(s) as follows:

(1) Zero the analyzer using the appropriate zero gas. Adjust analyzer zero if necessary. Zero reading should be stable.

(2) Span the analyzer using the appropriate span gas for the range being calibrated. Adjust the analyzer to the calibration set point if necessary.

(3) Recheck zero and span set points.

(4) If the response of the zero gas or span gas differs more than one percent of full scale, then repeat paragraphs (e)(1) through (3) of this section.

27. Sampling System Requirements.

(a) Sample component surface temperature. For sampling systems which use heated components, use engineering judgment to locate the coolest portion of each component (pump, sample line section, filters, and so forth) in the heated portion of the sampling system that has a separate source of power or heating element. Monitor the temperature at that location. If several components are within an oven, then only the surface temperature of the component with the largest thermal mass and the oven temperature need be measured.

(b) If water is removed by condensation, monitor the sample gas temperature or sample dew point either within the water trap or downstream. It may not exceed 7 deg.C.

28. Measurement Equipment Accuracy/Calibration Frequency Table.

(a) The accuracy of measurements must be such that the maximum tolerances shown in Table 1 in Appendix A to this Part are not exceeded.

(b) Calibrate all equipment and analyzers according to the frequencies shown in Table 1 in Appendix A to this Part.

(c) Prior to initial use and after major repairs, bench check each analyzer (see Part III, section 23).

(d) Calibrate as specified in Part III, section 6 and sections 15 through 22.

(e) At least monthly, or after any maintenance which could alter calibration, perform the following calibrations and checks.

(1) Leak check the vacuum side of the system (see Part III, section 24(a)).

(2) Verify that the automatic data collection system (if used) meets the requirements found in Table 1 in Appendix A of this Part.

(3) Check the fuel flow measurement instrument to insure that the specifications in Table 1 in Appendix A to this Part are met.

(f) Verify that all NDIR analyzers meet the water rejection ratio and the CO_2 rejection ratio as specified in Part III, section 25.

(g) Verify that the dynamometer test stand and power output instrumentation meet the specifications in Table 1 in Appendix A to this Part.

29. Catalyst Thermal Stress Test.

(a) Oven characteristics. The oven used for thermally stressing the test catalyst must be capable of maintaining a temperature of 500 deg.C ± 5 deg.C and 1000 deg.C ± 10 deg.C.

(b) Evaluation gas composition.

(1) A synthetic exhaust gas mixture is used for evaluating the effect of thermal stress on catalyst conversion efficiency.

(2) The synthetic exhaust gas mixture must have the following composition:

Constituent	Volume Percent	Parts per million
Carbon Monoxide[1]	1	—
Oxygen	1.3	—
Carbon Dioxide	9	—
Water Vapor	10	—
Sulfur Dioxide	—	20
Oxides of Nitrogen	—	280
Hydrogen	—	3500
Hydrocarbon[1,2]	—	4000
Nitrogen=Balance	—	—

[1] Alternatively, the carbon monoxide and hydrocarbon proportions of the mixture may be changed to 1.2% and 4650 ppm, respectively (using one of these concentrations requires that the other be used simultaneously.

[2] Propylene/propane ratio = 2/1.

Appendix A to Part III

Table 1 -- Measurement Accuracy Calibration Frequency

No.	Item	Permissible deviation from reading[1]		Calibration frequency
		non-idle	idle	
1	Engine speed	± 2%	± 2%	Monthly
2	Torque	± 5%	—	Monthly
3	Fuel consumption	± 1%	± 5%	Monthly
4	Air consumption	± 2°C	± 5%	As required
5	Coolant temperature	± 2°C	Same	As required
6	Lubricant temperature	± 2%	Same	As required
7	Exhaust backpressure	± 5%	Same	As required
8	Inlet depression	± 5%	Same	As required
9	Exhaust gas temperature	± 15%	Same	As required
10	Air inlet temperature (combustion air)	± 2°C	Same	As required
11	Atmospheric pressure	± 0.5%	Same	As required
12	Humidity (combustion air) (relative)	± 3.0%	Same	As required
13	Fuel temperature	± 2°C	Same	As required
14	Temperature with regard to dilution system	± 2°C	Same	As required
15	Dilution air humidity	± 3.0% absolute	Same	As required
16	HC analyzer	± 2%[2]	Same	Monthly
17	CO analyzer	± 2%[2]	Same	Monthly
18	NO_x analyzer	± 2%[2]	Same	Monthly
19	NO_x converter check	90%	Same	Monthly
20	CO_2 analyzer	± 2%[2]	Same	Monthly

[1]All accuracy requirements pertain to the final recorded value which is inclusive of the data acquisition system.

[2] If reading is under 100 ppm then the accuracy shall be ± 2 ppm.

Appendix B to Part III – Figures

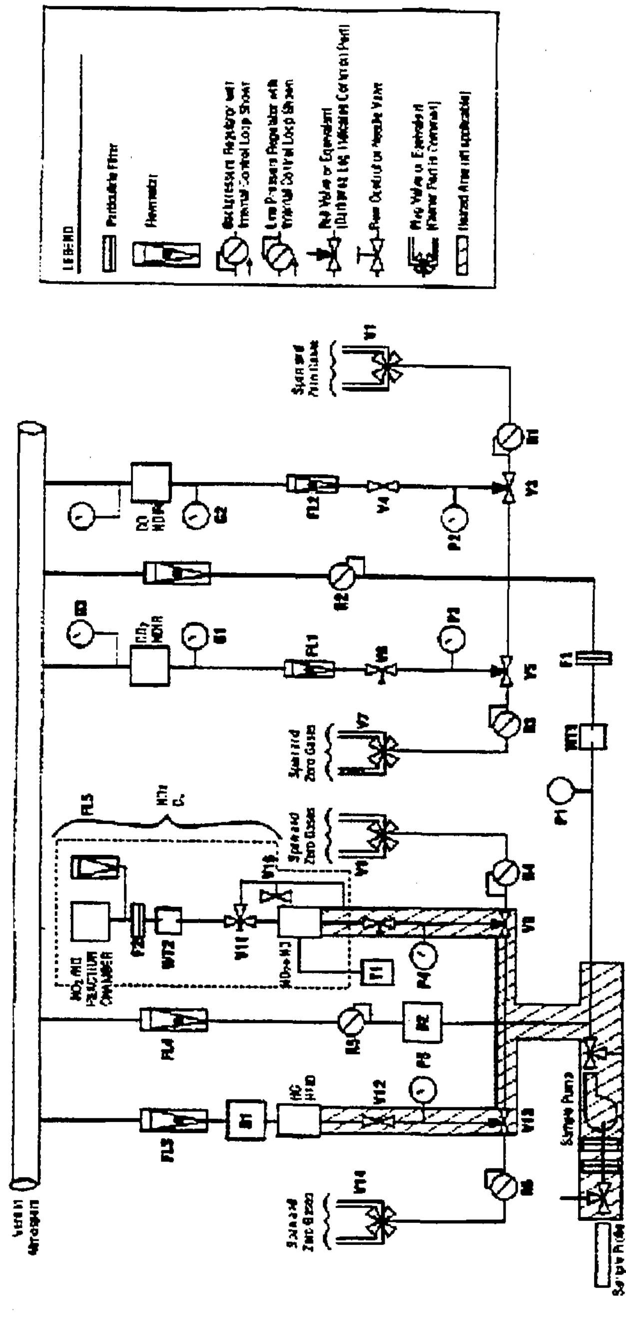

Figure 1. — Exhaust Gas Sampling and Analytical Train, Continuous Sampling

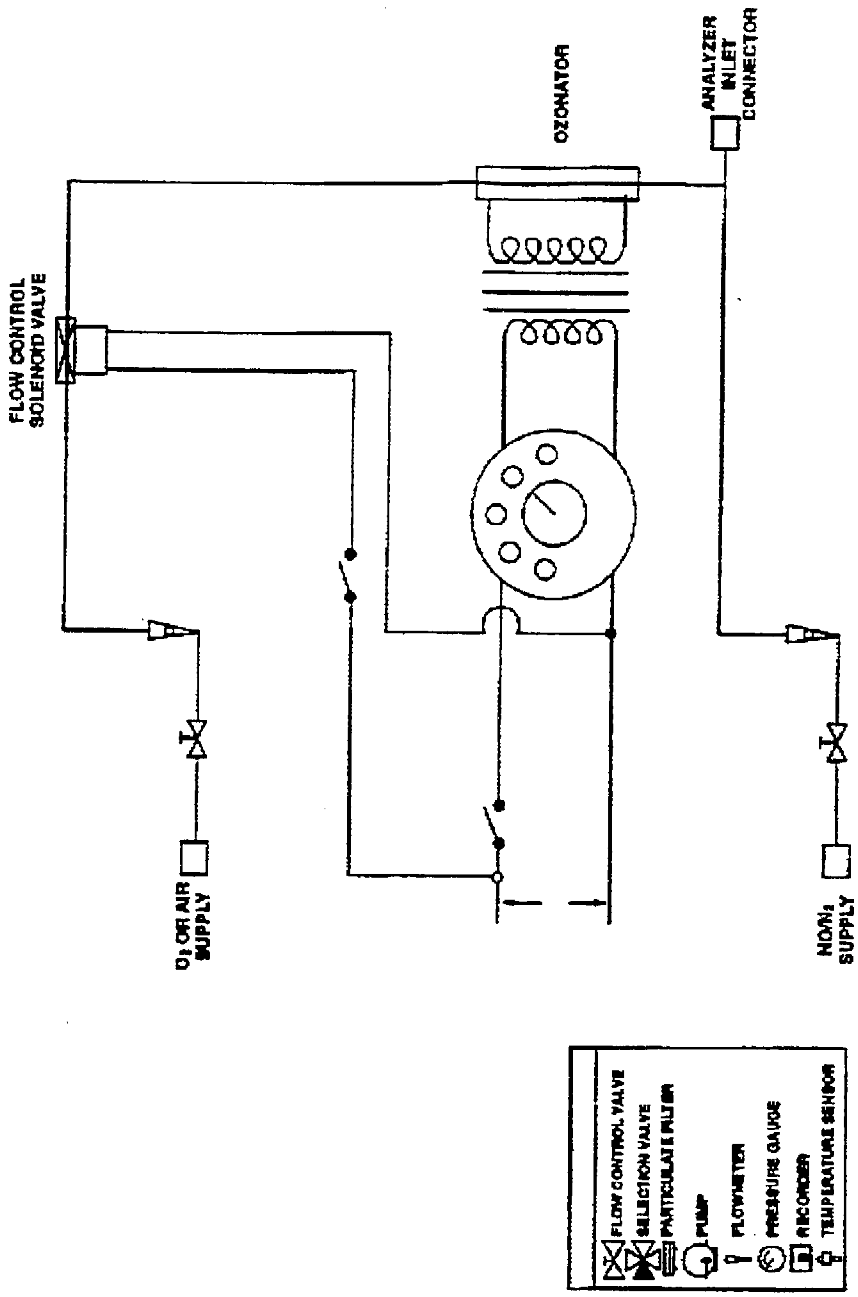

Figure 2. — NOx Converter Efficiency Detector

Part IV. Gaseous Exhaust Test Procedures

1. Scope; Applicability.

(a) This Part describes the procedures to follow in order to perform exhaust emission tests on new spark-ignition marine engines subject to the provisions of Part I. Provisions specific to raw gas sampling are in Part IV, sections 14 through 19, provisions specific to constant volume sampling are in Part IV, sections 20 through 26. All other sections in this Part apply to both raw gas sampling and constant volume sampling unless indicated otherwise.

(b) Requirements for emission test equipment and calibrating this equipment as required to perform the procedures in this Part are found in Part III.

2. Definitions.

The definitions in Part I, section 2 apply to this Part.

3. Abbreviations.

The abbreviations in Part I, section 3 apply to this Part.

4. Test Procedure Overview.

(a) The test consists of prescribed sequences of engine operating conditions to be conducted on an engine dynamometer or equivalent load and speed measurement device. The exhaust gases generated during engine operation are sampled either raw or dilute, and specific components are analyzed through the analytical system.

(b) The tests are designed to determine the brake-specific emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen. The test consists of one idle mode and four power modes with an exponential relationship between torque and speed which span the typical operating range of spark-ignition marine engines. These procedures require the determination of the concentration of each pollutant, fuel flow, and the power output during each mode. The measured values are weighted and used to calculate the grams of each pollutant emitted per brake kilowatt hour (g/kW-hr).

(c) (1) When an engine is tested for exhaust emissions the complete engine is tested, with all emission control devices installed and functioning.

(2) Additional accessories (for example, oil cooler, alternators, and so forth) may be installed, but such accessory loading will be considered parasitic in nature and observed power is used in the emission calculation.

(d) All emission control systems installed on or incorporated in the application must be functioning during all procedures in this Part. In cases of component malfunction or failure, no maintenance is allowed without prior approval from the Executive Officer in accordance with Part I, section 23.

5. Recorded Information.

(a) Record the information described in this section for each test where applicable.

(b) Test data; general.
(1) Engine identification number.
(2) Engine emissions control system.
(3) Test operator(s).
(4) Number of hours of operation accumulated on the engine before beginning the warm-up portion of the test (to the nearest tenth hour).
(5) Fuel identification.
(6) For two-stroke engines, fuel/oil mixture ratio.
(7) Date of most recent analytical assembly calibration.
(8) All pertinent instrument information such as tuning, gain, serial numbers, detector number, and calibration curve numbers. As long as this information is traceable, it may be summarized by system number or analyzer identification numbers.

(c) Test data; pre-test.
(1) Date and time of day.
(2) Test number.
(3) Barometric pressure; as an option, barometric pressure can be measured as a modal measurement instead of or in addition to a pre- and post-test measurement.
(4) Recorder chart or equivalent. Identify for each test segment zero traces for each range used, and span traces for each range used.

(d) Test data; modal.
(1) Recorder chart or equivalent. Identify for each test mode the emission concentration traces and the associated analyzer range(s).
(2) Observed engine torque.
(3) Observed engine rpm.

(4) Engine intake air flow, if applicable.
(5) Test cell temperature and humidity for each mode.
(6) For raw gas testing; fuel flow for each mode. Fuel flow measurement is not required for dilute testing but is allowed. If the fuel flow measurement is a volume measurement system, record the fuel temperature in the measurement system for fuel density corrections to the mass flow rate. If the fuel temperature is within 3 deg.C of the calibration temperature, no density correction is required.
(7) Engine intake temperature and humidity for each mode, if applicable.
(8) Exhaust sample line temperature, if applicable.

(e) Test data; post-test.
(1) Recorder chart or equivalent. Identify the hang-up check.
(2) Recorder chart or equivalent. Identify the zero traces for each range used and the span traces for each range used.
(3) Total number of hours of operation accumulated on the engine (to the nearest tenth hour).
(4) Barometric pressure, post-test segment.

6. Engine Parameters to be Measured and Recorded.

Measure or calculate, then record, the engine parameters in the table below:

Parameter	Units
Airflow rate (dry), if applicable	g/h
Fuel flow rate	g/h
Engine speed	rpm
Engine torque output	N-m
Power output	kW
Air inlet temperature	°C
Air humidity	mg/kg
Coolant temperature (liquid cooled)	°C
Exhaust mixing chamber surface temperature, if applicable	°C
Total accumulated hours of engine operation	H
Barometric pressure	kPa

7. Engine Inlet and Exhaust Systems.

(a) The engine manufacturer is liable for emission compliance over the full range of restrictions that are specified by the engine manufacturer for that particular engine.

(b) The air inlet filter system and exhaust muffler system combination used on the test engine must be the systems expected to yield the highest emission levels.

8. **Pre-test Procedures.**

(a) Engine service accumulation and stabilization procedure. Use the service accumulation procedure determined by the manufacturer for exhaust emission stabilizing of an engine, consistent with good engineering practice (see Part 1, section 21).

(1) The manufacturer determines, for each engine family, the number of hours at which the engine exhaust emission control system combination is stabilized for emission testing. However, this stabilization procedure may not exceed 12 hours. The manufacturer must maintain, and provide to the Executive Officer upon request, a record of the rationale used in making this determination. If the manufacturer can document that, at some time before the full 12 hour service accumulation period, the engine emissions are decreasing for the remainder of the 12 hours, the service accumulation may be completed at that time. The manufacturer may elect to accumulate 12 hours on each test engine within an engine family without making this determination.

(2) During service accumulation, the fuel and lubricants specified in Part III, section 8 must be used.

(3) Engine maintenance during service accumulation is allowed only in accordance with Part I, section 22.

(b) Engine pre-test preparation.

(1) Drain and charge the fuel tank(s) with the specified test fuel (see Part III, section 8) to 50 percent of the tank's nominal capacity. If an external fuel tank is used, the engine fuel inlet system pressure must be typical of what the engine will see in use.

(2) Operate the engine on the dynamometer measuring the fuel consumption (fuel consumption required only for raw gas sampling method) and torque before and after the emission sampling equipment is installed, including the sample probe, using mode 1 from Table 1-1 in Part 1, section 20. The emission sampling equipment may not significantly affect the operational characteristics of the engine (typically, the results should agree within five percent).

(c) Analyzer pre-test procedures.

(1) If necessary, warm up and stabilize the analyzer(s) before calibrations are performed.

(2) Replace or clean the filter elements and then vacuum leak check the system per Part III, section 24(a). If necessary, allow the

heated sample line, filters, and pumps to reach operating temperature.

(3) Perform the following system checks:

(A) If necessary, check the sample-line temperature. Heated FID sample line temperature must be maintained between 110 deg.C and 230 deg.C, a heated NO_X sample line temperature must be maintained between 60 deg.C and 230 deg.C.

(B) Check that the system response time has been accounted for before sample collection data recording.

(C) A hang-up check is permitted.

(4) Check analyzer zero and span before and after each test at a minimum. Further, check analyzer zero and span any time a range change is made or at the maximum demonstrated time span for stability for each analyzer used.

(d) Check system flow rates and pressures and reset if necessary.

9. Engine Dynamometer Test Run.

(a) Engine and dynamometer start-up.

(1) Only adjustments in accordance with Part I, section 17, may be made to the test engine before starting a test.

(2) If necessary, warm up the dynamometer as recommended by the dynamometer manufacturer or in accordance good engineering practice.

(3) At the manufacturer's option, the engine can be run with the throttle in a fixed position or by using the engine's governor (if the engine is manufactured with a governor). In either case, the engine speed and load must meet the requirements specified in paragraph (b)(12) of this section.

(b) Each test consists of the following:

(1) Record the general test data as specified in section 5 of this Part.

(2) Precondition the engine in the following manner;

(A) Operate the engine at idle for 2 to 3 minutes;

(B) Operate the engine at a power greater than or equal to 50 percent power at the rated speed for 5 to 7 minutes;

(C) Operate the engine at rated speed and maximum power for 25 to 30 minutes;

(D) Option. For four-stroke engines, where appropriate, it is permitted to precondition the engine at rated speed and maximum power until the oil and water temperatures are stabilized. The temperatures are defined as stabilized if they are maintained within 2 percent of point for 2 minutes. The engine must be operated a minimum of 10 minutes for this option. This optional procedure may be substituted for step in paragraphs (b)(2)(iii) of this section;

(E) Option. If the engine has been operating on service accumulation for a minimum of 40 minutes, the service accumulation may be substituted for steps in paragraphs (b)(2) (i) through (iii) of this section.

(3) Record all pre-test data specified in Part IV, section 5(c).

(4) Start the test cycle (see Part IV, section 10) within 10 minutes of the completion of the steps required by paragraph (b)(2) of this section.

(5) During the first mode calculate the torque corresponding to 71.6, 46.5, and 25.3 percent of the maximum observed torque for the rated speed.

(6) Once engine speed and load are set for a mode, run the engine for a sufficient period of time to achieve thermal stability. At the manufacturers option, determine and document the appropriate criterion for thermal stability for each engine family.

(7) Record all modal data specified in Part IV, section 5(e) for a minimum time period of the last two minutes of each mode. Longer averaging periods are acceptable, but the data averaged must be from a continuous time period. The duration of time during which this data is recorded is referred to as the "sampling period." The data collected during the sampling period is used for modal emission calculations.

(8) Continuously record the analyzer's response to the exhaust gas during the sampling period.

(9) Modes may be repeated.

(10) If a delay of more than one hour occurs between the end of one mode and the beginning of another mode, the test is void and must be restarted as described at paragraph (b)(1) of this section.

(11) The engine speed and load must be maintained within the requirements of Part IV, section 10 during the sampling period for each mode. If this requirement is not met, the mode is void and must be restarted.

(12) If at any time during a mode, the test equipment malfunctions or the specifications in Part IV, section 10 can not be met, the test is void, and must be aborted. Corrective action should be taken and the test restarted.

(13) Fuel flow and air flow during the idle condition may be determined just before or immediately following the dynamometer sequence, if longer times are required for accurate measurements. If the dilute sampling method (Constant Volume Sampling) is used, neither fuel flow nor air flow measurements are required.

(c) Exhaust gas measurements.
   (1) Measure HC, CO, CO_2, and NO_X concentration in the exhaust sample.
   (2) Each analyzer range that may be used during a test segment must have the zero and span responses recorded before the start of the test. Only the range(s) used to measure the emissions during the test is required to have its zero and span recorded after the completion of the test. Depending on the stability of each individual analyzer, more frequent zero checks or spans between modes may be necessary.
   (3) It is permitted to change filter elements between test segments.
   (4) A leak check is permitted between modes.
   (5) A hang-up check is permitted between modes (see Part IV, section 13).
   (6) If, during the emission measurement portion of a mode, the value of the gauges downstream of the NDIR analyzer(s) G3 or G4 (See Figure 1 in Appendix B of Part III) differs by more than ± 0.5 kPa, the mode is void.

10. Engine Test Cycle.

(a) The 5-mode cycle specified in Part I, section 20 shall be followed in dynamometer operation tests of spark-ignition marine engines.

(b) During each non-idle mode the specified speed and load shall be held to within ± 50 rpm or ± two percent of point, whichever is greater. During each idle mode the engine speed shall be held within ± 75 rpm or ± five percent of the manufacturers specified idle speed, whichever is greater. For direct drive products (no neutral gear), it is acceptable to have an accessory load on the engine during the idle mode provided that the engine speed is within ± five percent of the manufacturers specified idle speed and the accessory load is representative of in use operation.

(c) If the operating conditions specified in paragraph (b) of this section for modes 2, 3, 4, and 5 cannot be maintained, the Executive Officer may authorize deviations from the specified load conditions. Such deviations shall not exceed 10 percent of the maximum torque at the test speed. The minimum deviations, above and below the specified load, necessary for stable operation shall be determined by the manufacturer and approved by the Executive Officer before the test run.

(d) Do not include power generated during the idle mode (mode 5) in the calculation of emissions results.

11. Post-test Analyzer Procedures.

(a) Perform a hang-up check within 60 seconds of the completion of the last mode in the test. Use the following procedure:
  (1) Introduce a zero-grade gas or room air into the sample probe or valve V2 (see Figure 1 in Appendix B of Part III) to check the Ahangup zero≅ response. Simultaneously start a time measurement.
  (2) Select the lowest HC range used during the test.
  (3) Within four minutes of beginning the time measurement in paragraph (a)(1) of this section, the difference between the zero gas response and the hang-up zero response shall not be greater than 5.0 percent of full scale or 10 ppmC whichever is greater.

(b) Begin the analyzer span checks within six minutes after the completion of the last mode in the test. Record for each analyzer the zero and span response for each range used during the preceding test or test segment.

(c) If during the test, the filter element(s) were replaced or cleaned, a vacuum check must be performed per Part III, section 24(a) immediately after the span checks. If the vacuum side leak check does not meet the requirements of Part III, section 24(a) the test is void.

(d) Read and record the post-test data specified in Part IV, section 5(e).

(e) For a valid test, the analyzer drift between the before-segment and after-segment span checks for each analyzer must meet the following requirements:
  (1) The span drift (defined as the change in the difference between the zero response and the span response) must not exceed two percent of full-scale chart deflection for each range used.
  (2) The zero response drift must not exceed two percent of fullscale chart deflection for each range used above 155 ppm (or ppm C), or three percent of full-scale chart deflection for each range below 155 ppm (or ppm C).

12. Data Logging.

(a) A computer or any other automatic data collection (ADC) device(s) may be used as long as the system meets the requirements of this Part.

(b) Determine from the data collection records the analyzer responses corresponding to the end of each mode.

(c) Record data at a minimum of one Hz (one time per second).

(d) Determine the final value for power by averaging the individually calculated power points for each value of speed and torque recorded during the sampling period. As an alternative, the final value for power can be calculated from the average values for speed and torque, collected during the sampling period.

(e) Determine the final value for CO_2, CO, HC, and NO_X concentrations by averaging the concentration of each point taken during the sample period for each mode.

13. Exhaust Sample Procedure – Gaseous Components.

(a) Automatic data collection equipment requirements. The analyzer response may be read by automatic data collection (ADC) equipment such as computers, data loggers, etc. If ADC equipment is used the following is required:
   (1) For dilute grab ("bag") analysis, the analyzer response must be stable at greater than 99 percent of the final reading for the dilute exhaust sample bag. A single value representing the average chart deflection over a 10-second stabilized period shall be stored.
   (2) For continuous analysis systems, a single value representing the average integrated concentration over a cycle shall be stored. Alternatively, the ADC may store the individual instantaneous values collected during the measurement period.
   (3) The chart deflections or average integrated concentrations required in paragraphs (a)(1) and (a)(2) of this section may be stored on long-term computer storage devices such as computer tapes, storage discs, punch cards, and so forth, or they may be printed in a listing for storage. In either case a chart recorder is not required and records from a chart recorder, if they exist, need not be stored.
   (4) If ADC equipment is used to interpret analyzer values, the ADC equipment is subject to the calibration specifications of the analyzer as if the ADC equipment is part of analyzer system.

(b) Data records from any one or a combination of analyzers may be stored as chart recorder records.

(c) Grab sample analysis. For dilute grab sample analysis perform the following sequence:
   (1) Calibrate analyzers using the procedure described in Part III, section 26.
   (2) Record the most recent zero and span response as the preanalysis value.

(3) Measure HC, CO, CO_2, and NO_X background concentrations in the sample bag(s) and background sample bag(s) using the same flow rates and pressures.
(4) Good engineering practice dictates that analyzers used for continuous analysis should be operated such that the measured concentration falls between 15 percent and 100 percent of full scale.
(5) A post-analysis zero and span check of each range must be performed and the values recorded. The number of events that may occur between the pre and post checks is not specified. However, the difference between pre-analysis zero and span values (recorded in paragraph (c)(5) or (c)(6) of this section) versus those recorded for the post-analysis check may not exceed the zero drift limit or the span drift limit of 2 percent of full scale chart deflection for any range used. Otherwise the test is void.

(d) Continuous sample analysis. For continuous sample analysis, perform the following sequence:
(1) Calibrate analyzers using the procedures described in Part III, section 26.
(2) Leak check portions of the sampling system that operate at negative gauge pressures when sampling, and allow heated sample lines, filters, pumps, and so forth to stabilize at operating temperature.
(3) Option: Determine the hang-up for the FID or HFID sampling system:
(A) Zero the analyzer using zero air introduced at the analyzer port.
(B) Flow zero air through the overflow sampling system. Check the analyzer response.
(C) If the overflow zero response exceeds the analyzer zero response by two percent or more of the FID or HFID full-scale deflection, hang-up is indicated and corrective action must be taken (see paragraph (e) of this section).
(D) The complete system hang-up check specified in paragraph (f) of this section is recommended as a periodic check.
(4) Obtain a stable zero reading.
(5) Good engineering practice dictates that analyzers used for continuous analysis should be operated such that the measured concentration falls between 15 percent and 100 percent of full scale.
(6) Record the most recent zero and span response as the preanalysis values.
(7) Collect background HC, CO, CO_2, and NO_X in a sample bag (for dilute exhaust sampling only, see Part IV, section 22).

(8) Perform a post-analysis zero and span check for each range used at the conditions specified in paragraph (d)(1) of this section. Record these responses as the post-analysis values.
(9) Neither the zero drift nor the span drift between the preanalysis and post-analysis checks on any range used may exceed three percent for HC, or two percent for NO_X, CO, and CO_2, of full scale chart deflection, or the test is void. (If the HC drift is greater than three percent of full-scale chart deflection, hydrocarbon hang-up is likely.)
(10) Determine background levels of NO_X, CO, or CO_2 (for dilute exhaust sampling only) by the grab ("bag") technique outlined in paragraph (c) of this section.

(e) Hydrocarbon hang-up. If HC hang-up is indicated, the following sequence may be performed:
(1) Fill a clean sample bag with background air.
(2) Zero and span the HFID at the analyzer ports.
(3) Analyze the background air sample bag through the analyzer ports.
(4) Analyze the background air through the entire sample probe system.
(5) If the difference between the readings obtained is two ppm or more, clean the sample probe and the sample line.
(6) Reassemble the sample system, heat to specified temperature, and repeat the procedure in paragraphs (e)(1) through (e)(5) of this section.

14. Raw Gaseous Exhaust Sampling and Analytical System Description.

(a) Schematic drawing. An example of a sampling and analytical system which may be used for testing under this Part is shown in Figure 4 in Appendix A of this Part. All components or parts of components that are wetted by the sample or corrosive calibration gases shall be either chemically cleaned stainless steel or inert material (e.g., polytetrafluoroethylene resin). The use of "gauge savers" or "protectors" with nonreactive diaphragms to reduce dead volumes is permitted.

(b) Sample probe.
(1) The sample probe shall be a straight, closed end, stainless steel, multi-hole probe. The inside diameter shall not be greater than the inside diameter of the sample line + 0.03 cm. The wall thickness of the probe shall not be greater than 0.10 cm. The fitting that attaches the probe to the exhaust pipe shall be as small as practical in order to minimize heat loss from the probe.
(2) The probe shall have a minimum of three holes. The spacing of the radial planes for each hole in the probe must be such that they cover approximately equal cross-sectional areas of the exhaust

duct. The angular spacing of the holes must be approximately equal. The angular spacing of any two holes in one plane may not be 180 deg. ± 20 deg. (i.e., section C-C of Figure 1 in Appendix A of this Part). The holes should be sized such that each has approximately the same flow. If only three holes are used, they may not all be in the same radial plane.

(3) The exhaust gas probe must be located in a position which yields a well mixed, homogeneous sample of the engine exhaust. The probe must extend radially through the exhaust duct before where the exhaust mixes with the cooling water. The cooling water flow may be rerouted if necessary to obtain an emission sample provided that the modification has no significant effect on the performance or emissions characteristics of the engine. The probe must pass through the approximate center and must extend across at least 80 percent of the diameter of the duct. The exact position of the probe may vary from engine family to engine family.

(c) Sample transfer line.

(1) The maximum inside diameter of the sample line shall not exceed 1.32 cm.

(2) If valve V2 in Figure 1 of Appendix B of Part III is used, the sample probe must connect directly to valve V2 in Figure 1 of Appendix B of Part III. The location of optional valve V2 may not be greater than 1.22 m from the exhaust duct.

(3) The location of optional valve V16 in Figure 1 of Appendix B of Part III may not be greater than 61 cm from the sample pump. The leakage rate for this section on the pressure side of the sample pump may not exceed the leakage rate specification for the vacuum side of the pump.

(d) Venting. All vents including analyzer vents, bypass flow, and pressure relief vents of regulators should be vented in such a manner to avoid endangering personnel in the immediate area.

(e) Any variation from the specifications in this Part including performance specifications and emission detection methods may be used only with prior approval by the Executive Officer.

(f) Additional components, such as instruments, valves, solenoids, pumps, switches, and so forth, may be employed to provide additional information and coordinate the functions of the component systems.

(g) The following requirements must be incorporated in each system used for raw testing under this Part.

(1) Take the sample for all components with one sample probe and split it internally to the different analyzers.

(2) Heat the sample transport system from the engine exhaust pipe to the HC analyzer for the raw gas sampling method as indicated in Figure 1 in Appendix B of Part III. The NO_X analyzer for the raw gas sampling method may be heated as indicated in Figure 1 in Appendix B of Part III. The HC analyzer and the NO_X analyzer for the dilute sampling method may be heated as indicated in Figure 1 in Appendix B of Part III.

15. Raw Gaseous Sampling Procedures.

Fit all heated sampling lines with a heated filter to extract solid particles from the flow of gas required for analysis. The sample line for HC measurement must be heated. The sample line for CO, CO_2, and NO_X may be heated or unheated.

16. Intake Air Flow Measurement Specifications.

(a) If used, the engine intake air flow measurement method used must have a range large enough to accurately measure the air flow over the engine operating range during the test. Overall measurement accuracy must be ± two percent of full-scale value of the measurement device for all modes except the idle mode. For the idle mode, the measurement accuracy shall be ± five percent or less of the full-scale value. The Executive Officer must be advised of the method used before testing.

(b) When an engine system incorporates devices that affect the air flow measurement (such as air bleeds, air injection, pulsed air, and so forth) that result in understated exhaust emission results, make corrections to the exhaust emission results to account for such effects.

17.Fuel Flow Measurement Specifications.

(a) Fuel flow measurement is required only for raw testing but is allowed for dilute testing.

(b) The fuel flow rate measurement instrument must have a minimum accuracy of ± two percent of full-scale flow rate for each measurement range used.

18. Data Evaluation for Gaseous Emissions.

For the evaluation of the gaseous emissions recording, record the last two minutes of each mode and determine the average values for HC, CO, CO_2, and NO_X during each mode from the average concentration readings determined from the corresponding calibration data.

19. Raw Emission Sampling Calculations.

(a) Derive the final test results through the steps described in this section.

(b) Air and fuel flow method. If both air and fuel flow mass rates are measured, the following equations are used to determine the weighted emission values for the test engine:

$$W_{HC} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{HC_{exh}}}{M_{exh}}\, x\, WHX\, x \frac{1}{10^6}$$

$$W_{NO_x} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{NO_2}}{M_{exh}}\, x\, WNO_x\, x\, K_H\, x \frac{1}{10^6}$$

Where:
W_{HC} = Mass rate of HC in exhaust [g/hr],
G_{AIRD} = Intake air mass flow rate on dry basis [g/hr],
G_{FUEL} = Fuel mass flow rate [g/hr],

$$W_{CO} = (G_{AIRD} + G_{FUEL})\, x \frac{M_{CO}}{M_{exh}}\, x\, WCO\, x \frac{1}{10^6}$$

M_{HCexh} =Molecular weight of hydrocarbons in the exhaust; see the following equation:

~~$M_{HC_{exh}} = 12.01 + 1.008 x \alpha$~~

$$M_{HC_{exh}} = 12.01 + 1.008 x\alpha$$

Where:
α =Hydrocarbon/carbon atomic ratio of the fuel.
M_{exh} =Molecular weight of the total exhaust; see the following equation:

~~$M_{exh} = \frac{M_{HC_{exh}}\, x\, WHC}{10^6} + \frac{28.01\, x\, WCO}{10^2} + \frac{44.1\, x\, WCO_2}{10^2} + \frac{46.01 + WNO_x}{10^6} + \frac{2.016\, x\, WH_2}{10^2} + 18.01\, x\, (1-K) +$~~

$$M_{exh} = \frac{M_{HC_{exh}}\, x\, WHC}{10^6} + \frac{28.01\, x\, WCO}{10^2} + \frac{44.1\, x\, WCO_2}{10^2} + \frac{46.01\, x\, WNO_x}{10^6} + \frac{2.016\, x\, WH_2}{10^2} + 18.01\, x\, (1-K) +$$

$$28.01\, x \frac{\left[100 - \frac{WHC}{10^4} - WCO - WCO_2 \frac{WNO_x}{10^4} - WH_2 - 100\, x\, (1-K)\right]}{10^2}$$

Where:
WHC = HC volume concentration in exhaust, ppmC wet
WCO = CO percent concentration in the exhaust, wet
DCO = CO percent concentration in the exhaust, dry
WCO_2 = CO_2 percent concentration in the exhaust, wet
DCO_2 = CO_2 percent concentration in the exhaust, dry
WNO_X = NO volume concentration in exhaust, ppm wet
WH_2 = H_2 percent concentration in exhaust, wet
K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration x K, where K is:

$$\frac{1}{1+0.005\,x\,(DCO+DCO_2)\,x\,\alpha-0.01\,x\,DH_2}$$

DH_2 = H2 percent concentration in exhaust, dry, calculated from the following equation:

$$DH_2=\frac{0.5\,x\,\alpha\,x\,DCO\,x\,(DCO+DCO_2)}{DCO+(3\,x\,DCO_2)}$$

W_{CO} = Mass rate of CO in exhaust, [g/hr]
M_{CO} = Molecular weight of CO = 28.01
W_{NOx} = Mass rate of NO_X in exhaust, [g/hr]
M_{NO2} = Molecular weight of NO_2 = 46.01
K_H = Factor for correcting the effects of humidity on NO_2 formation for four-stroke gasoline engines; see the equation below:

$$K_H=\frac{1}{1-0.0329\,x\,(H-10.71)}$$

Where:
H = specific humidity of the intake air in grams of moisture per kilogram of dry air.
For two-stroke gasoline engines, KH should be set to 1.

(c) Fuel flow method. The following equations are to be used when fuel flow is selected as the basis for mass emission calculations using the raw gas method.

$$W_{HC} = \frac{G_{FUEL}}{TC} x \frac{WHC}{10^4}$$

$$W_{CO} = \frac{M_{CO}}{M_F} x \frac{G_{FUEL}}{TC} x WCO$$

$$W_{NO_x} = \frac{M_{NO_x}}{M_F} x \frac{G_{FUEL}}{TC} x \frac{WNO_x}{10^4} x K_H$$

Where:
W_{HC} = Mass rate of HC in exhaust, [g/hr]
M_F = Molecular weight of test fuel; see following equation:

$$M_F = 12.01 + 1.008 x \alpha$$

G_{FUEL} = Fuel mass flowrate, [g/hr]
TC = Total carbon; see following equation:

$$TC = WCO + WCO_2 + \frac{WHC}{10^4}$$

WHC = HC volume concentration in exhaust, ppmC wet
WCO = CO percent concentration in the exhaust, wet
DCO = CO percent concentration in the exhaust, dry
WCO_2 = CO_2 percent concentration in the exhaust, wet
DCO_2 = CO_2 percent concentration in the exhaust, dry
WNO_x = NO volume concentration in exhaust, ppm wet
WH_2 = H_2 percent concentration in exhaust, wet
K = correction factor to be used when converting dry measurements to a wet basis. Therefore, wet concentration = dry concentration x K, where K is:

$$K = \frac{1}{1 + 0.005 x (DCO + DCO_2) x \alpha - 0.01 x DH_2}$$

DH_2 = H_2 percent concentration in exhaust, dry, calculated from the following equation:

$$DH_2 = \frac{0.5\,x\,\alpha\,x\,DCO\,x\,(DCO + DCO_2)}{DCO + (3\,x\,DCO_2)}$$

W_{CO} = Mass rate of CO in exhaust, [g/hr]
M_{CO} = Molecular weight of CO = 28.01
W_{NOx} = Mass rate of NO_X in exhaust, [g/hr]
M_{NO2} = Molecular weight of NO_2 = 46.01
K_H = Factor for correcting the effects of humidity on NO_2 formation for four-stroke gasoline engines; see the equation below:

$$K_H = \frac{1}{1 - 0.0329\,x\,(H - 10.71)}$$

Where:
H = specific humidity of the intake air in grams of moisture per kilogram of dry air.
For two-stroke gasoline engines, KH should be set to 1.

(d) The final reported emission test results must be computed by using the following formula for each individual gas component:

$$Y_{wm} = \frac{\sum (W_i\,x\,f_i)}{\sum (P_i\,x\,f_i)}$$

Where:
Y_{wm} = Weighted mass emission level (HC, CO, NO_x) for a test [g/kW-hr].
W_i = Average mass flow rate (W_{HC}, W_{CO}, W_{NOx}) of an emission from the test engine during mode i, [g/hr].
f_i = Weighting factors for each mode according to Part IV, section 10(a)
P_i = Average power measured during mode i, [kW], calculated according to the formula given in Part IV, section 23(b). Power for the idle mode shall always be zero for this calculation.

(e) The final reported weighted brake-specific fuel consumption (WBSFC) shall be computed by use of the following formula:

$$WBSFC = \frac{\sum (F_i\,x\,f_i)}{\sum (P_i\,x\,f_i)}$$

Where:
WBSFC = Weighted brake-specific fuel consumption in grams of fuel per kilowatt-hour (g/kW-hr).
F_i = Fuel mass flow rate of the engine during mode i, [g/hr].
f_i = Weighting factors for each mode according to Part IV, section 10(a)
P_i = Average power measured during mode i, [kW], calculated according to the formula given in Part IV, section 23(b). Power for the idle mode shall always be zero for this calculation.

20. CVS Concept of Exhaust Gas Sampling System.

(a) A dilute exhaust sampling system is designed to directly measure the true mass of emissions in engine exhaust without the necessity of measuring either fuel flow or intake air flow. This is accomplished by diluting the exhaust produced by an engine under test with ambient background air and measuring the total diluted exhaust flow rate and the concentration of emissions within the dilute flow. Total mass flow of an emission is then easily calculated.

(b) A constant volume sampler (CVS) is typically used to control the total amount of dilute flow through the system. As the name implies, a CVS restricts flow to a known value dependent only on the dilute exhaust temperature and pressure.

(c) For the testing described in this Part, a CVS must consist of: A mixing tunnel into which the engine exhaust and dilutant (background) air are dumped; a dilute exhaust flow metering system; a dilute exhaust sample port; a background sample port; a dilute exhaust sampling system; and a background sampling system.

(1) Mixing tunnel. The mixing tunnel must be constructed such that complete mixing of the engine exhaust and background air is assured before the sampling probe.

(2) Exhaust flow metering system. A dilute exhaust flow metering system must be used to control the total flow rate of the dilute engine exhaust as described in Part IV, section 21.

(3) Exhaust sample port. A dilute exhaust sample port must be located in or downstream of the mixing tunnel at a point where complete mixing of the engine exhaust and background air is assured.

(4) Background sample port. A dilute background sample port must be located in the stream of background air before it is mixed with the engine exhaust. The background probe must draw a representative sample of the background air during each sampling mode.

(5) Exhaust sampling system. The dilute exhaust sampling system controls the flow of samples from the mixing tunnel to the

analyzer system. This could be either a continuous sampling system or grab (bag) sampling system. If a critical flow venturi (CFV) is used on the dilute exhaust sample probe, this system must assure that the sample CFV is in choke flow during testing. If no CFV is used, this system must assure a constant volumetric flow rate through the dilute exhaust sample probe or must incorporate electronic flow compensation.

(6) Background sampling system. The background sampling system controls the flow of samples from the background air supply to the analyzer system. This could be either a continuous sampling system or grab (bag) sampling system. This system must assure a constant volumetric flow rate through the background sample probe.

21. Dilute Gaseous Exhaust Sampling and Analytical System Description.

(a) General. The exhaust gas sampling system described in this section is designed to measure the true mass emissions of engine exhaust. This system utilizes the Constant volume Sampling (CVS) concept (described in Part IV, section 20) of measuring mass emissions of HC, NO_x, CO, and CO_2. Grab sampling for individual modes is an acceptable method of dilute testing for all constituents, HC, NO_x, CO, and CO_2. Continuous dilute sampling is not required for any of the exhaust constituents, but is allowable for all. Heated sampling is not required for any of the constituents, but is allowable for HC and NO_x. The mass of gaseous emissions is determined from the sample concentration and total flow over the test period. As an option, the measurement of total fuel mass consumed over a cycle may be substituted for the exhaust measurement of CO_2. General requirements are as follows:

(1) This sampling system requires the use of a Positive Displacement Pump-Constant Volume Sampler (PDP-CVS) system with a heat exchanger, or a Critical Flow Venturi-Constant Volume Sampler (CFV-CVS) system with CVS sample probes and/or a heat exchanger or electronic flow compensation. Figure 2 in Appendix A of this Part is a schematic drawing of the PDP-CVS system. Figure 3 in Appendix A of this Part is a schematic drawing of the CFV-CVS system.

(2) The HC analytical system requires:

(i) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

(ii) Continuously integrated measurement of diluted HC meeting the minimum requirements and technical specifications contained in paragraph (b)(2) of this section.

(iii) The dilute HC analytical system for spark-ignition marine engines does not require a heated flame ionization detector (HFID).

(iv) If used, the HFID sample must be taken directly from the diluted exhaust stream through a heated probe and integrated continuously over the test cycle.

(v) The heated probe must be located in the sampling system far enough downstream of the mixing area to ensure a uniform sample distribution across the CVS duct at the sampling zone.

(3) The CO and CO_2 analytical system requires:

(i) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

(ii) Continuously integrated measurement of diluted CO and CO_2 meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(4) The NO_x analytical system requires:

(i) Grab sampling (see Part IV, section 20, and Figure 2 or Figure 3 in Appendix A of this Part) and analytical capabilities (see Part IV, section 23, and Figure 4 in Appendix A of this Part), or

(ii) A continuously integrated measurement of diluted NO_x meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(5) Since various configurations can produce equivalent results, exact conformance with these drawings is not required. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components, such as snubbers, which are not needed to maintain accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgment.

(6) Other sampling and/or analytical systems may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.

(b) Component description. The components necessary for exhaust sampling must meet the following requirements:

(1) Exhaust dilution system. The PDP-CVS must conform to all of the requirements listed for the exhaust gas PDP-CVS in Part IV, section 20 of this chapter. The CFV-CVS must conform to all of the requirements listed for the exhaust gas CFV-CVS in Part IV, section 20. In addition, the CVS must conform to the following requirements:

(i) The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream in the dilution system at a temperature of 190 deg.C or less at the sampling zone for hydrocarbon measurement and as required to prevent condensation at any point in the dilution system. Gaseous emission samples may be taken directly from this sampling point.

(ii) For the CFV-CVS, either a heat exchanger or electronic flow compensation is required (see Figure 3 in Appendix A of this Part).

(iii) For the CFV-CVS when a heat exchanger is used, the gas mixture temperature, measured at a point immediately ahead of the critical flow venturi, must be within ± 11 deg.C of the average operating temperature observed during the test with the simultaneous requirement that condensation does not occur. The temperature measuring system (sensors and readout) must have an accuracy and precision of ± 2 deg.C. For systems utilizing a flow compensator to maintain proportional flow, the requirement for maintaining constant temperature is not necessary.

(2) Continuous HC measurement system.

(i) The continuous HC sample system (as shown in Figure 2 or 3 in Appendix A of this Part) uses an "overflow" zero and span system. In this type of system, excess zero or span gas spills out of the probe when zero and span checks of the analyzer are made.

(ii) No other analyzers may draw a sample from the continuous HC sample probe, line, or system, unless a common sample pump is used for all analyzers and the sample line system design reflects good engineering practice.

(iii) The overflow gas flow rates into the sample line must be at least 105 percent of the sample system flow rate.

(iv) The overflow gases must enter the sample line as close as practical to the outside surface of the CVS duct or dilution system.

(v) The continuous HC sampling system consists of a probe (which for a HFID analyzer must raise the sample to the specified temperature) and, where used, a sample transfer system (which for a HFID must maintain the specified temperature). The HFID continuous hydrocarbon sampling system (exclusive of the probe) must:

(A) Maintain a wall temperature of 190 deg. C ± 11 deg. C as measured at every separately controlled heated component (that is, filters, heated line sections), using permanent thermocouples located at each of the separate components.

(B) Have a wall temperature of 190 deg. C ± 11 deg. C over its entire length. The temperature of the system is demonstrated by profiling the thermal characteristics of the system where possible at initial installation and after any major maintenance performed on the system. The profiling is to be accomplished using the insertion thermocouple probing technique. The system temperature must be monitored continuously during testing at the locations and temperature described in Part IV, section 21(b)(2).

(C) Maintain a gas temperature of 190 deg. C ± 11 deg. C immediately before the heated filter and HFID. Determine these gas temperatures by a temperature sensor located immediately upstream of each component.

(vi) The continuous hydrocarbon sampling probe:

(A) Is defined as the first 25.4 to 76.2 cm of the continuous hydrocarbon sampling system.

(B) Has a 0.483 cm minimum inside diameter.

(C) Is installed in the dilution system at a point where the dilution air and exhaust are well mixed and provide a homogenous mixture.

(D) Is sufficiently distant (radially) from other probes and the system wall so as to be free from the influence of any wakes or eddies.

(E) For a continuous HFID sample probe, the probe must increase the gas stream temperature to 190 deg. C ± 11 deg. C at the exit of the probe. Demonstrate the ability of the probe to accomplish this using the insertion thermocouple technique at initial installation and after any major maintenance. Demonstrate compliance with the temperature specification by continuously recording during each test the temperature of either the gas stream or the wall of the sample probe at its terminus.

(vii) The response time of the continuous measurement system must be taken into account when logging test data.

(3) Sample mixing.

(i) Configure the dilution system to ensure a well mixed, homogeneous sample before the sampling probe(s).

(ii) Make the temperature of the diluted exhaust stream inside the dilution system sufficient to prevent water condensation.

(iii) Direct the engine exhaust downstream at the point where it is introduced into the dilution system.

(4) Continuously integrated NO_x, CO, and CO_2 measurement systems.

(i) Sample probe requirements:

(A) The sample probe for continuously integrated NO_x, CO, and CO_2 must be in the same plane as the continuous

HC probe, but sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influences of any wakes or eddies.

(B) The sample probe for continuously integrated NO_x, CO, and CO_2 must be heated and insulated over the entire length, to prevent water condensation, to a minimum temperature of 55 deg. C. Sample gas temperature immediately before the first filter in the system must be at least 55 deg. C.

(ii) Conform to the continuous NO_x, CO, or CO_2 sampling and analysis system to the specifications of Part III with the following exceptions and revisions:

(A) Heat the system components requiring heating only to prevent water condensation, the minimum component temperature is 55 deg. C.

(B) Coordinate analysis system response time with CVS flow fluctuations and sampling time/test cycle offsets, if necessary.

(C) Use only analytical gases conforming to the specifications of Part III, section 12 for calibration, zero and span checks.

(D) Use a calibration curve conforming to Part III, section 21 for CO and CO_2 and Part III, section 18 for NO_x for any range on a linear analyzer below 155 ppm.

(iii) Convert the chart deflections or voltage output of analyzers with non-linear calibration curves to concentration values by the calibration curve(s) specified in Part III section ~~91.~~321 before flow correction (if used) and subsequent integration takes place.

22. [Reserved].

23. Exhaust Gas Analytical System; CVS Grab Sample.

(a) Schematic drawings. Figure 4 in Appendix A of this Part is a schematic drawing of the exhaust gas analytical system used for analyzing CVS grab "bag" samples from spark-ignition engines. Since various configurations can produce accurate results, exact conformance with the drawing is not required. Additional components such as instruments, valves, solenoids, pumps and switches may be used to provide additional information and coordinate the functions of the component systems. Other components such as snubbers, which are not needed to maintain accuracy in some systems, may be excluded if their exclusion is based on good engineering judgement.

(b) Major component description. The analytical system, Figure 4 in Appendix A of this Part, consists of a flame ionization detector (FID) or a heated flame ionization detector (HFID) for the measurement of hydrocarbons, nondispersive infrared analyzers (NDIR) for the measurement of carbon monoxide and carbon dioxide, and a chemiluminescence detector (CLD) (or heated CLD (HCLD)) for the measurement of oxides of nitrogen. The exhaust gas analytical system shall conform to the following requirements:
   (1) The CLD (or HCLD) requires that the nitrogen dioxide present in the sample be converted to nitric oxide before analysis. Other types of analyzers may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.
   (2) If CO instruments are used which are essentially free of CO_2 and water vapor interference, the use of the conditioning column may be deleted. (See Part III, sections 17 and 20.)
   (3) A CO instrument will be considered to be essentially free of CO_2 and water vapor interference if its response to a mixture of three percent CO_2 in N_2, which has been bubbled through water at room temperature, produces an equivalent CO response, as measured on the most sensitive CO range, which is less than one percent of full scale CO concentration on ranges above 300 ppm full scale or less than 3 ppm on ranges below 300 ppm full scale. (See Part III, section 17.)

(c) Alternate analytical systems. Analysis systems meeting the specifications and requirements of this Part for dilute sampling may be used upon approval of the Executive Officer.

(d) Other analyzers and equipment. Other types of analyzers and equipment may be used if shown to yield equivalent results and if approved in advance by the Executive Officer.

24. Dilute Sampling Procedure – CVS Calibration.

(a) The CVS is calibrated using an accurate flowmeter and restrictor valve.
   (1) The flowmeter calibration shall be traceable to the National Institute for Standards and Testing (NIST), and will serve as the reference value (NIST "true" value) for the CVS calibration. (Note: In no case should an upstream screen or other restriction which can affect the flow be used ahead of the flowmeter unless calibrated throughout the flow range with such a device.)
   (2) The CVS calibration procedures are designed for use of a "metering venturi" type flowmeter. Large radius or American Society of Mechanical Engineers (ASME) flow nozzles are considered equivalent if traceable to NIST measurements. Other measurement systems may be used if shown to be equivalent

under the test conditions in this section and traceable to NIST measurements.

(3) Measurements of the various flowmeter parameters are recorded and related to flow through the CVS.

(4) Procedures used by ARB for both PDP-CVS and CFV-CVS are outlined below. Other procedures yielding equivalent results may be used if approved in advance by the Executive Officer.

(b) After the calibration curve has been obtained, verification of the entire system may be performed by injecting a known mass of gas into the system and comparing the mass indicated by the system to the true mass injected. An indicated error does not necessarily mean that the calibration is wrong, since other factors can influence the accuracy of the system (e.g., analyzer calibration, leaks, or HC hangup). A verification procedure is found in paragraph (e) of this section.

(c) PDP-CVS calibration.

(1) The following calibration procedure outlines the equipment, the test configuration, and the various parameters which must be measured to establish the flow rate of the CVS pump.

(i) All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump.

(ii) The calculated flow rate, in cm^3/s, (at pump inlet absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters.

(iii) The linear equation which relates the pump flow and the correlation function is then determined.

(iv) In the event that a CVS has a multiple speed drive, a calibration for each range used must be performed.

(2) This calibration procedure is based on the measurement of the absolute values of the pump and flowmeter parameters that relate the flow rate at each point. Two conditions must be maintained to assure the accuracy and integrity of the calibration curve:

(i) The temperature stability must be maintained during calibration. (Flowmeters are sensitive to inlet temperature oscillations; this can cause the data points to be scattered. Gradual changes in temperature are acceptable as long as they occur over a period of several minutes.)

(ii) All connections and ducting between the flowmeter and the CVS pump must be absolutely void of leakage.

(3) During an exhaust emission test the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

(4) Connect a system as shown in Figure 5 in Appendix A of this Part. Although particular types of equipment are shown, other configurations that yield equivalent results may be used if approved in advance by the Executive Officer. For the system indicated, the following measurements and accuracies are required:

Parameter	Symbol	Units	Sensor-readout tolerances
Barometric pressure (corrected)	P_B	kPa	± 0.34 kPa
Ambient temperature	T_{EI}	°C	± 0.28 °C
Air temperature into metering venturi	T_{EI}	°C	± 1.11 °C
Pressure drop between inlet & throat of venturi	P_{ED}	kPa	± 0.012 kPa
Air flow	Q_S	M^3/min.	± 0.5 percent of NIST value
Air temperature at CVS pump inlet	P_{TI}	°C	± 1.11 °C
Pressure depression at CVS pump inlet	P_{PI}	kPa	± 0.055 kPa
Pressure head at CVS pump outlet	P_{PO}	KPa	± 0.055 kPa
Air temperature at CVS pump outlet (optional)	P_{YO}	°C	± 1.11 °C
Pump revolutions during test period	N	Revs	± 1 Rev.
Elapsed time for test period	t	s	± 0.5 s

(5) After the system has been connected as shown in Figure 5 of Appendix A of this Part, set the variable restrictor in the wide open position and run the CVS pump for 20 minutes. Record the calibration data.

(6) Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression that will yield a minimum of six data points for the total calibration. Allow the system to stabilize for 3 minutes and repeat the data acquisition.

(7) Data analysis:

(i) The air flow rate, Qs, at each test point is calculated in standard cubic feet per minute 20 deg.C, 101.3 kPa from the flowmeter data using the manufacturer's prescribed method.

(ii) The air flow rate is then converted to pump flow, V_O, in cubic meter per revolution at absolute pump inlet temperature and pressure:

$$V_O = \frac{Q_S}{n} x \frac{T_P}{293} x \frac{101.3kPa}{P_P}$$

Where:

V_O =Pump flow, m^3/rev at T_P, P_P.

Q_S =Meter air flow rate in standard cubic meters per minute, standard conditions are 20 deg.C, 101.3 kPa.

n =Pump speed in revolutions per minute.

T_P =Pump inlet temperature in Kelvin,=P_{TI} +273 [deg.K].

P_P =Absolute pump inlet pressure, kPa. =Pp-P_{PI}

Where:

P_P =barometric pressure, kPa.

P_{PI} =Pump inlet depression, kPa.

(iii) The correlation function at each test point is then calculated from the calibration data:

$$X_O = \frac{1}{n}\sqrt{\left(\frac{\Delta P}{P_E}\right)}$$

Where:

X_O = correlation function.

Δ P = The pressure differential from pump inlet to pump outlet, kPa.

= P_E-P_P.

P_E = Absolute pump outlet pressure, [kPa] =P_B+P_{PO}

Where:

P_{PO} = Pressure head at pump outlet, kPa (inches fluid).

(iv) A linear least squares fit is performed to generate the calibration equation which has the form:

$$V_O = D_O - M(X_O)$$

D_O and M are the intercept and slope constants, respectively, describing the regression line.

(8) A CVS system that has multiple speeds should be calibrated on each speed used. The calibration curves generated for the ranges will be approximately parallel and the intercept values, D_O, will increase as the pump flow range decreases.

(9) If the calibration has been performed carefully, the calculated values from the equation will be within ± 0.50 percent of the measured value of V_O. Values of M will vary from one pump to

another, but values of D_O for pumps of the same make, model and range should agree within ± three percent of each other. Calibrations should be performed at pump start-up and after major maintenance to assure the stability of the pump slip rate. Analysis of mass injection data will also reflect pump slip stability.

(d) CFV-CVS calibration.

(1) Calibration of the CFV is based upon the flow equation for a critical venturi.

(i) Gas flow is a function of inlet pressure and temperature:

$$Q_S = \frac{K_V P}{\sqrt{T_K}}$$

Where:

Q_S = flow rate [m^3/min].

K_V = calibration coefficient.

P = absolute pressure [kPa].

T_K = absolute temperature [deg.K].

(ii) The calibration procedure described in paragraph (d)(3) of this section establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

(2) The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

(3) Measurements necessary for flow calibration are as follows:

Parameter	Symbol	Units	Tolerances
Barometric pressure (corrected)	P_B	kPa	± 0.34 kPa
Air temperature into flowmeter	T_{EI}	°C	± 0.28 °C
Pressure drop between inlet & outlet of venturi	P_{ED}	kPa	± 0.012 kPa
Air flow	Q_S	m^3/min.	± 0.5 percent of NIST value
CVS inlet depression	P_{PI}	kPa	± 0.055 kPa
Pressure head at CVS pump outlet	P_{PO}	kPa	± 0.055 kPa
Temperature at venturi inlet	T_V	°C	± 2.22 °C

(4) Set up equipment as shown flow measuring devices and the critical flow venturi will seriously affect the accuracy in Figure 6 in Appendix A of this Part and eliminate leaks. (Leaks between the of the calibration.)

(5) Set the variable flow restrictor to the open position, start the blower, and allow the system to stabilize. Record data from all instruments.

(6) Vary the flow restrictor and make at least eight readings across the critical flow range of the venturi.

(7) Data analysis. The data recorded during the calibration are to be used in the following calculations:

(i) The air flow rate (designated as Qs) at each test point is calculated in standard cubic feet per minute from the flow meter data using the manufacturer's prescribed method.

(ii) Calculate values of the calibration coefficient for each test point::

$$K_V = \frac{Q_S \sqrt{T_V}}{P_V}$$

Q_S = Flow rate in standard cubic meter per minute, at the standard conditions of 20 deg.C, 101.3 kPa.
T_V = Temperature at venturi inlet, deg.K.
P_V = Pressure at venturi inlet, kPA $=P_B-P_{PI}$

Where:
P_{PI} = Venturi inlet pressure depression, kPa.

(iii) Plot K_V as a function of venturi inlet pressure. For choked flow, K_V will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_V decreases. (See Figure 7 in Appendix A of this Part.)

(iv) For a minimum of eight points in the critical region calculate an average K_V and the standard deviation.

(v) If the standard deviation exceeds 0.3 percent of the average K_V, take corrective action.

(e) CVS system verification. The following "gravimetric" technique can be used to verify that the CVS and analytical instruments can accurately measure a mass of gas that has been injected into the system. (Verification can also be accomplished by constant flow metering using critical flow orifice devices.)

(1) Obtain a small cylinder that has been charged with 99.5 percent or greater propane or carbon monoxide gas.

(2) Determine a reference cylinder weight to the nearest 0.01 grams.

(3) Operate the CVS in the normal manner and release a quantity of pure propane into the system during the sampling period (approximately five minutes).
(4) The calculations are performed in the normal way except in the case of propane. The density of propane (0.6109 kg/m^3) carbon atom is used in place of the density of exhaust hydrocarbons.
(5) The gravimetric mass is subtracted from the CVS measured mass and then divided by the gravimetric mass to determine the percent accuracy of the system.
(6) Good engineering practice requires that the cause for any discrepancy greater than ± two percent must be found and corrected.

25. CVS Calibration Frequency.

Calibrate the CVS positive displacement pump or critical flow venturi following initial installation, major maintenance or as necessary when indicated by the CVS system verification (described in Part IV, section 24(e)).

26. Dilute Emission Sampling Calculations.

(a) The final reported emission test results must be computed by use of the following formula:

$$A_{wm} = \frac{\sum (W_i \, x \, WF_i)}{\sum (P_i \, x \, WF_i)} \, x \, K_{Hi}$$

Where:

A_{wm}= Weighted mass emission level (HC, CO, CO_2, or NO_x) for a test [g/kW-hr].

W_i = Average mass flow rate of an emission from a test engine during mode i [g/hr].

WF_i = Weighting factor for each mode i as defined in Part IV, section 10(a).

P_i = Gross average power generated during mode i [kW] calculated from the following equation (power for the idle mode shall always be zero for this calculation):

$$P_i = \frac{2\pi}{60{,}000} \, x \, speed \, x \, torque$$

speed = average engine speed measured during mode i [rev./minute]
torque = average engine torque measured during mode i [N-m]

K_{Hi} = Humidity correction factor for mode i. This correction factor only affects calculations for NO_x and is equal to one for all other emissions. K_{Hi} is also equal to one for all two-stroke engines.

(b) The mass flow rate (W_i) of an emission for mode i is determined from the following equation:

$$W_i = Q_i \; x \; D \; x \left(C_{Di} - C_{Bi} \; x \left(1 - \frac{1}{DF_i} \right) \right)$$

Where:
Q_i = Volumetric flow rate of the dilute exhaust through the CVS at standard conditions [m^3/hr at STP].
D = Density of a specific emission (D_{HC}, D_{CO}, D_{CO2}, D_{NOx}) in the exhaust [g/m^3].
DF_i = Dilution factor of the dilute exhaust during mode i.
C_{Di} = Concentration of the emission (HC, CO, NO_x) in the dilute exhaust extracted from the CVS during mode i [ppm].
C_{Bi} = Concentration of the emission (HC, CO, NO_x) in the background sample during mode i [ppm].
STP = Standard temperature and pressure. All volumetric calculations made for the equations in this section are to be corrected to a standard temperature of 20 deg.C and 101.3 kPa.

(c) Densities for emissions that are to be measured for this test procedure are:
D_{HC} = 576.8 g/m^3
D_{NOx} = 1912 g/m^3
D_{CO} = 1164 g/m^3
D_{CO2} = 1829 g/m^3
(1) The value of D_{HC} above is calculated based on the assumption that the fuel used has a carbon to hydrogen ratio of 1:1.85. For other fuels, D_{HC} can be calculated from the following formula:

$$D_{HC} = \frac{M_{HC}}{R_{STP}}$$

Where:
M_{HC} = Molecular weight of the hydrocarbon molecule divided by the number of carbon atoms in the molecule [g/mole].
R_{STP} = Ideal gas constant for a gas at STP = 0.024065 [m^3- mole].
(2) The idealized molecular weight of the exhaust hydrocarbons, i.e., the molecular weight of the hydrocarbon molecule divided by the number of carbon atoms in the molecule, M_{HC} can be calculated from the following formula:

$$M_{HC} = M_C + \alpha M_H + \beta M_O$$

Where:
M_C = Molecular weight of carbon = 12.01 [g/mole].
M_H = Molecular weight of hydrogen = 1.008 [g/mole].
α = Hydrogen to carbon ratio of the test fuel.

(3) The value of D_{NOx} above assumes that NO_x in entirely in the form of NO_2.

(d) The dilution factor (DF) is the ratio of the volumetric flow rate of the background air to that of the raw engine exhaust. The following formula is used to determine DF:

$$DF = \frac{13.4}{C_{D_{HC}} + C_{D_{CO}} + C_{D_{CO_2}}}$$

Where:
C_{DHC} = Concentration of HC in the dilute sample [ppm].
C_{DCO} = Concentration of CO in the dilute sample [ppm].
C_{DCO2} = Concentration of CO_2 in the dilute sample [ppm].

(e) The humidity correction factor K_H is an adjustment made to the measured NO_x. This corrects for the sensitivity that a spark-ignition engine has to the humidity of its combustion air. The following formula is used to determine K_H for NO_x calculations:

$$K_H = \frac{1}{1 - 0.0329(H - 10.71)}$$

Where:
H = Absolute humidity of the engine intake air [grams of water per kilogram of dry air].

(f) The absolute humidity of the engine intake air H is calculated using the following formula:

$$H = \frac{6.211 P_{dew}}{P_B - \left(\frac{P_{dew}}{100}\right)}$$

Where:
P_{dew} = Saturated vapor pressure at the dew point temperature [kPa].
P_B = Barometric pressure [kPa].

(g) The fuel mass flow rate F_i can be either measured or calculated using the following formula:

$$F_i = \frac{M_f}{T}$$

Where:
M_f = Mass of fuel consumed by the engine during the mode [g].
T = Duration of the sampling period [hr].

(h) The mass of fuel consumed during the mode sampling period, M_{FUEL} can be calculated from the following equation:

$$M_f = \frac{G_S}{R_2 \, x \, 273.15}$$

Where:
G_S = Mass of carbon measured during the mode sampling period [g].
R_2 = The fuel carbon weight fraction, which is the mass of carbon in fuel per mass of fuel [g/g].

(i) The grams of carbon measured during the mode G_S can be calculated from the following equation:

$$G_S = \frac{12.011 \, x \, HC_{mass}}{12.011 + 1.008\alpha} + 0.429\, CO_{mass} + 0.273\, CO_{2\ mass}$$

Where:
HC_{mass} = mass of hydrocarbon emissions for the mode sampling period [g].
CO_{mass} = mass of carbon monoxide emissions for the mode sampling period [g].
CO_2 mass = mass of carbon dioxide emissions for the mode sampling period [g].
α = The atomic hydrogen to carbon ratio of the fuel.

27. Catalyst Thermal Stress Resistance Evaluation.

(a) (1) The purpose of the evaluation procedure specified in this section is to determine the effect of thermal stress on catalyst conversion efficiency. The thermal stress is imposed on the test catalyst by exposing it to quiescent heated air in an oven. The evaluation of the effect of such stress on catalyst performance is based on the resultant degradation of the efficiency with which the conversions of specific pollutants are promoted. The application of this evaluation procedure involves the several steps that are described in the following paragraphs.

(2) The engine manufacturer need not submit catalyst conversion efficiency data for pollutants that the catalyst being tested was not designed to reduce/oxidize. The engine manufacturer must specify the pollutants that the catalyst will be converting and submit catalyst conversion efficiency data on only those pollutants.

(b) Determination of initial conversion efficiency.

(1) A synthetic exhaust gas mixture having the composition specified in section 29 is heated to a temperature of 450 deg.C ± 5 deg.C and passed through the new test catalyst or, optionally, a test catalyst that has been exposed to temperatures less than or equal to 500 deg.C for less than or equal to two hours, under flow conditions that are representative of anticipated in-use conditions.

(2) The concentration of each pollutant of interest, that is, hydrocarbons, carbon monoxide, or oxides of nitrogen, in the effluent of the catalyst is determined by means of the instrumentation that is specified for exhaust gas analysis in Part III.

(3) The conversion efficiency for each pollutant is determined by:

(i) Subtracting the effluent concentration from the initial concentration,

(ii) Dividing this result by the initial concentration,

(iii) Multiplying this result by 100 percent.

(c) Imposition of thermal stress.

(1) The catalyst is placed in an oven that has been pre-heated to 1000 deg.C and the temperature of the air in the oven is maintained at 1000 deg.C ± 10 deg.C for six hours. Optionally, the catalyst may instead be placed in an oven having a 90% nitrogen/10% water vapor environment that has been pre-heated to at least 850 deg.C and the temperature of the nitrogen/water vapor environment in the oven is maintained at 850 deg.C ± 10 deg.C for six hours.

(2) The catalyst is removed from the oven and allowed to cool to room temperature.

(d) Determination of final conversion efficiency. The steps ~~listen~~listed in paragraph (b) of this section are repeated.

(e) Determination of conversion efficiency degradation.

(1) The final conversion efficiency determined in paragraph (c) of this section is subtracted from the initial conversion efficiency determined in paragraph (b) of this section.

(2) This result is divided by the initial conversion efficiency.

(3) This result is multiplied by 100 percent.

(f) Determination of compliance with degradation limit. The percent degradation determined in paragraph (e) of this section must not be greater than 20 percent.

Appendix A to Part IV – Figures.

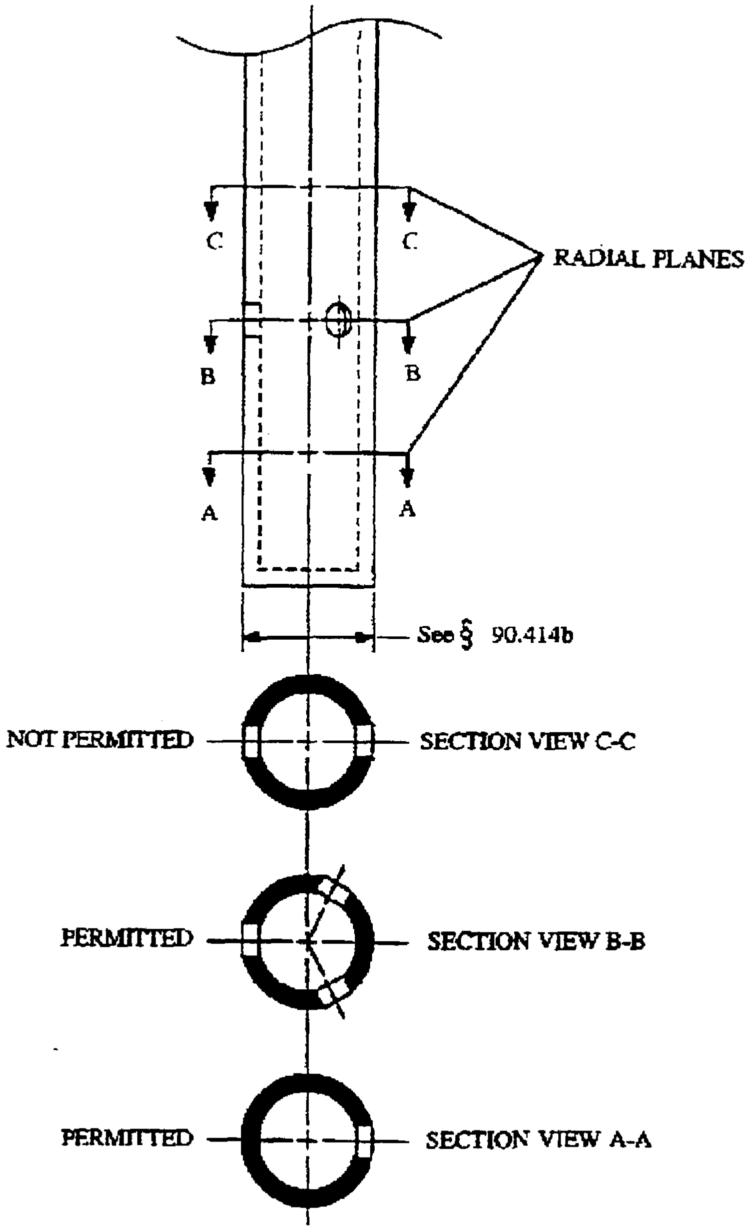

Figure 1.—Sample Probe and Typical Hole Spacings

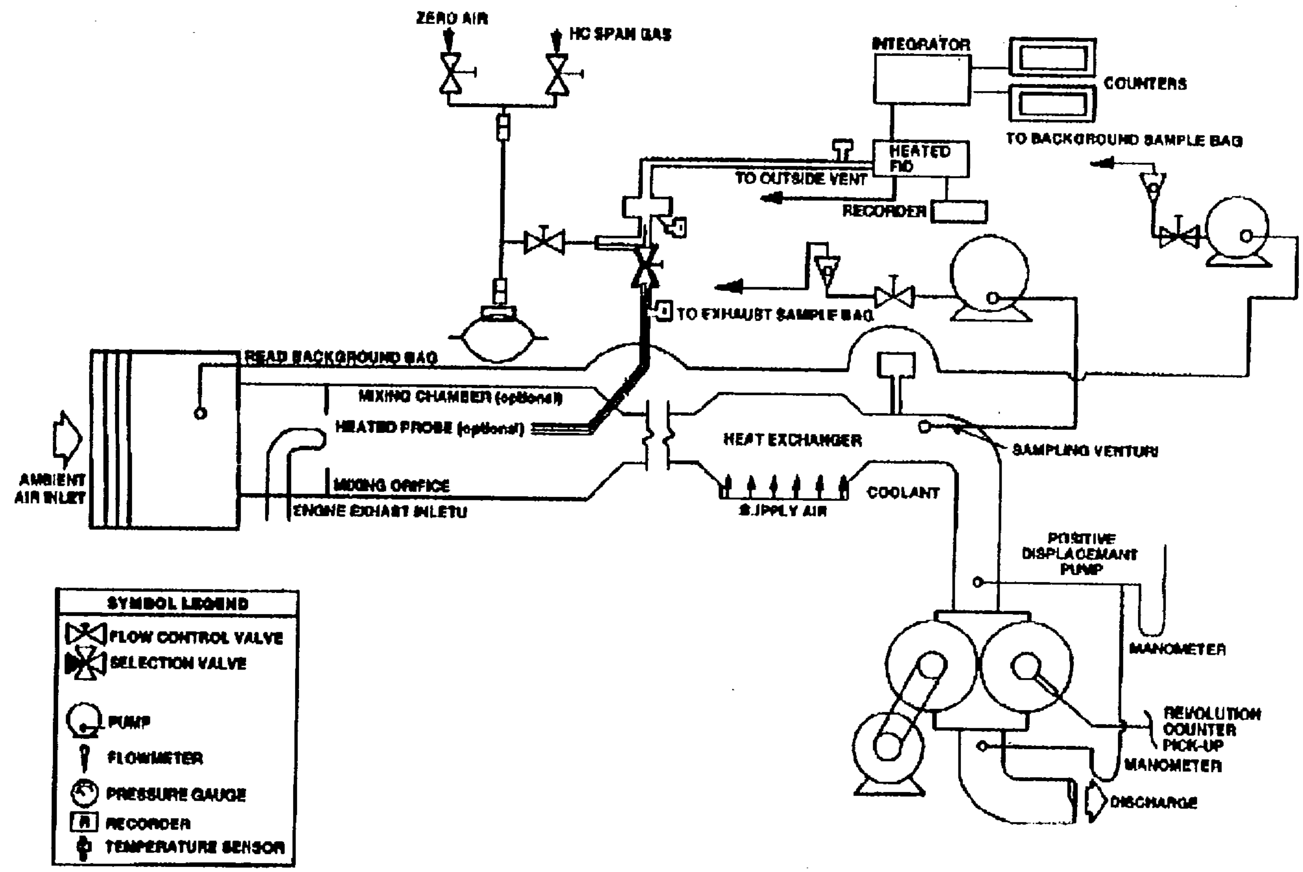

Figure 2 — Gaseous Emissions Sampling System (PDP-CVS)
Showing both grab bag sampling and continous sampling

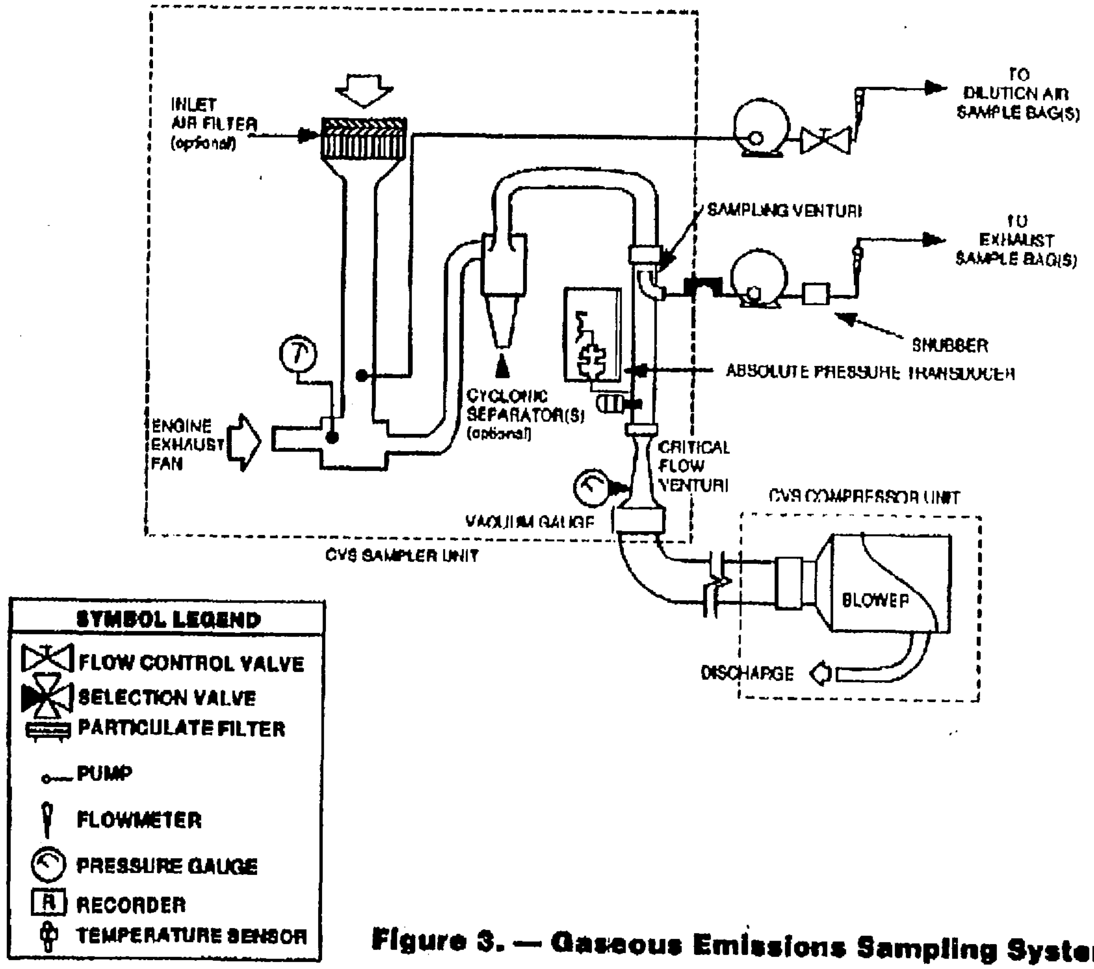

Figure 3. — Gaseous Emissions Sampling System (CVF-CVS)

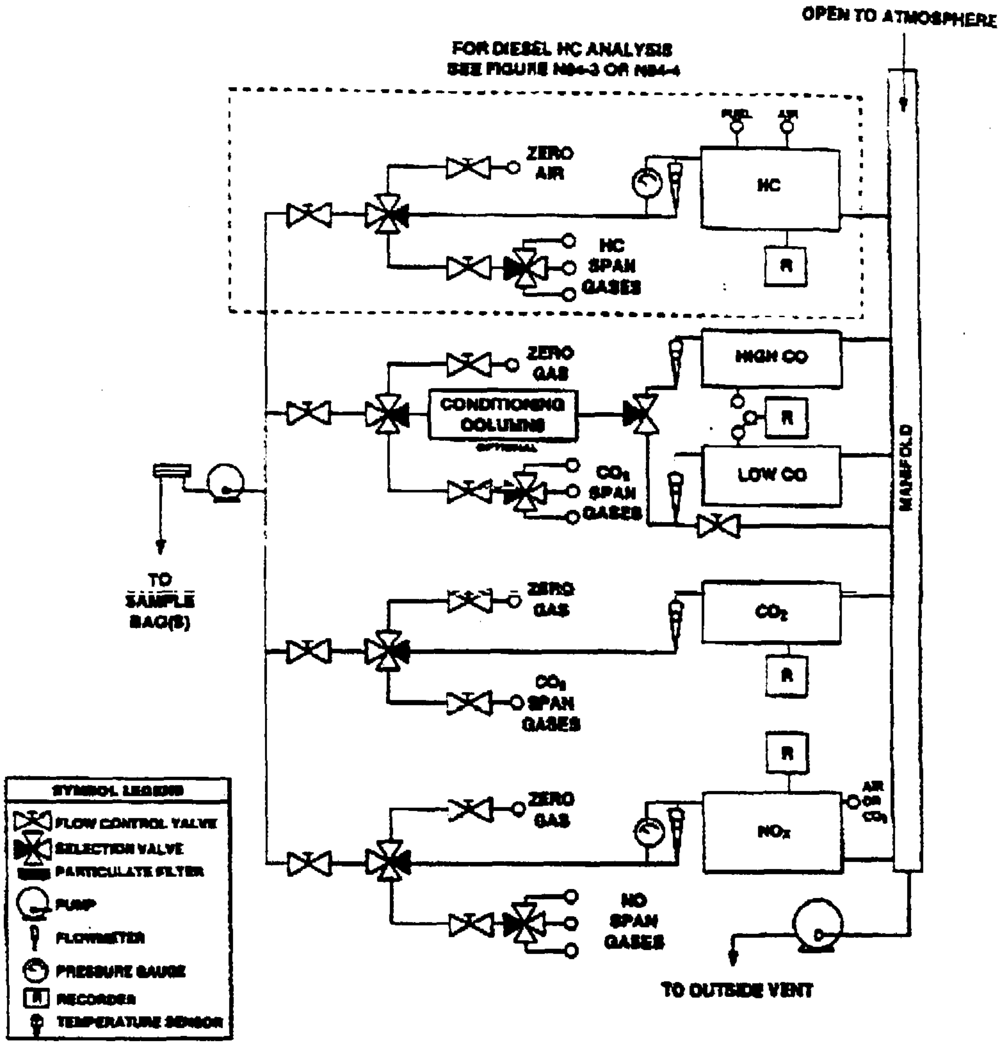

Figure 4. — Exhaust Gas Analytical System

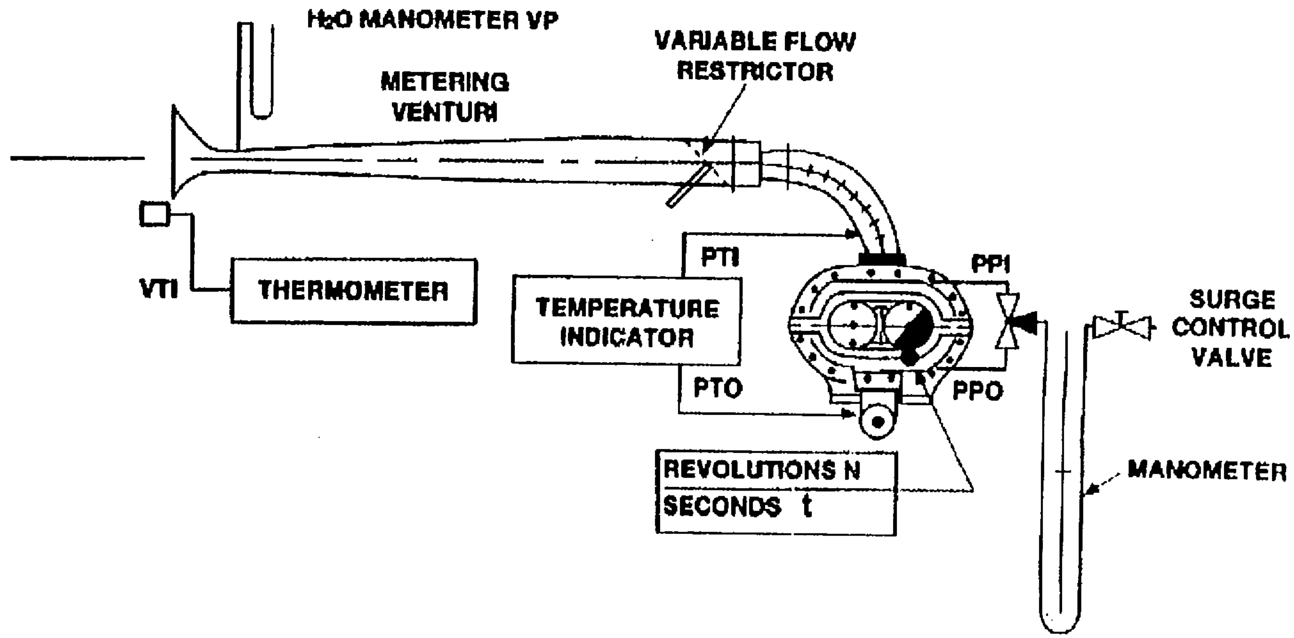

Figure 5. — PDP-CVS Calibration Configuration

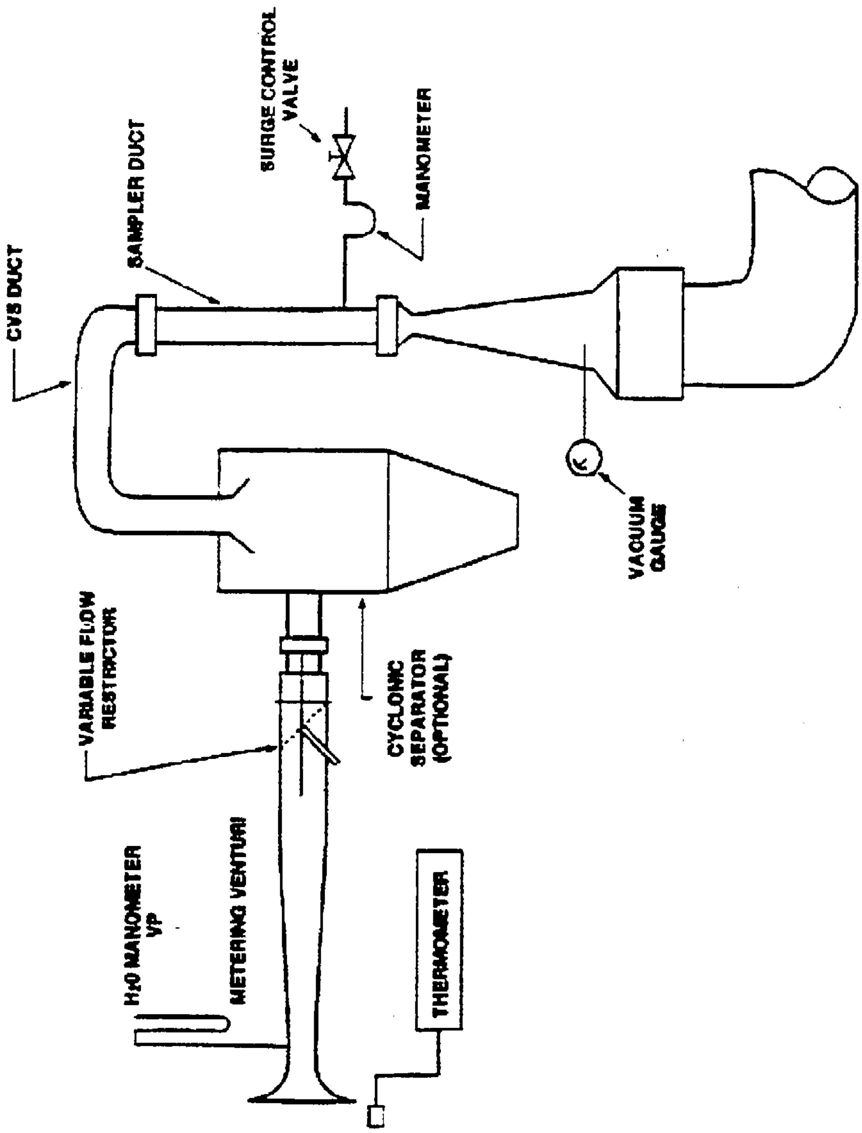

Figure 6. — CFV-CVS Calibration Configuration

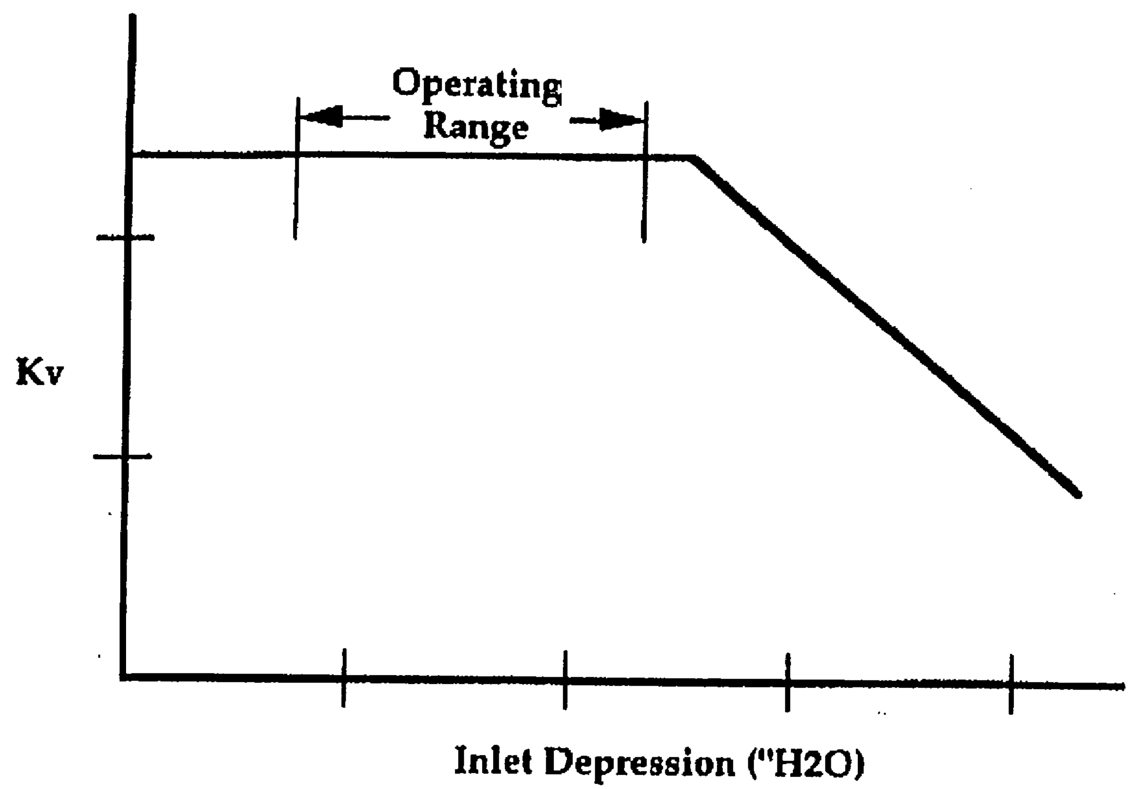

Figure 7.—Sonic Flow Choking

ATTACHMENT C

ENGINE TESTING PROGRAM

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C3 External Cylindrical Catalysts Installed on Engine
C4 Cylindrical Riser Cat (Water-jacketed)

1. Summary of Emissions Tests

ARB staff has gathered E4 emission data from the U.S. EPA (who performed in-house tests) and Mercury Marine. The data are shown below in Table C-1. "BSO" calibration refers to the "*Bodensee Schiffahrts Ordnung,*" the Swiss boat engine emission requirements. "Base" calibration refers to the factory air-fuel ratio programming or setting.

The table shows that carbureted uncontrolled (new) engines have emissions of about 8 g/kW-hr HC and 6 g/kW-hr NOx, and rich-calibration (open-loop) EFI engines have emissions of about 5 g/kW-hr HC and 10 g/kW-hr NOx. Since about 1997, the engine makers have been phasing out production of non-EFI engines. The population of existing inboard gasoline engines is largely composed of carbureted engines now. It is expected that all new marine engines will be electronic multi-point fuel-injected by 2005.

The manufacturers have been leaning the mixture of their engines in response to the European standards which take effect in 2002. They have indicated that they plan to sell these leaned engines in the United States even though they are not yet required to meet any emission levels. The average of the emission results for these engines is 3.5 g/kW-hr HC and 13.0 g/kW-hr NOx. The population this was based on was not extensive, and the calibrations were not optimized.

2. Engine Test Program

ARB and U.S. EPA have been testing a catalyst-controlled, oxygen-feedback electronically fuel-controlled marine engine. GM Powertrain and Mercury Marine each donated 454-CID V-8 engines, and Southwest Research Institute installed, optimized, and evaluated the performance of the various control schemes over a wide-range of test conditions as well as the E-4 recreational marine test cycle. Engelhard and DCL International have developed and donated candidate catalysts.

Table C-1

Baseline Engines Summary of E4 Emission-test Results

Engine CID[1]	Power hp	Fuel sys[3]	Calibra-tion[4]	HC g/kW-hr	NOx g/kW-hr	CO g/kW-hr
L-4 181	106	Carb	Base	11.3	8.1	282
NK[2]	115	Carb		5.8	4.8	207
NK	120	Carb		8.6	4.3	200
NK	150	Carb		6.2	5.5	208
302	162	Carb	Base	8.5	6.0	247
L-4 230	165	Carb	Base	15.4	6.8	184
NK	200	Carb		5.8	6.7	208
350	220	Carb	Base	4.7	4.2	262
350	224	Carb	Base	8.1	5.8	173
351	212	Carb	Base	7.2	6.0	229
351	263	Carb	Base	4.4	10.3	101
454	282	Carb	Base	4.6	12.2	131
351	248	EFI	Base	5.2	9.7	149
454	280	MPI		4.4	8.5	170
454	294	MPI		4.7	9.4	160
V-6 262	213	TBI	BSO	3.0	8.7	42
351	243	EFI	BSOa	5.8	11.7	48
351	256	EFI	BSOb	3.4	18.2	72
454	307	MPI	BSO	2.7	13.4	44
460	307	MPI	BSO	2.7	13.1	44

[1]CID means cubic inches displacement. The engines are V-8 configuration unless otherwise marked.
[2]NK means not known
[3]The abbreviations and acronyms are as follows
Carb means carbureted
EFI means electronic fuel injection, not otherwise specified
MPI mean multi-port fuel injection
TBI means throttle-body fuel injection
[4]Calibration refers to air-fuel mixture program for the engine.
Blank means factory calibration
Base means factory calibration
BSO means calibrated lean according the Swiss Bodensee standards
BSOa means 1st attempt at BSO lean calibration
BSOb means alternative attempt at BSO lean calibration

Following are the data on the engine used in the testing. A big-block 454 cubic-inch displacement engine was chosen becauseit is supplied from the factory with electronically controlled fuel-injection. The engine control module was ready to receive exhaust gas recirculation and oxygen feedback signals. The small-block 350 cubic-inch displacement V-8 is the most common engine as far as sales, but is not offered with this capability at this time. Some data on the test engine are shown in Table C-2.

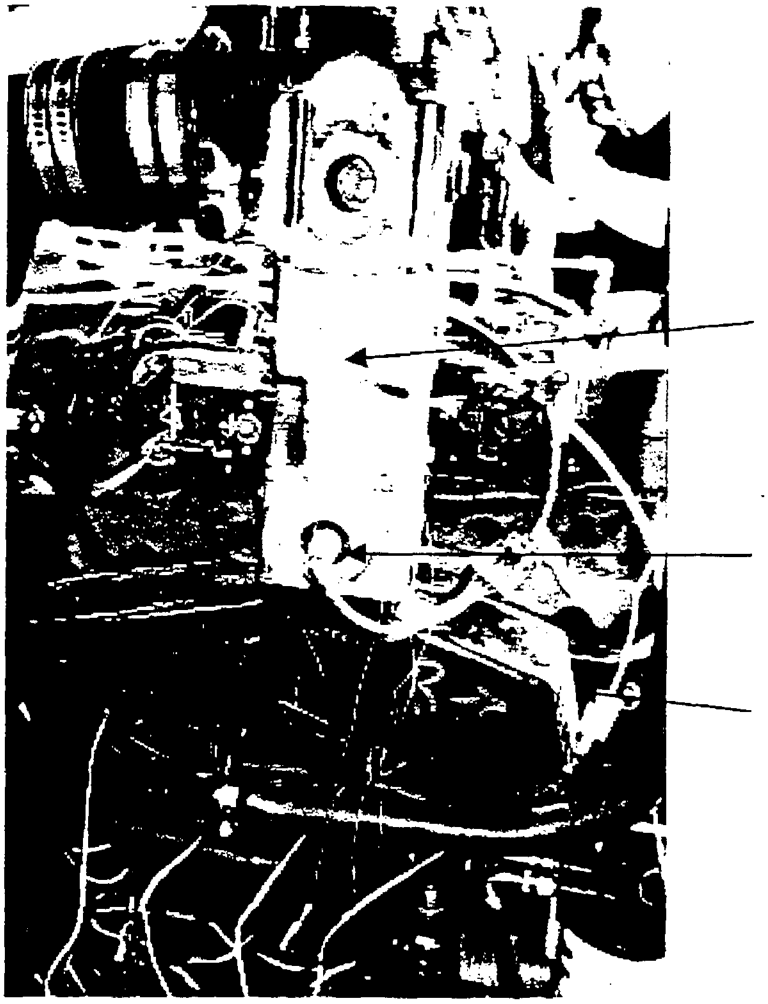
Table C-2 Test Engine Description	
Engine Model	Mercury 7.4-liter MPI
Engine Supplier	General Motors (Marine Std)
Displacement	454 cubic inches
Power rating	310 hp at 4600 rpm
Exhaust Back pressure at 4600 rpm WOT	10 inches Hg (294 hp)
Material, valves	Cast-iron, overhead valve, push-rod operated, roller followers
Fuel System	Electronic multi-point fuel-injection
Cooling	Raw water jacket cooling, raw water exhaust manifold cooling. Engine jacket cooling modified later to be closed anti-freeze with water-to-water radiator.

Note: WOT is wide-open throttle.

SwRI outfitted the original factory engine with exhaust gas recirculation, oxygen-feedback air-fuel control, and exhaust catalysts. The exhaust gas recirculation modification consisted of an original factory (General Motors) exhaust gas recirculation valve to admit exhaust gases into the air intake manifold, a moisture knock-out drum, a small exhaust pipe from the exhaust manifold to the intake manifold, and an electrical connection to actuate and control the unit. The exhaust gas recirculation valve was linear in operation (gas flow is approximately linear with applied voltage or pulse-width), and fed its position back to the engine control module for fine-tuning and diagnostics.

The engine was outfitted with oxygen feedback air-fuel control. This included original factory General Motors parts: oxygen sensor and connection or wiring harness. The engine control module was programmed to accept these signals. The oxygen sensor was first installed near the dry exhaust gas sampling point, at the top of the exhaust elbow, about 3 to 6 inches upstream from the water-exhaust gas mixing point. But the oxygen sensors would be prone to shorting out or thermally cracking on exposure to inadvertent water contact at this location. So the oxygen sensor was moved another 6 to 12 inches upstream, near to the exhaust manifold joint to the riser (see figure C-1). In this position it has performed properly in over 100 hours of testing.

Figure C-1
View of Marine Engine Exhaust Manifold with Catalyst and Oxygen Sensor Visible



The engine was fitted with a succession of three-way catalysts. Three different catalyst substrates were installed in a stock Mercury Marine exhaust riser extension which has a rectangular cross-sectional flow area (see Figure C-2). This cast-iron water-jacketed piece is made to be placed in the exhaust pipe between the manifold and the elbow to raise the elbow above the water-line of the boat. Both Engelhard and DCL International supplied cut-to-fit 2" x 2" x 6" rectangular catalyst elements to fit in these risers. Specifications for these catalysts are listed in Table C-3. Substrates with varying densities were evaluated, including 400 cells-per-square-inch (cpsi), 200 cpsi, and 60 cpsi. The 400-cpsi catalyst had very high resistance-to-flow; consequently the engine was not run close to full-speed WOT with the catalysts. The 200 cpsi riser catalysts offered less resistance, but this still resulted in an unacceptably high power decrease (from 280 hp base-configuration down to less than 230 hp). The 200 cpsi substrates are the coarsest ones available for automobile service. However, 60 cpsi substrates were obtained through DCL International of Toronto, Ontario, in order to test a compact low-resistance candidate. These substrates are typically only used on two-stroke motorcycles in Asia.

Figure C-2
Riser Catalysts Installed in Factory Cast-iron Jacketed Exhaust Riser

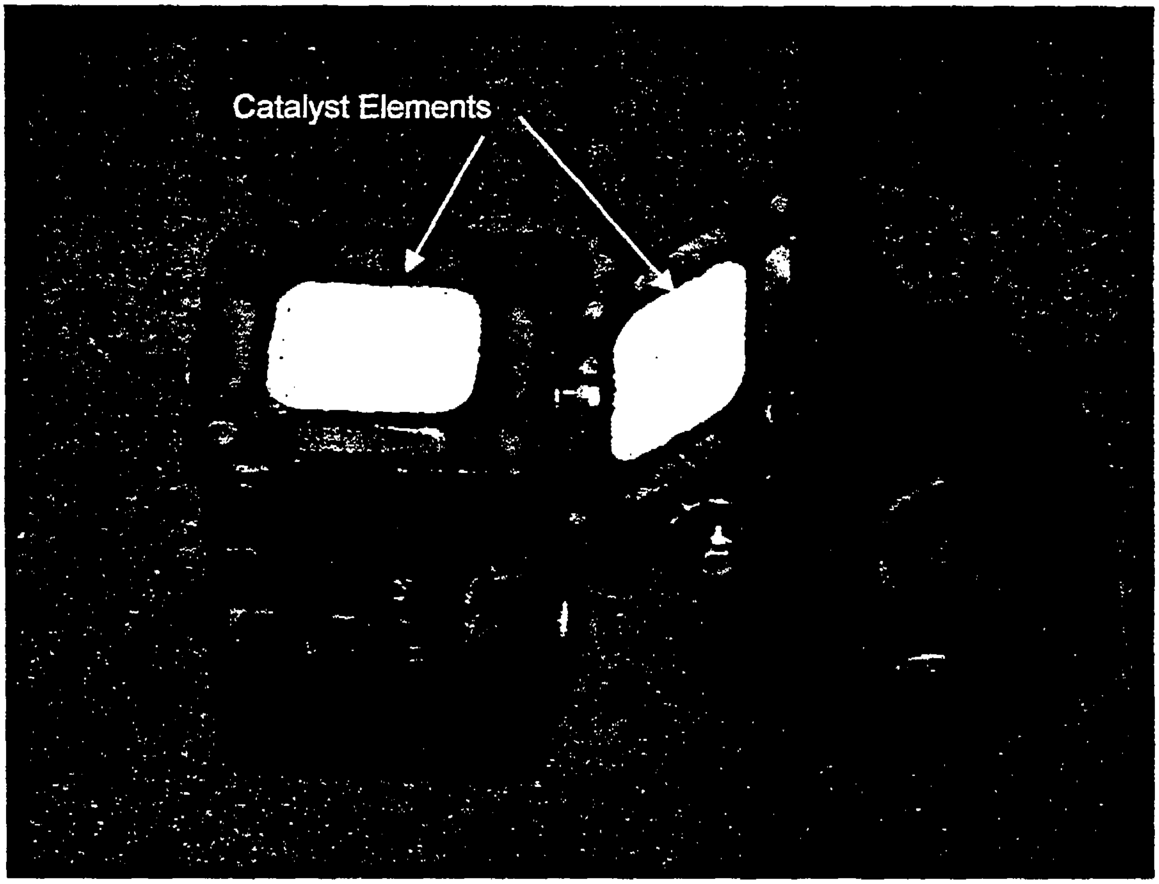


Table C-3 200 cpsi Compact Riser Catalyst Description	
Manufacturer	Engelhard Corporation
Volume	25 cubic inches (0.4 liters)
Number	2 required (left and right)
Substrate Density	200 cells per square inch. Ceramic. 8 mil wall thickness
Dimensions	2.25" x 1.88" x 6" long. Rectangular
Flow resistance at WOT, 4600 rpm	12 inches of mercury (catalyst only)
Cooling	Fully water-jacketed. (Installed in factory cast-iron exhaust riser).
Connections	Cast flange

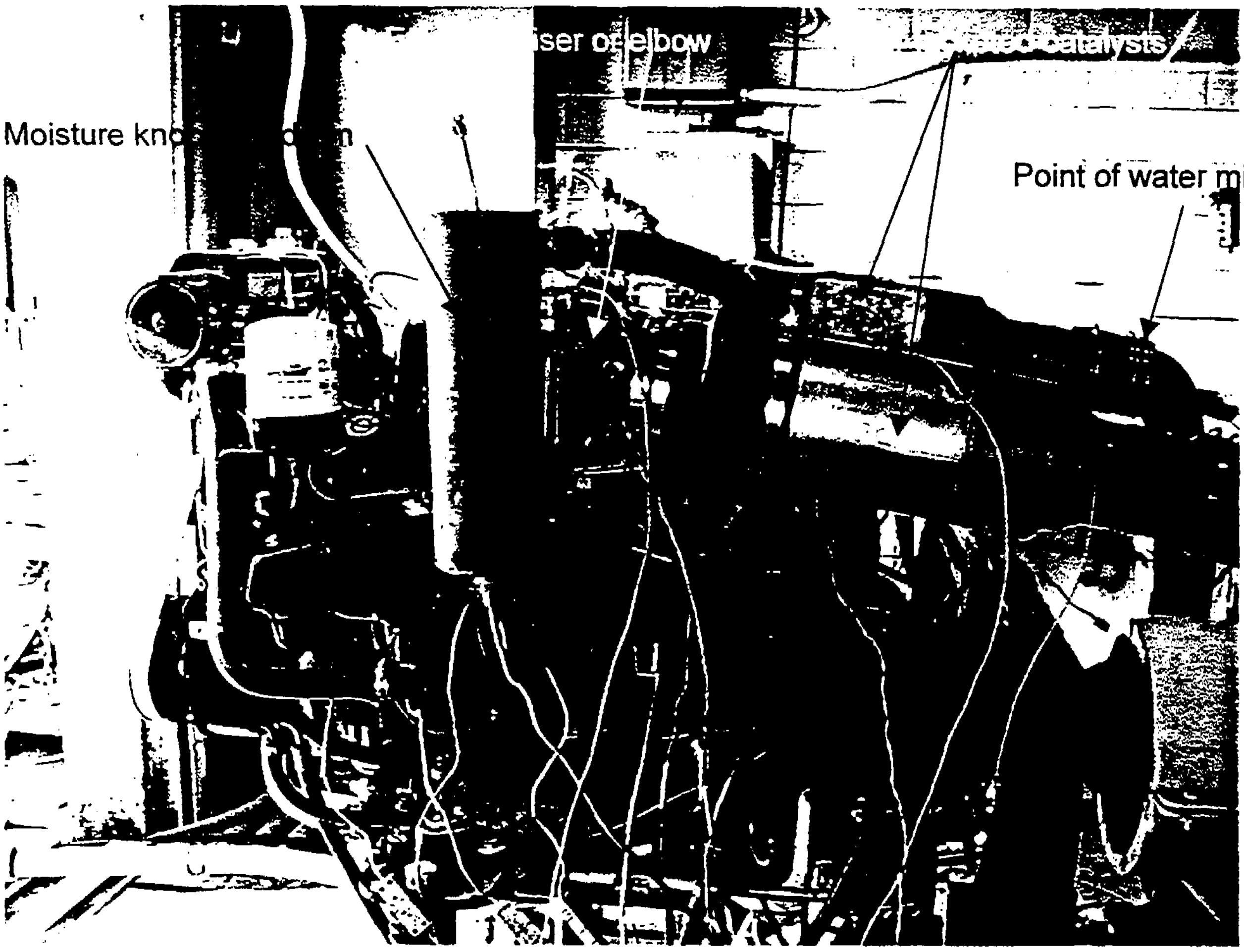
Note: cpsi is cells per square inch. WOT is wide-open throttle

An automotive-size cylindrical catalyst from Engelhard was also installed on the down-leg of the exhaust elbow, where there is more room (see Figure C-3). Specifications for this catalyst are listed in Table C-4. For a proper installation the point of injection of raw cooling water into the exhaust gases had to be moved downstream, past the catalyst. So the catalyst is quite near the water injection point. The advantage of this position, however, is that an element with a larger cross-sectional flow area may be used, which would offer lower resistance-to-flow.

Table C-4 Full-size Catalyst Description	
Manufacturer	Engelhard
Volume	102 cubic inches (1.7 liters)
Number	2 required (left and right)
Substrate Density	200 cell per square inch. Ceramic. 8 mil wall thickness
Dimensions	4.66" diameter by 3" long, 2 bricks in series. Cylindrical
Flow resistance at WOT, 4600 rpm	2 to 2.4 inches of mercury (catalyst only)
Cooling	Fully water-jacketed
Connections	Hose-clamped, butted

Note: WOT means wide-open throttle

Figure C-3
External Cylindrical Catalysts Installed on Engine



Six-inch-long catalysts were also installed in the riser position between the exhaust manifold and the exhaust elbow. They were cylindrical with a larger cross-sectional flow area than the factory riser extensions, to minimize resistance-to-flow and engine power loss (compare Figure C-4 below with Figure C-2). DCL International fabricated cylindrical catalysts for this position which allow for the maximum cross-sectional area that would clear the mounting bolts on the flanges (about 3-3/8" diameter, increased from 2" x 2" square). DCL provided a 300-cpsi candidate and a 60-cpsi candidate. Figure C-4 shows the cylindrical riser catalysts with the water-jacket installed. Table C-5 lists the specifications for the cylindrical riser catalysts.

Figure C-4
Cylindrical Riser Cat (Water-jacketed)

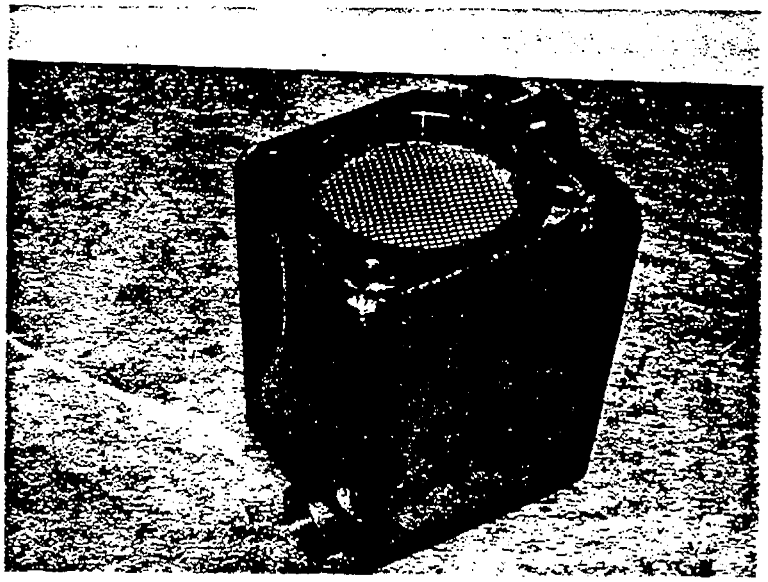


Table C-5 **Cylindrical Compact Riser Catalyst Description**	
Manufacturer	DCL International, Toronto
Volume	47 cubic inches (0.77 liters)
Number	2 required (left and right)
Substrate Density	300 cells per square inch. Ceramic. 10.5 mil wall thickness
Dimensions	3.38" diameter x 5.25" long. Cylindrical
Flow resistance at WOT, 4600 rpm	3.5 inches of mercury (catalyst only)
Cooling	Water-jacketed
Connections	Flanged

Note: WOT means wide-open throttle

3. Test Cycle

The engine was tested on a laboratory test stand using the International Organization for Standardization Standard ISO 8178-4 E4* (recreational marine gasoline) test-cycle. To simulate operation in a boat, the engine cooling system was connected to a raw water supply, and cooling water was injected into the exhaust manifolds downstream of the exhaust elbows.

The steady-state test points are specified as a function of the manufacturer's rated speed and the full-speed maximum torque. The torque percentages fall as a function of speed to the 1.5-power, mimicking the performance of a propeller in the water. The cycle is described in Table C-6 below. The five columns on the right are the mapped speed and power conditions for a General Motors 454 cubic-inch displacement engine during the E4 test. Also shown are the weighted contributions of power and fuel flow in each of the modes, to display the importance of the individual modes. For the E4 test cycle, mode 2 is the most important mode as far as fuel usage and power, and mode 1 is close behind in importance. Those two represent half the fuel usage. The idle mode, mode 5, in spite of its high weighting factor, only represents 5% of the fuel used over the cycle (0.25 gal/hr out of 5.55 gal/hr).

Table C-6

E4 Test Cycle

Stated Requirements				Calculated values for 7.4-liter engine example				
Mode No.	Percent Speed	Percent Torque	Weight factor	Speed rpm	Power hp	Weighted power, hp	Fuel flow gal/hr	Weighted fuel flow, gal/hr
1	100	100	0.06	4600	280	17	26.8	1.61
2	80	71.6	0.14	3680	162	23	13.5	1.89
3	60	46.5	0.15	2760	78	12	7.1	1.06
4	40	25.3	0.25	1840	28	7	3.0	0.75
5	Idle	--	0.40	590	0	0	0.6	0.25
						58		5.55

The importance of this comparison of the modes on the basis of weighted power or weighted fuel usage is that it is expected that the absolute emission rates (grams per hour) will be approximately proportional to the absolute fuel rates,

* International Standard ISO 8178-4. Reciprocating Internal Combustion Engines. Exhaust Emissions Measurement. Part 4: Test Cycles for Different Engine Applications. Test cycle E4—Spark-ignited pleasure-craft less than 24 m length. International Organization for Standardization. Geneva, Switzerland. The same test cycle, was adopted by U.S. EPA for marine outboard engines at 40 CFR 91.410(a), Subpart E Appendix Table 2. It was developed by the International Committee of Marine Industry Organizations (ICOMIA) and is also known by that name. (ICOMIA Standard 36, 1988)

thus the contribution to the composite results (weight factor times grams per hour divided by test-weighted power—the 58 hp in the bottom line of the table, 21% of the mode 1 rated power) will be approximately proportional to the contribution to weighted fuel rates.

Typically, the marine versions of automobile engines are rated for higher speeds than the automotive versions, and, at least in the case of the engine used in our testing, at a speed which is beyond the maximum power point of the engine and far beyond the maximum torque point. The full-speed points are rating points of marine engines, and the engines are expected to be able to operate there for many hours at a time. These engines are highly fuel-enriched at this condition, to keep cylinder temperatures low. This practice results in less efficient fuel usage and in greater carbon monoxide production than the optimum fuel-air condition. In automotive service, the engines rarely see wide-open throttle operation like this. Thus the automotive engines perform in marine service in conditions which they were not originally intended, and have to compensate at full load for this deficiency.

4. Results and Conclusions

Various combinations of stoichiometric air-fuel control were tested (performed with exhaust oxygen sensing, and feedback to the electronic engine control module), exhaust gas recirculation, and three-way exhaust catalysts. Below in Table C-7 is a summary of the results to date.

With the twin 1.7-liter catalysts installed on the engine with oxygen-feedback stoichiometric air-fuel control, a composite emission rate of 3.2 g/kW-hr of HC+NOx was achieved. This is compared to the baseline engine emission rate of 12.9 g/kW-hr HC+NOx. Adding exhaust gas recirculation to the catalyst-controlled engine, 2.6 g/kW-hr HC+NOx was achieved. The compact cylindrical 0.8-liter catalysts were tested in the exhaust manifold riser position, well upstream of the water mixing point. With these smaller catalyst units we achieved 3.6 g/kW-hr HC+NOx results, with a power degradation of 6 kW (from baseline power of 219 kW). Very compact (0.4-liter) catalysts stuffed in a stock riser extension were also tried. The results were 4.5 g/kW-hr HC+NOx without EGR, but the engine power was reduced to 172 kW (from 209 kW originally).

The conclusion is that regardless of the catalyst-system design, a catalyst near the exhaust-water mixing point, or a catalyst well upstream of the exhaust-water mixing point, the emission test results were below the proposed standard of 5 g/kW-hr. The compact-design catalyst resulted in a maximum-power decrease of the engine of 6 kW (about 3 percent). Exhaust gas recirculation improved the results for nitrogen oxides, but results without it also met the standards.

Table C-7
Emission Test Results
E4 Recreational Marine Steady-state Cycle

		HC	NOx	HC+NOx	CO	Weighted Air-fuel ratio	BSFC
	kW	g/kW-hr	g/kW-hr	g/kW-hr	g/kW-hr	kg/kg	g/kW-hr
Baseline	209	4.4	8.5	12.9	170	13.2	348
Baseline EGR	209	4.4	4.8	9.2	184	13.3	365
Stoich A/F-CL	209	3.5	11.7	15.2	117	13.7	338
Stoich A/F+EGR	209	3.2	6.8	10.0	105	14.0	345
CL A/F, TWC*	172	1.5	3.0	4.5	150	13.8	389
CL A/F, EGR, TWC*	172	1.3	1.9	3.2	143	13.9	389
Baseline Rebuilt	219	4.7	9.4	14.1	160	13.4	358
CL A/F, TWC**	221	2.0	1.2	3.2	83	13.8	341
CL A/F, EGR, TWC**	221	1.9	0.7	2.6	74	14.0	345
CL A/F, TWC***	213	1.7	1.9	3.6	87	13.9	345
CL A/F, EGR, TWC***	213	1.6	1.2	2.8	78	14.1	348

* 200 cpsi rectangular riser catalyst, 0.4 liters per side.
** 200 cpsi cylindrical external catalyst 1.7 liters per side.
*** 300 cpsi cylindrical riser catalyst, 0.8 liters per side.

EGR means exhaust gas recirculation
Stoich means stoichiometric
A/F means air-to-fuel ratio
CL means closed-loop
TWC means three-way catalyst
BSFC means brake-specific fuel consumption

ATTACHMENT D

EMISSIONS INVENTORY DEVELOPMENT

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Emissions Inventory Development

As part of this rulemaking effort, staff reviewed the assumptions and work in the Recreational Marine Emission Inventory published in December 1998 (ARB 1998c). Additional data pertaining to engine performance, activity, and emissions characteristics have been analyzed and used to modify several elements of the inventory baseline for gasoline inboards and sterndrives. The process of refining the inventory is ongoing and results presented in this report represent the most current conclusions of the Air Resources Board staff. Prior to incorporation of the new results in the formal inventory, ARB staff will conduct meetings, consider comment, and present the revised inventory to the Board for approval.

1. Population/Turnover

Our primary source for the number of gasoline inboards and sterndrives in the state is the Department of Motor Vehicles registration information. Listed below in Table D-1 are the inboard/sterndrive boat-hull registration counts for the years 1990 through 1997 and 2000. NMMA publishes the number of inboard and sterndrive engines sold in the country each year (NMMA, 2000). From these data the population of inboard boat engines in California was extrapolated forward to 2010 and 2020. Those figures are shown in Table D-1 below.

Table D-1

Inboard/Sterndrive Engine Population in California

	Total California Inboard/Sterndrive registrations	Assumed number of engines per boat	Calculated extrapolated California inventory of inboard/sterndrive boat engines
2020			448,572
2010			386,479
2000	296,624	1.126	333,999
1997	267,153	1.126	300,814
1996	263,218	1.126	296,383
1995	258,179	1.126	290,709
1994	252,968	1.126	284,842
1993	250,047	1.126	281,553
1992	247,629	1.126	278,830
1991	244,769	1.126	275,610
1990	237,816	1.126	267,781

The age distribution for inboard boats in California was calculated using data from the California Department of Motor Vehicles for the 2000 model year, and is shown below in Table D-2 for the year 2020. The number of hulls in each vintage year was multiplied by the composite number of engines per boat from NMMA sales data (national) (NMMA 2000).

It can be determined from Table D-2 that the median engine age is about 13 years, and the 90th percentile age is about 33 years. The apparent turnover (ratio of total population to new or one-year old engines) is about 20 years for this distribution. Based on sales rates in the 1990s, we would expect a turnover rate of about 20 to 30 years, so this has good agreement with observables.

Table D-2

Assumed 2020 Inboard/Sterndrive Boat-Engine Age Distribution

Vintage year	Number of boats per vintage	Number of engines per boat	Number of engines per vintage
2020	20,023	1.126	22,546
2019	20,686	1.126	23,293
2018	18,732	1.126	21,092
2017	16,869	1.126	18,994
2016	14,934	1.126	16,816
2015	13,780	1.126	15,517
2014	14,592	1.126	16,431
2013	13,613	1.126	15,328
2012	12,285	1.126	13,833
2011	11,732	1.126	13,210
2010	11,460	1.126	12,903
2009	10,854	1.126	12,222
2008	10,214	1.126	11,501
2007	9,790	1.126	11,023
2006	9,082	1.126	10,227
2005	8,414	1.126	9,474
2004	7,760	1.126	8,738
2003	7,375	1.126	8,304
2002	10,575	1.126	11,908
2001	5,903	1.126	6,647
2000	15,237	1.126	17,157
1999	7,109	1.126	8,004
1998	6,625	1.126	7,459
1997	7,376	1.126	8,305
1996	7,593	1.126	8,549

Table D-2 Continued

Assumed 2020 Inboard/Sterndrive Boat-Engine Age Distribution

1995	7,668	1.126	8,635
1994	7,058	1.126	7,947
1993	5,918	1.126	6,663
1992	5,805	1.126	6,537
1991	5,855	1.126	6,593
1990	8,613	1.126	9,698
1989	9,232	1.126	10,395
1988	9,458	1.126	10,650
1987	8,654	1.126	9,744
1986	7,652	1.126	8,616
1985	6,998	1.126	7,880
1984	6,787	1.126	7,642
1983	4,877	1.126	5,491
1982	3,536	1.126	3,982
1981	3,645	1.126	4;104
1980	4,008	1.126	4,513
	398,376		448,572

2. Activity

The existing model parameters for average activity are specified as 93 hr/yr for inboards, 73 hr/yr for sterndrives, and 73 hr/yr for jet-drives. These values were determined using survey data provided by a contractor (ARB 1998c).

Mercury Marine did a survey of 35 boats that came in for service in September of 2000 at two or three Mercury Marine service sites in California. Most of the boats were less than one year old. Serial number information was consulted to determine purchase dates of the engines or boats. The average use was about 58 hours per year. If only the boats over 1 year old were considered (17 out of the 35), the average was about 55 hours per year.

In 1994, Mercury Marine surveyed eleven old boats in California and Florida to determine long-term usage rates and useful life (Mercury Marine 1994). Three of the eleven were nine years old, and no boat was younger than two or older than nine. The average use was 68 hours per year.

As part of a study for ARB, Science Applications International (SAI) surveyed 1500 inboard boat owners in California by random mail questionnaire (SAI, 1995). A summary of these data is shown in Table D-3. The recipients were asked about their usage in the previous two weeks before receiving or filling out the survey. Questionnaires were sent in all months of the year, but most of the respondents sent in responses in August. The recipients were asked what their total elapsed boating time was, and their percent engine-off time. The annual usage was inferred by multiplying the reported two-week usage times 26. The average usage rate determined this way was 3.1 hours per engine per two weeks, (out of 5.8 hr/2-wk total on-the-water time) or about 81 hours per year per engine. Many respondents answered that they had not used their boats at all in the previous two weeks.

Table D-3
Results of SAI Inboard/Sterndrive Boat-Owner Mail Survey

Number of boats	1459
Number of engines	1529
Fuel use per engine, gal/2-wk	13.85
Composite number average power, hp	211
Hours of engine-on use per 2 weeks	3.1
Hours of boating per 2 weeks	5.8
Average fuel use gal/h	4.5
Theoretical rated fuel use gal/h	21
Average load factor	21%

Additionally, the U.S. Coast Guard estimates average boating activity to be approximately 100 hours per year according to its 1998 recreational boating survey (Mangione *et al.*, 1999). The intended purpose of this study was to calculate the risk to boat occupants associated with boating activity, and in so doing the survey measured the amount of time boat occupants used their boats. So this 100 hours might include engine-off time as well as engine-on time.

Based on this information, staff concludes that modification of the existing inventory activity numbers is not warranted. Therefore, the activity numbers of 93 hr/yr for inboards, 73 hr/yr for sterndrives, and 73 hr/yr for jet-drives are retained for calculation of the revised emission inventory. With the population breakdown from Department of Motor Vehicles registration data, this averages to a value of 78 hr/yr over all three categories.

3. Average rated power.

The existing model parameter for average rated power is 164 hp. This value was calculated using data provided by an ARB contractor in 1998 (ARB 1998c). Since that time, 1997-1999 sales breakdowns have been provided to the ARB from industry indicating that the 350 cubic-inch engine represents the average size for inboard/sterndrive engines and has the highest sales volume. Based on this information, the sales-weighted average power for inboard/sterndrive engines is about 275 hp. Staff proceeded to analyze the SAI survey representing approximately 1459 inboard and sterndrive boat owners and found that the average name-plate power for the inboards, sterndrives and jet-drives was 211 hp. Accordingly, the existing model parameter for average rated power was changed to a composite value of 211 hp and used in calculating the emissions inventory numbers presented in this report.

4. Average load-factor.

The weighted power for the ISO 8178-4 E4 recreational marine test cycle is 21% of rated or maximum power. This was generated from actual time-at-speed or throttle-position determinations of average outboard boaters in Wisconsin (Morgan and Lincoln 1990). The SAI study commissioned for California asked approximately 1459 inboard and sterndrive boat owners how much fuel they consumed, how many hours on the water, percent of time the engine was on, what was the rated power of the engines, and number of engines per boat. As shown in Table D-3, the mail-out survey confirmed the average load factor of 21%.

5. Emission Factors/Deterioration

The emission factors used in our modeling are shown in Table D-4. Results of baseline engines were gathered from the manufacturers new-engine data and several tests done by the U.S. EPA at their facilities. The results from 12 carbureted engines from the early 1990s have been gathered along with 4 runs from rich-calibration electronically fuel-injected engines from the last 5 years. These revised results differ with respect to the existing model parameters, 12.2 g/kW-hr for HC and 7.2 g/kW-hr for NOx, and are shown in Table C-1 of Attachment C to this staff report.

Table D-4

Engine Emissions, New Engines

	HC g/kW-hr	NOx g/kW-hr
Carbureted	7.8	6.2
Electronically fuel-injected	4.7	9.9
Three-way Catalyst, Feedback A/F	1.9	2.0

A/F means air-fuel ratio

The engine manufacturers are making a shift away from carbureted engines to fuel-injected engines over the next five years. This will tend to lower HC emissions but raise the NOx emissions.

The three-way catalyst entry was based on the results from recent testing at Southwest Research Institute on catalyst-controlled marine engines. These data are presented in Table C-7 of Attachment C to this staff report. The values chosen for use in the controlled inventory calculations were an average of the 200 cell-per-square-inch rectangular riser catalyst result and an early result from the external cylindrical catalyst.

Deterioration is the assumed increase of exhaust emissions as a function of engine age. For automobiles, this is done on a mileage basis. For boats and generators and other off-road engines this is done on an engine-hour basis. For automobile gasoline engines at present, the deterioration of performance is mostly due to deactivation of the catalyst with age, due to poisoning or thermal sintering of the sites. It is the full-deteriorated emission value (evaluated at the compliance lifetime period) that is to be compared with the standards.

To model the deterioration of emissions with age for the uncontrolled boat engines, staff compiled carbureted automotive data of emissions versus mileage, and fit the best line to determine the slope (grams per kilowatt-hour per hour). The area of interest for boat engines is at about 480 hours, about one fifth of the equivalent hours to 100,000 miles of car travel. The EFI deterioration rates at 480 hours were calculated using the same percent increase in emissions attributed to a carbureted engine using carbureted deterioration factors. This was assumed because deterioration data for engines that are EFI-controlled but without catalysts is rare. The deterioration rate for the catalyst-controlled engine was chosen such that deteriorated emission levels would minimally comply with the combined HC+NOx standard of 5 g/kW-hr after 480 hours of use. This equates to approximately 1 g/kW-hr growth (about 25% of zero hour emissions) over the 480 hours. This is the value of deterioration allowance estimated by the engine manufacturers for a catalyst-controlled engine.

Table D-5 below shows the effect of the incorporation of deterioration estimates. The deteriorated emission factors for carbureted baseline engines, electronically fuel-injected baseline engines, and three-way catalyst/oxygen feedback air-fuel controlled engines were determined by staff from automobile data (ARB 1998c). For HC and NOx, the new-engine (or new-catalyst) emission rates and the 480-hr rates are shown. The zero-hour values are what would be expected from a new engine test, the most common basis to test at the factory or in development. The figure of 480 hours for compliance life is much smaller than that expected for automobiles, or even smaller than assumed in the age distribution of Table D-2 above. It is based on the assumed usage period from the engine manufacturers.

Table D-5

Effect of Deterioration on Boat-Engine Emissions

	HC Zero-hour	HC 480-hr	NOx Zero-hour	NOx 480-hr
Carbureted emission rates, g/kW-hr	7.8	8.0	6.2	6.3
Deterioration rate, g/kW-hr^2	3.15×10^{-4}		1.81×10^{-4}	
EFI emission rates, g/kW-hr	4.7	5.0	9.9	9.9
Deterioration rate, g/kW-hr^2	4.89×10^{-4}		3.07×10^{-5}	
TWC emission rates, g/kW-hr	1.9	2.4	2.0	2.6
Deterioration rate, g/kW-hr^2	1.01×10^{-3}		1.30×10^{-3}	

EFI means electronically fuel-injected
TWC means three-way catalyst