Final Report

Collection of Evaporative Emissions Data From Off-Road Equipment

Prepared For The
California Air Resources Board
and the
California Environmental Protection Agency

In partial fulfillment of

Air Resources Board Contract #00-315

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Disclaimer

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgements

The support of the members of the Air Resources Board staff is gratefully acknowledged. The diverse population of equipment tested required contact with a large number of equipment owners. The trust and cooperation of these owners is particularly acknowledged.

This Report was submitted in partial fulfillment of Air Resources Board Contract #00-315 entitled "Collection of Evaporative Emissions Data from Off-Road Equipment" by Automotive Testing Laboratories, Inc. under the sponsorship of the California Air Resources Board.

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Abstract

The purpose of this study was to collect evaporative emissions data on a variety of in-use gasoline-powered off-road equipment. Significant changes in evaporative emissions measurement procedures were implemented for on-road mobile sources in the 1990's. Before this study, only limited data had been gathered on off-road equipment using the new superior methods.

The off-road gasoline powered equipment category encompasses a wide variety of different types. The categories included in this study were Lawn and Garden, Marine Recreational, Off-Road Recreational, and Light Commercial. The primary test fuel was summer grade commercial California Phase II reformulated gasoline purchased in early summer of 2001. Testing included Hot Soak, Diurnal, Running Loss, and Refueling emission measurements.

Data was collected continuously throughout each test. The continuous data was provided to ARB staff in electronic format. The results of this program are to be used by ARB to validate and improve the emissions factor model OFFROAD, which includes this class of equipment.

Executive Summary

Background

While remarkable improvements in California's air quality have been attained, additional progress will be required to achieve healthful air pollution levels. Regulations and resultant technology refinements have resulted in significant reductions of pollution from major sources. What were once considered less important sources of pollution have become relatively significant, and regulations are being considered to control those sources previously passed over. The equipment tested in this program is included in that category.

Methods

This effort was performed to collect current evaporative emissions data from a wide variety of gasoline-powered off-road equipment. The testing protocols used for this study parallel those implemented in the mid-1990s for on-road automobiles and trucks. These enhanced testing protocols much more closely mimic performance in the field, and provide superior data for comparison of different emission sources. This provides more informed indicators of the impact that reductions in emissions from these sources would have on ambient pollution levels. In particular, the testing focuses on evaporative hydrocarbon emissions that are generated by the gasoline used to power the equipment.

The classes of equipment tested in this program included Lawn and Garden, Off-Road Recreational, Commercial, and Recreational Marine equipment. The Lawn and Garden category included walk behind mowers, string trimmers, hedge trimmers, chain saws, and leaf blowers. Off-Road Recreational equipment included dirt bikes and all terrain vehicles (ATVs). Commercial equipment tested included generators and forklift trucks. The recreational Marine equipment included outboard and stern drive boats and personal watercraft (PWC).

The test fuels were commercial summer and winter grade gasolines subject to the gasoline regulations effective in California in 2001 ("Phase 2" reformulated gasoline regulations). The summer gasoline was blended from volumes drawn from three deliveries to a retail distributor. The winter gasoline (subject to a higher limit on RVP) was provided by ARB.

The basic data collection equipment and measurement protocols defined for on-road new vehicle certification were adapted to each of the categories of off-road equipment. These are defined in the State of California Air Resources Board document "CALIFORNIA EVAPORATIVE EMISSION STANDARDS AND TEST PROCEDURES FOR 2001 AND SUBSEQUENT MODEL MOTOR VEHICLES" adopted August 5, 1999.

All equipment received a Hot Soak and Diurnal test sequence at summer time temperature levels using summer grade fuel. The remaining testing was performed on subsets of the different equipment classes. Running loss tests were performed on 4 of 8 mowers, 1 of 4 string trimmers, 0 of 4 saw/trimmers and leaf blowers, 3 of 4 ATVs, 2 of 4 dirt bikes, 2 of 3 generators, 1 of 2 forklifts, and 0 of 12 marine craft. Refueling tests were performed on at least one sample of each equipment type.

Additional testing was performed to measure sensitivity of evaporative emissions to the differences in winter and summer fuels, and high and low temperature cycles. California commercial fuels were used. The higher temperature cycle conformed to the California Light Duty Vehicle 65° to 105°F requirements. The lower temperature cycle, nominally 50° to 90°F, was derived by subtracting 15 degrees from each point in the certification cycle. Laboratory hardware limitations prevented achievement of the 50°F target temperature.

Evaporative emission sensitivity to fuel tank level, and the impact of fuel weathering over time were measured. Certification testing is performed at a 40% fuel fill level. Most testing for this emission factors program was performed with a 50% fuel level. The "Fuel Level" sensitivity testing was performed with 100%, 75%, 50%, and 25% fuel fills. Some testing before and after evaporative related equipment repairs is included. Both two stroke and four stroke engines were included.

Testing of an ARB developed method of controlling lawn and garden equipment evaporative emissions was performed.

Results

The Contract called only for ATL to measure and report certain data on evaporative emissions. Those data are summarized in Tables 5 through 8 and have been transferred to ARB staff. The project involved no data analysis or other tasks beyond conducting the test procedures and delivering data in prescribed formats.

All measurements called for by the amended test plan were successfully taken.

Collection of Evaporative Emissions Data from Off-Road Equipment
November 24, 2003

I. Introduction

Significant improvements have been achieved in the exhaust and evaporative emission performance of nearly every type and kind of equipment which contributes to unhealthful air quality. Regulations have been put in place covering nearly every major man-made source of emissions, including exhaust and evaporative emissions from gasoline powered equipment. Initial efforts were focused on the largest contributors of emissions. As time passed the most significant sources were substantially reduced, making the smaller sources relatively larger. Healthful ambient air quality levels, however, have not been achieved, mandating that additional reductions be made.

Regulators are faced with the task of recommending the specific methods to be used to achieve healthful air quality levels. Knowledge of the source of ambient pollutants is required to make informed decisions. The amount and quality of data concerning relative emission generation rates, however, are not unlimited. Measurements of the known sources of various pollutants, when available, have been gathered and combined into a variety of tables and computer programs, which allow comparison of the relative contribution of each source. Some elements of these inventories are less certain than others. California uses a model titled OFFROAD to estimate the contribution of off-highway equipment to the total emissions inventory. The purpose of this study was to collect additional data regarding the equipment included in the OFFROAD model, specifically in the area of evaporative emissions from those pieces of equipment that are powered by gasoline. This data will be used to confirm model elements initially based on limited data, to refine the model where possible, or to indicate the need for additional data collection.

Such refinements are necessary as consideration is currently being given to regulations to control evaporative emissions produced by off-road equipment used in California.

A number of different types of equipment are included in the OFFROAD model. Total emission rate depends on both the number of generators, and the emission rate from each unit. For example, the quantity of string trimmers and walk-behind mowers greatly exceed the number of portable motor/generator sets used on construction sites. Exhaust emissions from a heavily loaded generator are expected to greatly exceed the emissions from a single piece of lawn and garden equipment, but the number and frequency of use of the latter increase the total emissions generated. Precise data is required to correctly assess relative contributions, and to focus improvement efforts efficiently.

Much less evaporative emissions data than exhaust data is available for off-road equipment. Uncontrolled emission rates for refueling and diurnal emissions can be estimated with knowledge of fuel properties, fuel tank capacity, equipment utilization patterns, and ambient temperatures. Actual testing results are required to quantify running loss, hot soak, and resting loss emissions, however.

The purpose of this study was to significantly augment the quantity and quality of evaporative emissions data for off-road gasoline powered equipment. Consistent testing protocols were used to measure hot soak, diurnal, resting loss, running loss and refueling evaporative emissions on a variety of off-road equipment samples. Tests were performed to enable ARB to assess such important factors as fuel level, fuel weathering, ambient temperature, and fuel properties. The types of equipment tested ranged from tiny lawn and garden engines to much larger fork lifts and generators. Fuel tank capacities ranged from ounces to tens of gallons. Minute by minute electronic data was provided to ARB staff to allow them to perform detailed analysis of time based emission rates. Each test data point was intended to verify current assumptions or to be used to improve current evaporative emission estimates for each class of equipment that was tested.

The number of pieces of each type of equipment was initially specified in the RFP for the contract. These quantities were modified during the performance of the contract in response to ARB's ability to supply equipment they had originally intended to provide, and to meet their needs for testing of specific equipment types.

II. Test Materials and Methods

This section of the report will describe the selection and procurement of the equipment tested during this program, the fuels used for testing, and the testing protocols used.

A. Equipment Tested

The population included in the OFFROAD emission inventory model is very diverse. The test sample specified for this program was limited to gasoline powered equipment. Based on in-use population demographics, four categories of equipment were selected by ARB for inclusion in the program. These categories were Lawn and Garden, Marine Recreational, Off-Road Recreational, and Light Commercial. These broad categories were further subdivided, with specifications including type, manufacturer, emission certification class, and 2 and 4 stroke engine technology.

Changes in the definition of the sample to be tested were agreed to after testing was begun. ARB was unable to provide all of the originally specified lawn and garden pieces of equipment, so the sample was supplemented by ATL. Interest was also expressed in locating gasoline powered forklift trucks. Two such units were procured and tested in this program.

Table 1 summarizes the equipment tested in each of the four major categories.

Sixteen pieces of equipment were tested from the Lawn and Garden category. The sample included eight lawn mowers ranging in age from 1973 through 2001, including one high emitter. One of the lawnmowers was powered with a 2-stroke engine. A total of four string trimmers were tested – two powered by 2-stroke and two powered by 4-stroke engines. One hedge trimmer, a new Echo, was tested. One chain saw, a 1989 McCulluch, was tested. Two leaf-blowers, a 2000 Echo and a 1999 John Deere, were tested. Two stroke engines powered both of the leaf-blower units.

Eight pieces of Off-Road Recreational equipment were tested. Recreational vehicles included off-road motorcycles and all terrain vehicles (ATV). Each of the recreation vehicle classes was to include 2 stroke and 4 stroke samples, and engines manufactured prior to emission control implementation (1995), and after current regulations (1999). These objectives were met in both the dirt bike and ATV categories.

Five pieces of Light Commercial equipment were tested. Three generators were specified in the Request for Proposal. The three generators tested in the program included a 1968 Homelite 2 stroke, a 1995 Honda four stroke, and a 2002 Coleman powered by a Briggs and Stratton 4 stroke engine. ARB staff requested that we locate and test gasoline powered forklifts. Two units were tested, a 1987 Toyota and a 1995 Komatsu, both powered by 4 stroke 4 cylinder in-line engines.

Table 1
Equipment Tested

Category	Identification		Year	Make	Model	Engine Stroke	Source
Lawn & Garden	Mower	01	1999	Toro	SR-2105	4	ARB
	Mower	02	1999	Murray	20111X192A	4	ARB
	Mower	03	2001	Scotts	OVRM120	4	ARB
	Mower	04	1989	Toro	20511	4	ARB
	Mower	05	1990	Toro	22036	2	ATL
	Mower	06	1973	Builders Best	F111C / 93502	4	ATL
	Mower	07	1994	Sears	917.38359	4	ATL
	Mower	08	2001	Honda	HRT216KTDA	4	ATL
	Trimmer	01	1994	Ryobi	970R	4	ARB
	Trimmer	02	1999	Stihl	FS80	2	ARB
	Trimmer	03	1988	McCulloch	40003102	2	ATL
	Trimmer	04	2000	Makita USA Inc	EM4251	4	ATL
	Hedge Trim	01	2001	Echo	HC-1500	2	ARB
	Chain Saw	02	1989	McCulloch	60001620	2	ATL
	Leaf Blower	01	2000	Echo	PB-231LN	2	ARB
	Leaf Blower	02	1999	John Deere	UT08087	2	ATL
Off Road Rec	Dirt Bike	01	1982	Honda	XR200R	4	ATL
	Dirt Bike	02	2000	Kawasaki	KX250	2	ATL
	Dirt Bike	03	1984	Suzuki	RM125	2	ATL
	Dirt Bike	04	2001	Yamaha	WR250F	4	ATL
	ATV	01	1983	Honda	Odyssey FL250	2	ATL
	ATV	02	2001	Yamaha	Banshee YFZ350N-W	2	ATL
	ATV	03	2001	Suzuki	Quadrunner LT-F250	4	ATL
	ATV	04	1988	Kawasaki	Bayou KLF220	4	ATL
Light Commercial	Generator	01	1995	Honda	EX5500	4	ATL
	Generator	02	1968	Homelite	XL-A115	2	ATL
	Generator	03	2002	Coleman	PL0545005	4	ATL
	Fork Lift	01	1995	Komatsu	FG30G-11	4	ATL
	Fork Lift	02	1987	Toyota	2FG25-10579	4	ATL
Marine Recreational	PWC	01	1992	Yamaha	Wave Runner III	2	ATL
	PWC	02	1991	Bombardier	Sea-Doo XP	2	ATL
	PWC	03	2001	Yamaha	Super Jet (SJ700AZ)	2	ATL
	Outboard	01	1977	Evinrude	66054	2	ATL
	Outboard	02	2001	Mercury	Opti-Max	4	ATL
	Outboard	03	2000	Johnson	RJ90PLSSE	4	ATL
	Stern Drive	01	1972	Schuster	Jet Boat	4	ATL
	Stern Drive	02	1998	Yahama	EXT 1200W	2	ATL
	Stern Drive	03	2002	Volvo	Penta	4	ATL

The original RFP and proposal included testing of twelve marine recreational samples. The previously discussed change in procurement specifications resulted in a reduction in this category to nine samples. Testing included (3) personal watercraft (a 1991 Skidoo Bombardier, a 1992 Yamaha, and a 2001 Yamaha, all powered by two stroke engines). Three outboards (a 1977 Evinrude, a 2001 Mercury, and a 2000 Johnson) and three stern drives (a 1977 Schuster, a 1998 Yamaha, and a 2002 Volvo) were tested.

The procurement specifications reflected equipment expected in the current and near-term in-use population. ATL's procurement personnel visually inspected equipment as it was identified. Unusual conditions that would make the equipment not representative were cause for rejection. Some used Lawn and Garden equipment, for example, was passed over because they would not start, or ran so poorly that they were not usable. Equipment was rented directly from the owner, from rental agencies, or from new and used equipment dealers. All samples except the forklifts were procured in the Los Angeles, California area. The California equipment presumably had always been operated with California commercial fuels. Detailed identification details for some the units were difficult to determine because no stickers or serial numbers could be found. Additional equipment description details are included in the appendix.

B. <u>Test Fuels</u>

All testing was performed with commercial fuel obtained in California.

The majority of the testing was performed using summer grade fuel. Two tests on two pieces of equipment (a total of four tests) were performed using winter grade fuel. The primary difference between the seasonal fuels is Reid Vapor Pressure (RVP). The summer fuel had a nominal RVP of 7.0 psi, while the winter grade fuel had a nominal RVP of 9.5 psi.

Special steps were taken to insure that the summer grade fuel used was representative of typical summer grade fuel in California.

The summer grade fuel was purchased from a wholesale distributor in Coachella, California. The distributor was instructed to divert four drums from three separate fuel deliveries as they arrived at the terminal. The deliveries selected were made on April 27, 2001, May 3, 2001, and May 4, 2001. Each delivery was intended for sale to retail outlets, and was subject to California Phase II reformulated fuel requirements in effect in at that time. Samples were collected from each of the three deliveries. The samples were delivered to ARB's El Monte laboratory for analysis.

The distributor sealed and capped each barrel, and facilitated delivery of all twelve barrels to ATL's Mesa, Arizona site. Fuel storage facilities at ATL include chilled barrel storage that is maintained at 50 to 60°F. All barrels were stored in this area until used.

Test fuel was prepared by mixing equal portions from each of the three groups of fuel. Fuel was mixed in sets of three barrels. One barrel from each receipt date was included. An equal amount from each of the three source barrels was transferred to three clean barrels. Two of the newly mixed barrels would then be tightly sealed and held for future use. All three of the new drums remained in the cold storage area. Fuel was dispensed from a barrel and transferred directly to the test equipment as it was required for testing.

Table 2 displays the results of the fuel inspections of the three fuel deliveries prior to being mixed. The headings “4/27/01”, “5/3/01”, and “5/4/01” are used to identify the group of four drums of fuel that were segregated from the delivery truck on the indicated date. The test sponsors selected the properties to be measured and set specifications to ensure that the test fuel would represent commercial Phase II gasoline. While some properties are off specification, it was determined that the blended test fuel resembled the “average” Phase II gasoline in the summer of 2001.

Table 2
Fuel Analysis Prior to Mixing

	Specification	4/27/01	5/3/01	5/4/01
Distillation				
10%	130-150	140	138	141
50%	190-210	200	198	200
90%	290-300	315	321	318
Sulfur (ppm)	30-40	13	18	17
Reid Vapor Pressure	6.7-7.0	6.64	6.76	6.74
Olefins (vol%)	4.0-5.0	4.7	4.2	4.4
Aromatics (vol%)	22-25	22.8	23.2	23.3
Benzene (vol%)	0.8-1.0	0.52	0.62	0.63
Oxygenates (vol%)	10.8-11.2	10.69	11.97	11.78
Specific Gravity	-	0.7420	0.7426	0.7425

Fuel for testing was mixed after approval of the individual deliveries was received. A sample was drawn from this mix for analysis by an independent testing laboratory. Paragon Laboratories, Inc. in Livonia, Michigan was selected by ATL for this analysis. Table 3, dated 06/08/01, displays the results of their inspection. Based on the results of this inspection, the program sponsors accepted the mixed fuel as appropriate for use in this program.

The winter grade fuel was provided by ARB. No analysis other than RVP was performed. The RVP of this fuel, as determined using a Grabner instrument (ASTM D5191) was 9.5 psi.

Paragon
Laboratories, Inc.

Table 3
Independent Laboratory Fuel Inspection Results

L A B O R A T O R Y   T E S T S   R E S U L T S
06/08/001

JOB NUMBER: 124841   CUSTOMER: Automotive Testing Labs.   ATTN: Michael Strunck

CLIENT I.D.........: Commercial Gasoline
DATE SAMPLED.......: 05/31/01100:00
TIME SAMPLED.......: 00:00
WORK DESCRIPTION...: Commercial GAsoline/Baseline test

LABORATORY I.D...: 124841-0001
DATE RECEIVED....: 06/01/01110:00
TIME RECEIVED....: 10:00
REMARKS..........:

TEST DESCRIPTION	FINAL RESULT	LIMITS/*DILUTION	UNITS OF MEASURE	TEST METHOD	DATE	TECHN
Distillation - Gasoline		*1		ASTM D86	06/05/01	PIN
Initial Boiling Point	101	1	Deg. F	ASTM D86		
05% Evaporated Temperature	131	1	Deg. F	ASTM D86		
10% Evaporated Temperature	141	1	Deg. F	ASTM D86		
20% Evaporated Temperature	153	1	Deg. F	ASTM D86		
30% Evaporated Temperature	164	1	Deg. F	ASTM D86		
40% Evaporated Temperature	178	1	Deg. F	ASTM D86		
50% Evaporated Temperature	197	1	Deg. F	ASTM D86		
60% Evaporated Temperature	230	1	Deg. F	ASTM D86		
70% Evaporated Temperature	249	1	Deg. F	ASTM D86		
80% Evaporated Temperature	277	1	Deg. F	ASTM D86		
90% Evaporated Temperature	312	1	Deg. F	ASTM D86		
95% Evaporated Temperature	336	1	Deg. F	ASTM D86		
End Point	407	1	Deg. F	ASTM D86		
% Overhead Recovery	98.4	0.1	%	ASTM D86		
% Residue	0.9	0.1	%	ASTM D86		
% Loss	0.7	0.1	%	ASTM D86		
Fluorescent Indicator Adsorption		*1		ASTM D1319	06/08/01	TJJ
Saturates	71.6	0.1	L.V.%	ASTM D1319		
Olefins	4.8	0.1	L.V.%	ASTM D1319		
Aromatics	23.6	0.1	L.V.%	ASTM D1319		
Grabner EPA,ASTM, & CARB		*1		GBR1	06/08/01	TJJ
Vapor Pressure (EPA calc.)	7.13	0.01	psi	ASTM D5191		
Vapor Pressure (ASTM calc.)	7.00	0.01	psi	ASTM D5191		
Vapor Pressure (CARB calc.)	6.89	0.01	psi	ASTM D5191		
Oxygenates by G.C. + TAME		*1		ASTM D4815-89	06/08/01	PIN
Methanol in Gasoline by G.C.	<0.1	0.1	L. V. %	ASTM D4815-89		
Ethanol in Gasoline by G.C.	<0.1	0.1	L. V. %	ASTM D4815-89		
Tert-Butanol in Gasoline by G.C.	<0.1	0.1	L. V. %	ASTM D4815-89		
MTBE in Gasoline by G.C.	11.1	0.1	L. V. %	ASTM D4815-89		
t-Amyl Methyl Ether	<0.1	0.1	L. V. %	ASTM D4815-89		
Gravity, Specific,Digit.Dens.Meter	0.7418	0.0001		ASTM D4052	06/04/01	PIN
Total Sulfur by Microcoulometry	18	1	ppm wt.	ASTM D3120	06/08/01	MAL

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C. Test Protocols

This section of the report is the most complex because of the differences in the equipment tested and the different tests performed on the different types of equipment. An overview of evaporative emission types will be followed by detailed descriptions of the test protocols used. Included will be the variations required to accommodate the different types of test equipment. The section will end with a description of test permutations used to measure sensitivity to different effects.

Emission models should include the variables that affect the emissions. One strategy for collecting emission model data is to select a standard condition, to collect data using that definition, and then to perform additional testing to measure the sensitivity of the emissions to selected variables. That is the approach that was used in this program. It is important to note that the purpose of this program was only to collect data for use by ARB staff, not to actually perform data analysis or update the models used by California. This program was performed specifically to generate data useful to the evaporative emission factor modeling effort.

The definition and specifications of the test measurement equipment used in this program generally conform to those specified for new vehicle certification. The procedures, quality control requirements, computations, and tolerances are summarized in Air Resources Document "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Year Motor Vehicles"[1] adapted August 5, 1999. This document cites and adopts the federal evaporative emission regulations specified in Title 40, Code of Federal Regulations (CFR), Part 86, Subparts A and B as adopted or amended as of July 1, 1989 with modifications defined in the ARB document. The equipment used to test the off-road equipment in this document conforms to the automotive regulations, except as required to perform tests on the variety of equipment measured in this program. The differences will be addressed while describing the tests for each type of equipment.

The understanding and definition of evaporative emissions have been greatly improved since vehicle certification testing was started in the 1970's. Evaporative emissions from gasoline powered equipment are divided into several categories for analysis and modeling. A piece of equipment at rest is subjected to changes in ambient temperature throughout the day. These temperature changes can cause heating of the vapor space in the equipment fuel tank, which results in expansion and displacement of the saturated vapors. "Diurnal emissions" are those that occur during this daily temperature cycle. Emissions continue to be generated, even as temperatures are dropping and the vapor space is contracting. This component of the diurnal emission is referred to as "resting losses". Evaporative emissions occurring while the engine is running are referred to as "running losses". The heat from the engine and fuel agitation caused by movement of the equipment and vibration from the engine generates these emissions. Following engine shutdown, evaporative emissions classified as "hot-soak emissions" occur. The elevated

[1] "http://www.arb.ca.gov/msprog/evap/evap.htm/evaptp01.pdf"

temperatures resulting from engine operation generally dominate this class of emissions. When gasoline is added to an open fuel tank, saturated vapors are displaced to the atmosphere. These displaced vapors result in “refueling emissions”. The previous types are all vapor based. When fuel is spilled, or when it leaks out of the fuel storage or delivery system, grossly higher evaporative emissions occur. These are classified as “liquid leak” driven evaporative emissions.

Many factors influence evaporative emissions. The fuel used is critical, in particular the Reid Vapor Pressure, or RVP. RVP is a measure of the volatility of the fuel, by definition its propensity to evaporate. Ambient temperature around the equipment and the temperature that is observed in the fuel tank are important. The range of temperatures observed in a diurnal cycle is very important. Fuel temperature generally rises during engine operation, and the duration of operation generally results in higher end temperatures. Higher temperatures result in higher evaporative emissions. The fuel level in the tank defines the remaining vapor space above the fuel. More saturated vapors in this space normally result in elevated evaporative emissions.

Each piece of equipment included in this program received a standardized hot soak and twenty-four hour diurnal/resting loss evaporative emission test. This standard test included the following steps:

1. Drain and refuel tank to 50% capacity with summer fuel.

2. Operate equipment for 15 minutes at rated speed (precondition).

3. Soak for 12-36 hours at 68-86°F.

4. Operate equipment for 15 minutes at rated speed outside of Hot Soak SHED enclosure (warm-up). Stop equipment and transport into the SHED.

5. Monitor HC emissions in Hot Soak SHED for 3 hours at 95°F.

6. Soak equipment for 6 to 36 hours. Last 6 hours were at nominal initial temperature specified for upcoming Diurnal Test.

7. Seal equipment in Diurnal SHED.

8. Perform one 24-hour diurnal/resting loss test. Temperature followed California light-duty vehicle pattern of 65 to 105 to 65°F in 24 hour period.

Preconditioning and 15 minute warm-ups

The standard test sequence required operation of the test equipment for 15 minutes as preconditioning following refueling and for warm-up immediately prior to the hot soak test. Speed governed engines, including the mowers, trimmers, leaf blowers, and chain saws were operated out doors at wide-open throttle for 15 minutes to satisfy this requirement. The marine engines, which required water cooling, were operated in a water filled tank for 15 minutes. The recreational vehicles, including the dirt bikes and ATVs, were operated outdoors in a catch basin located on ATL's property. The basin is large enough to permit typical operation of these types of equipment. The forklifts were operated in the test laboratory parking lot for 15 minutes. Wide-open throttle was applied in straight runs, with reduced speed required to maneuver in turns. The outdoor operations were performed during daylight hours on sunny days.

The generators required external loading to simulate normal operation. Engine power and heat generation are proportional to the amount of electricity generated. Combinations of light bulbs and electric fans were used to provide a load equivalent to the rated capacity of the generator. The motor/generator set was operated under full load for 15 minutes.

Hot Soak Testing

All equipment received a hot soak test following the warm-up. The standard hot soak tests were performed at an ambient (SHED) temperature of 95°F. Immediately before the start of the test the SHED FID was zeroed and spanned and set to monitor the enclosure atmosphere continuously. A data logger was activated to record HC, temperature, and barometric pressure in the enclosure. The SHED was thoroughly purged between tests. The enclosure door was left cracked and the enclosure temperature was allowed to settle at the desired set-point temperature while the engine preconditioning was completed.

At the end of the warm-up the test equipment was promptly moved into the SHED, the enclosure door was sealed, and the initial HC reading noted. This initial reading was completed within two minutes of engine shutdown. Readings were electronically recorded at 30-second intervals on the SHED data logger throughout the calibration and sampling periods. Temperature in the enclosure was permitted to rise up to 10°F above the set point within the first 10 minutes of the test, but was required to remain within ±5°F of the 95°F set point for the remainder of the sample period. The test equipment remained in the enclosure for 180 minutes. Cumulative vehicle HC emissions were computed and reported at one-minute intervals throughout the period.

Diurnal/Resting Loss Testing

A temperature cycle of 65 to 105 to 65°F was used for the standard diurnal evaporative emission tests in this program. The cycle used was identical to that specified for California light-duty on-road vehicles.

The diurnal cycle was started within 6 to 36 hours of the end of the hot soak test. The equipment was stabilized at the initial (65°F) temperature of the diurnal cycle for the last 6 hours of the soak period. The test equipment was normally moved to a diurnal SHED set at 65°F immediately after completion of the hot soak test. The diurnal sequence was initiated the next morning (14-20 hour soak). In any case, the last hour of the pre-diurnal soak was performed in the diurnal enclosure to minimize any fuel sloshing effects that might occur during equipment relocation.

The diurnal SHED was thoroughly purged before the start of the test. During soak the enclosure temperature set point was adjusted to the initial diurnal temperature and the door was cracked open to permit air circulation, minimizing the initial enclosure HC level. The enclosure HC analyzer was zeroed and spanned immediately before the start of the test, and remained on sample until the end of the 24-hour test. The SHED data logger was started and used to continuously record ambient pressure, enclosure HC level, and temperature at the SHED walls and 3 inches above the SHED floor. The start of the test was marked on the data logger, and the 24-hour temperature cycle was initiated. At the end of the 24-hour test period a final reading was noted, the HC analyzer received a zero and span check, the doors were unsealed, and the test equipment was removed from the enclosure.

Running Loss Testing

A limited number of Running Loss tests were specified for selected equipment types in this program. These tests were performed to provide an estimate of the magnitude of this type of emission. The operating conditions the different types of equipment normally encounter, the standardized test used for new vehicle certification, and the costs associated with alternative methods were considered before recommended methods were proposed to ARB staff for performing running loss measurements. Differences between the broad variety of equipment types included in this program precluded using a single standardized test for all units.

Running loss emissions are primarily the result of temperature changes developed in the fuel tank during engine operation. Several differences exist between modern, on-road light duty vehicles and the equipment studied here.

Running loss testing of on-road vehicles must properly account for fuel heating affects resulting from high-pressure fuel injection systems. Off-road equipment is not subjected to high pavement temperatures during operation. Heat radiated to the bottom the fuel tank of an on-road vehicle is a significant source of fuel heating. Fuel tank heating of the off-road equipment primarily results from direct transfer of heat from the operating engine and exhaust system to the fuel reservoir. It is therefore critical that the spatial relationship of the engine and fuel tank components not be disturbed during a running loss test. It is equally critical, however, that reasonable loads be applied to the engine to create heat typical of that generated during use. In addition, the amount of cooling provided must also be representative of in-use operation.

Running Loss tests were performed on four walk behind mowers, a string trimmer, the two forklifts, a generator set, four off-road dirt bikes and two ATVs. A loading strategy specific to each type of equipment was proposed to ARB staff and used during the running loss testing. The starting point was the equipment and procedures applied to on-road vehicles.

The first equipment type was the walk behind lawnmower. Lawnmowers typically include self-contained engine/fuel tank assemblies. This integrated unit can readily be removed from the lawn mower deck and be installed on an engine dynamometer. A small engine dynamometer is ideal for loading the engine, and therefore generating heat, while maintaining the engine/fuel tank assembly.

The operating cycle used to load the engine is an important factor in running loss measurements. The International Standards Organization (ISO) has published recommended dynamometer exhaust emission testing cycles for a variety of small engines, including those tested in this program. These standards are well defined and broadly circulated, provided a common basis of understanding of results generated using the procedures. The loading cycles reasonably represent actual usage patterns. The ISO recommended loading pattern for lawn mowers was therefore recommended and approved for use in this program.

In ISO exhaust emission testing of lawn mower engines, the equipment is operated at rated speed and load, allowed to stabilize, and then measurements are taken. The engine is then allowed to idle and the measurement process is repeated. The exhaust emission reported results are a 90/10 weighted average of full load and idle emissions. This stabilization and weighting procedure is not appropriate for evaporative running loss emissions. Running losses evaporative emissions are generated continuously as heat is transferred to the fuel tank, and the process cannot be paused to allow emissions to stabilize.

It is possible, however, to apply a 90%/10% loading ratio to a continuous engine run. A small engine dynamometer was set up in a running loss evaporative emissions measurement chamber. A self-contained water reservoir and pump was used to apply load and to cool the dynamometer. Operation of the equipment was divided into 10-minute periods. The engine was started and operated at full load and speed for 9 minutes. The engine was then allowed to idle for 1 minute. This cycle was repeated until the engine ran out of fuel. Cumulative hydrocarbon emissions were continuously monitored in the running loss SHED enclosure during the test.

The second type of equipment tested was a string trimmer. These have relatively tiny engines that have power ratings below the lowest resolution of the available small engine dynamometer. The equipment is self-governing with respect to maximum speed. The operating characteristics of the equipment provided a reasonable alternative - simply operate the trimmer in the running loss enclosure at wide-open throttle with no added load. The trimmer operator rocked the trimmer in a motion similar to actual use as fuel movement in the tank would be expected to generate more evaporative emissions than would occur if the equipment was held stationary.

The ISO time weighting again applied, with 90% of the time at full throttle and 10% at idle. Trimmer04 was tested using this procedure.

The next category was off-road recreational equipment, the dirt bikes and the ATVs. The fuel tanks of these units are mounted separately from the engine, requiring careful consideration if an engine stand test was to be used for running loss evaporative measurement. The fuel tanks of both dirt bikes and ATVs are typically mounted above and ahead of the engine and exhaust system, minimizing the amount of direct heat transfer. A chassis dynamometer procedure was used instead of the engine stand used for the walk behind mower.

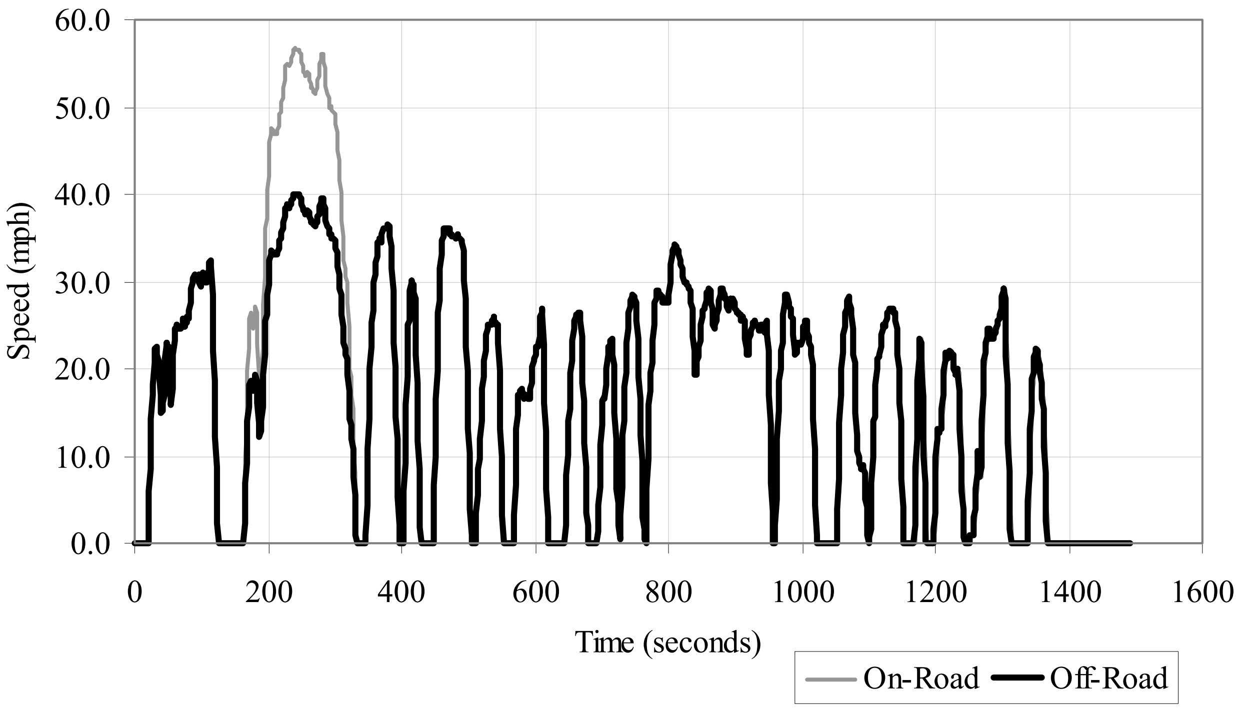
Exhaust emissions of on-road motorcycles are tested using a dynamometer procedure similar to automobiles. For the off-road dirt bikes and ATVs a modified Clayton twin roll dynamometer was used to provide load directly to the vehicles. Inertia weight setting was determined by weighing the vehicle and adding 160 pounds. The standard inertia wheels available for light duty vehicles were removed, and a single weight was selected to most closely match the vehicle inertia. The dynamometer roll frame assembly was mounted above ground, and could be moved with a forklift. The dynamometer was positioned in a running loss SHED for testing of the dirt bikes and ATVs. Air-cooling was provided to the bikes and ATVs. The fan was road speed modulated, as expected during use in the field.

The vehicles tested in this program were fitted with aggressively treaded tires appropriate for use in soft dirt. The tread pattern limited the useful top speed of the equipment, both on the open road and on a dynamometer.

The driving cycles specified for exhaust emission testing of on-road motorcycles with engine displacement larger than 170cc is the passenger car cycle. The standard cycle includes a top speed of 57 mph. This speed occurs during the off-idle interval between second 170 and second 340 of the Urban Dynamometer Driving Sequence (UDDS) from 40 CFR 86 Appendix I. For this program, a special driving cycle was developed by proportionally reducing all speeds in that time interval from 57 mph to 40 mph. This resulted in a reasonable loading pattern for the equipment power plants and drive trains tested in this program. The standard UDDS cycles and the modified cycle used in this program are displayed graphically in Figure 1.

In on-road vehicle running loss testing, a three-minute idle period is inserted between driving intervals. These three-minute idles were added to the standard UDDS schedule for this program, extending the duration of each cycle to 25.9 minutes. The 25.9-minute cycle was repeated three times. Hydrocarbon evaporative emissions were monitored continuously during this period, mirroring the procedures used for on-road vehicle running loss testing.

Figure 1
Off-Road Recreational Driving Cycle

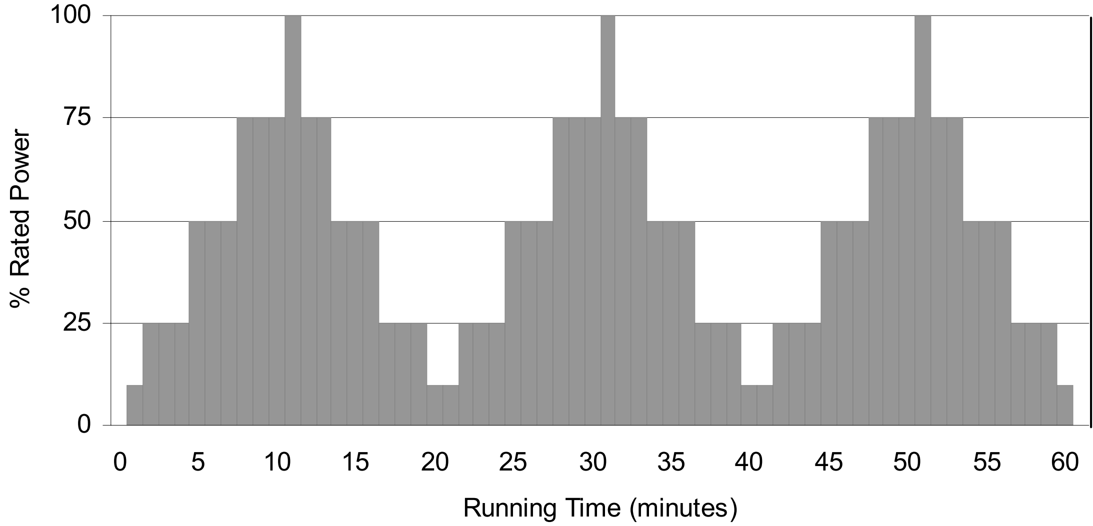


A generator set is similar to a lawn mower in that the engine is assembled with the fuel delivery system, but it is complicated by the typically very compact and integrated power generation system. Running loss emission factor testing should be performed as a motor/generator set to represent operation in the field. The generator, however, can be used to load the engine in place of the dynamometer used for exhaust emission testing. ISO testing loads and times were used, except "Watts generated" was used as a surrogate for "% Torque". The generator set was operated at 100, 75, 50, 25, and 10% load for 5, 25, 30, 30, and 10 % of the time. Running loss testing was performed for a continuous one-hour period, with load changes during the run using the schedule displayed in figure 2.

Preparation for the running loss tests of generators, fork lifts, ATVs and dirt bikes included a drain and refuel to 50% capacity with fresh summer fuel. The lawn mowers and string trimmers were filled to 100% of the tank capacity to permit longer run times on the smaller equipment. The engine was then operated for 15 minutes at rated capacity and soaked overnight for test starting from a cold start the next day.

Fresh air was provided to the engine from outside of the SHED to all equipment during running loss testing. Exhaust was ducted from the engine out of the running loss SHED. Immediately prior to the start of a running loss test the enclosure THC, CO, and CO_2 analyzers were zeroed and spanned and placed on continuous sample. CO and CO_2 were monitored to insure that engine exhaust did not contaminate the HC evaporative sample and to protect the laboratory technicians. Total SHED HC readings were logged continuously and reduced to minute-by-minute cumulative mass readings throughout the running loss tests.

Figure 2
Generator Running Loss Loading



Refueling Emissions

Two variations of refueling test were performed. The marine engines were tested using equipment and procedures that parallel those used for light-duty vehicles. These pieces of equipment are typically refueled at standard service stations while on a trailer, or from a dockside-refueling pump. The standard light-duty vehicle refueling test fuel dispenser and protocols simulate such operations. The remaining equipment types are typically refueled from a portable gas can that is transported from a service station to the site where the equipment is used. Refueling tests on those equipment types were performed using a portable gas can.

Much of the standard refueling testing protocol used for on-road vehicles is related to preconditioning of the charcoal canister that is used to control evaporative emissions. Off-Road engines are not equipped with such a device, eliminating the relevance of the elaborate preconditioning steps. Refueling tests in this program were performed following a standard hot soak/diurnal test. Any remaining fuel was drained, and 10% of the tank capacity was added. The test equipment was then placed in soak for 6 to 24 hours and then transferred to the refueling SHED. The FID analyzer was zeroed and spanned, and then allowed to continuously monitor the SHED interior prior to sealing the door. The SHED interior was thoroughly purged, and then the doors to the enclosure were sealed with the test piece inside. The FID was monitored to insure the pretest initial HC background was stabilized. The fuel fill cap was then removed, and the tank was filled to capacity. The automatic shut off was used for the marine engines. The operator continued filling the marine units until at least 85% of the tank capacity had been dispensed. The remaining equipment was filled from a portable fuel tank. Fuel was added until the level was within 1" of the top. Painstaking care to avoid over-filling and fuel spillage was practiced. Fuel spills would void the test. In both cases, hydrocarbon levels in the SHED enclosure were then allowed to stabilize. Refueling emissions were computed using the stable HC level before the fill and the stable HC readings following the refueling. The gallons added were divided into the grams measured to determine the grams/gallon refueling emissions.

Subsets of the test sample received additional testing, including:

1. Fuel level tests.
2. Fuel weathering tests.
3. Fuel/temperature sensitivity tests.
4. Evaluation of emission control systems.
5. Evaluation of evaporative emission related repairs.

The standardized test protocol applied to the initial test on all units was also used for the fuel level tests, the fuel weathering tests, the emission control system evaluation, and the emission related repair evaluation. The fuel/temperature sensitivity tests followed the standardized hot soak/diurnal protocol except for stepwise modification of the fuel used and the temperatures applied.

Fuel Level Testing

Four pieces of equipment received additional testing using different initial fuel fill levels. One dirt bike, one ATV, one generator and one stern drive boat were selected for this series of tests. The baseline test on all equipment was a hot soak and diurnal with the summer fuel at the 50% fill level. For the fuel level sensitivity testing, additional tests were performed under identical conditions except the fuel tanks were filled to 100%, 75% and 25% of capacity.

Fuel Weathering

A series of tests was performed on three pieces of equipment to measure the effect of fuel weathering over time. The equipment was tested once per week for four consecutive weeks. The equipment was stored outdoors in a shaded area between tests. The standard hot soak/diurnal test series was performed initially and each following week. Each piece of equipment received a drain and fill to 100% of capacity, followed by the 15 minute warm-up operation. Subsequent tests did not include either the fuel fill or the warm-up. The test fuel was the summer grade gasoline.

Fuel/Temperature sensitivity

Originally, six pieces of equipment were to be used to compare evaporative emissions results while using California Phase II commercial fuel and California Phase III commercial fuel. This testing was not performed in this study.

A study was performed to determine the sensitivity of evaporative emissions to the differences in summer and winter grade Phase II fuel, and temperatures expected during different seasons. Testing started on two pieces of equipment, mower 08 and trimmer 04, with the standard 7.0-psi summer fuel and the summer temperature range of 65 to 105°F for the diurnal evaporative test. Testing continued on these two pieces with a 65 to 105°F test using winter grade commercial Phase II fuel with an RVP of 9.5 psi. The series was completed with a test using the winter grade fuel and a diurnal range of 50 to 90°F.

Emission Control Devices

A standard hot soak and diurnal test was completed on Mower03. A special fuel tank, which had received treatment to reduce permeation (Level 5 fluorination), was then installed, and the standard test series was repeated. The engine was then removed from the mower deck and installed on a small-engine dynamometer. A running loss test was then performed using the original fuel tank. The fluorinated tank was reinstalled, and the running loss test was repeated. The fuel tank/engine assembly was then reinstalled on the mower deck. ARB staff then installed valves to seal the fuel tank and the fuel supply to the carburetor when the engine was shut down. These valves were intended to eliminate tank venting during the hot soak and diurnal while protecting the carburetor float control from excess pressure. The standard hot soak and diurnal tests were then performed using the fluorinated tank and extra shut off valves. Testing was completed following reinstallation of the engine on the small engine dynamometer, and performance of a running loss test with all controls.

Testing was performed on equipment selected by ARB staff following diagnosis and repair of evaporative emission related failures. Mower 04 resulted in high emissions during its incoming standard test. The unit was inspected to determine the source of the unusually high emissions. A fuel leak was found and repaired, and post repair testing measured the effectiveness of the repair. This unit received hot soak/diurnal and running loss tests before and after the repairs.

Two Forklift units were tested using the standard testing protocol. Significant fuel leakage from the carburetor of one was found, while the second was emitting crankcase blow-by emissions because of a missing PCV hose. The first forklift received standard tests before and after installation of a carburetor rebuild kit. A running loss test was performed with the rebuilt carburetor. The second unit received a standard test and a running loss test in the as-received state. Inspection revealed a missing PCV hose. A PCV hose was installed, and a running loss test was performed to measure the effect of the repair.

Table 4 summarizes the tests performed on the different equipment types. A total of 72 hot soak/diurnal tests were completed on the 38 pieces of equipment. Thirteen running loss tests and 8 refueling tests were completed. Fill level testing was performed on four units. Weathering tests were performed on three units. The RVP/temperature sensitivity tests were performed on two units. One unit received the prototype emission control equipment. Four pieces of equipment were repaired and retested.

Table 4
Distribution of Tests Performed

	Standard HS/Diurnal	Running Loss	Refueling	Fill Level HS/Diurnal	Weathering HS/Diurnal	RVP/Temp HS/Diurnal	Evap Control		Evap Repair	
							HS/Diurnal	Run Loss	HS/Diurnal	Run Loss
Mower	8	4	1	-	-	2	2	2	1	1
String Trimmer	4	1	1	-	-	2	-	-	-	-
Saw/Trimmer	2	-	1	-	-	-	-	-	-	-
Leaf Blower	2	-	1	-	-	-	-	-	-	-
ATV	4	3	1	3	4	-	-	-	1	1
Dirt Bike	4	2	1	3	4	-	-	-	-	-
Generator	3	2	1	3	-	-	-	-	-	-
Forklift	2	1	-	-	-	-	-	-	1	2
PWC	3	-	-	-	-	-	-	-	-	-
Out Board	3	-	-	-	-	-	-	-	-	-
Stern Drive	3	-	1	3	4	-	-	-	1	-
	38	13	8	12	12	4	2	2	4	4

III. Results

Results of all evaporative tests are summarized in the following tables. Additional detail for each test is presented in the Appendix to this report. Minute-by-minute results were presented to ARB staff in electronic form.

Table 5 displays the results obtained from the Lawn and Garden equipment category, including walk behind mowers, string trimmers, hedge trimmers, chain saws, and leaf blowers. Table 6 summarizes the off-road recreational vehicles, including dirt bikes and all terrain vehicles (ATVs). Table 7 displays the results from commercial equipment, including generators and fork lifts. Table 8 summarizes the recreational marine equipment, including personal water craft, out board engines, and stern drive engines.

In each of these tables the first columns display the equipment type and number (for example Mower 01), year of manufacture, make and model (99 Toro SR-2105) and engine combustion cycle (4 stroke). The fuel tank capacity in gallons (0.50) follows. A description of the test sequence (Basic) follows. “Basic” in this context is used to identify the standardized hot soak and diurnal test using the summer grade California Phase II commercial fuel. Other test types include “RL” for running loss tests, “refuel” for refueling tests, “Level %” for the tests performed with different levels of fuel in the tank, and “Weather #” to describe tests performed on successive weeks without refueling.

The fuel used for the test is described under the Fuel heading. “P2” is the blend of summer grade Phase II commercial fuel, while “9.5” is the winter grade phase II fuel. The Date column is the date the test began. The “HLS” column displays the net results in grams HC for the 3-hour Hot Loss Soak test. “DHB” identifies Diurnal Heat Build results. The grams HC over the 24-hour period is displayed. The “RLS” column displays the grams HC generated during the Running Loss test. The “Refuel” column displays the HC grams measured during the refueling test.

On-road vehicle emissions for running loss tests are reported on a grams/mile basis. Miles traveled is not appropriate metric for such equipment as a lawn mower or generator. The duration of the running loss test is reported in hours under “Dur”. This may be used to compute grams/hour for the running loss result. The smaller equipment did not have sufficient fuel tank capacity to operate an entire hour. The duration of the test for these pieces of equipment is reported as a decimal fraction (0.68 hours for Mower 03). The distance traveled during the running loss tests on ATVs and Dirt Bikes is recorded under “Dist”

Refueling results are normally reported on a grams/gallon of fuel added basis. The “gal” column reflects the gallons added. The final column “Note” is used for comments, and computed results such as grams/gallon, grams/hour, or grams/mile.

Table 5 - Lawn and Garden Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Mower	01	99 Toro	0.50	Basic	P2	9/06/01	0.74	5.36						
		SR-2105												
		4 stroke		Refuel	P2	9/27/01				2.54			0.425	5.97 grams/gal
Mower	02	99 Murray	0.25	Basic	P2	9/06/01	1.47	7.05						
		20111X192A												
		4 stroke												
Mower	03	01 Scotts	0.38	Basic	P2	10/25/01	0.58	3.54						Standard Tank
		OVRM120		Phase 2	P2	10/30/01	0.44	2.15						Special Tank
		4 stroke		Phase 4	P2	1/15/02	0.50	void						Cap Failed
				Phase 4	P2	1/15/02	0.28	1.23						Tank + valves
		Arb Supplied												
		Emission		RL (Basic)	P2	12/21/01			1.77		0.68			Standard Tank
		Controls		RL (Phase 2)	P2	12/27/02			0.95		0.75			Special Tank
				RL (Phase 4)	P2	1/18/02			0.99		0.58			Tank + valves
Mower	04	89 Toro	0.25	Basic	P2	10/23/01	2.88	23.99						Before Repair
		20511		Basic (AR)	P2	12/19/01	0.87	3.28						After Repair
		ARB Supplied		Runloss	P2	11/21/01			8.23		0.68			12.05 grams/hour
		High Emitter		Runloss (AR)	P2	12/06/98			6.73		0.75			8.97 grams/hour
Mower	05	90 Toro	0.31	Basic	P2	12/12/01	1.56	2.30						
		22036												
		2 stroke												
Mower	06	1973	0.25	Basic	P2	12/11/01	0.87	3.94						
		Builders Best												
		F111C												
		4 stroke												

Table 5 - Lawn and Garden Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Mower	07	94 Sears	0.50	Basic	P2	12/18/01	1.06	3.54						
		917.38359												
		4 stroke		Runloss	P2	1/07/02			20.27		0.75			27.03 grams/hour
Mower	08	2000 Honda	0.30	Basic	P2	4/16/02	0.89	3.18						
		Harmony II		Basic	P2	4/30/02	0.75	3.13						
		HRT216		65-105	9.5	5/07/02	1.13	4.03						Winter Fuel
		4 stroke		50-90	9.5	5/21/02	1.34	2.63						Winter Fuel/Temp
				Runloss	P2	4/25/02			0.44		0.75			.59 grams/hour
Trimmer	01	Ryobi	0.125	Basic	P2	9/07/01	0.15	0.89						
		970R												
		4 stroke		Refuel	P2	9/27/01				1.87			0.106	17.6 grams/gal
Trimmer	02	99 Stihl	0.125	Basic	P2	9/13/01	0.21	void						
		FS80		Basic	P2	9/18/01	0.17	1.08						
		2 stroke												
Trimmer	03	McCulloch	0.125	Basic	P2	12/20/01	0.40	0.53						
		40003102												
		2 stroke												
Trimmer	04	99 Makita	0.125	Basic	P2	5/01/02	0.23	1.35						
		EM4251		65-105	9.5	5/08/02	0.24	1.99						
		4 stroke		50-90	9.5	5/29/02	0.30	void						
				50-90	9.5	6/04/02	0.28	0.97						
				Runloss	P2	4/11/02			0.39		0.67			0.59 grams/hour

Table 5 - Lawn and Garden Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Saw	01	Echo	0.08	Basic	P2	9/11/01	0.15	0.94						
Hedge Trim		HC-1500												
		2 stroke		Refuel	P2	9/27/01				0.79			0.068	11.60 grams/gal
Saw	02	89 McCulloch	0.06	Basic	P2	12/12/01	0.79	0.56						
Chain Saw		60001620												
		2 stroke												
Leaf Blower	01	00 Echo	0.16	Basic	P2	9/11/01	0.14	1.17						
		PB-231LN												
		2 stroke		Refuel	P2	9/27/01				1.70			0.136	12.52 grams/gal
Leaf Blower	02	99 John Deer	0.125	Basic	P2	4/10/02	0.31	1.22						
		UT08087												
		2 stroke												

Table 6 - Off-Road Recreational Vehicle Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Dirt Bike	01	82 Honda	2.4	Level 100%	P2	6/20/01	3.71	8.60						
		XR200R		Level 75%	P2	6/28/01	3.45	8.75						
		4 stroke		Basic	P2	6/13/01	3.96	8.36						
				Level 25%	P2	6/25/01	4.05	10.10						
				Weather 1	P2	7/12/01	1.26	7.31						Initial
				Weather 2	P2	7/18/01	2.74	7.21						end week 1
				Weather 3	P2	7/25/01	1.74	6.17						end week 2
				Weather 4	P2	7/31/01	2.10	7.78						end week 3
				Runloss	P2	8/28/01			18.02		1.24	20.5		0.88 grams/mile
Dirt Bike	02	00 Kawasaki	2.2	Basic	P2	7/12/01	1.80	8.29						
		KX250												
		2 stroke		Refuel	P2	7/17/01				4.77			1.9	2.51 grams/gal
Dirt Bike	03	84 Suzuki	2.0	Basic	P2	7/31/01	4.49	6.81						
		RM125												
		2 stroke												
Dirt Bike	04	01 Yamaha	3.2	Basic	P2	8/02/01	9.70	18.57						
		WR250F												
		4 stroke		Runloss	P2	8/27/01			26.16		1.24	20.7		1.27 grams/mile
ATV	01	83 Honda	3.0	Level 100%	P2	7/06/01	7.64	8.25						
		FL250		Level 75%	P2	6/22/01	3.74	12.02						
		(Odyssey)		Basic	P2	6/19/01	2.24	16.98						
		2 stroke		Level 25%	P2	6/26/01	2.91	6.43						
				Weather 1	P2	7/17/01	2.84	19.93						Initial
				Weather 2	P2	7/24/01	2.38	18.13						end week 1
				Weather 3	P2	8/01/01	1.24	10.28						end week 2
				Weather 4	P2	8/08/01	1.04	8.59						end week 3

Table 6 - Off-Road Recreational Vehicle Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
ATV	02	01 Yamaha	3.2	Basic	P2	7/31/01	2.64	15.79						
		YFZ350N-W												
		(Banshee)		Runloss	P2	8/28/01			26.48		1.24	20.7		1.28 grams/mile
		2 Stroke												
ATV	03	01 Suzuki	3.2	Basic	P2	8/01/01	2.16	5.36						
		LT-F250												
		(Quadrunner)		Refuel	P2	8/08/01				8.11			2.8	2.95 grams/gallon
		4 stroke		Runloss	P2	8/27/01			1.55		1.24	20.5		0.08 grams/gallon
ATV	04	88 Kawasaki	2.6	Basic	P2	9/05/01	6.24	20.48						As Received
		KLF220		After Repair	P2	11/29/01	4.96	15.4						After Repair
		(Bayou)												
		4 stroke		Runloss	P2	9/26/01			65.36			20.3		3.21 grams/mile
				Rloss (AR)	P2	11/29/01			18.54			20.5		0.90 grams/mile

Table 7 - Off-Road Commercial Equipment Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Generator	01	95 Honda	4.4	Level 100%	P2	6/14/01	2.38	4.06						
		EX5500		Level 75%	P2	6/18/01	3.66	7.16						
		4 stroke		Basic	P2	6/07/01	4.64	8.08						
				Level 25%	P2	6/11/01	6.65	8.96						
				Runloss	P2	6/21/01			19.45		1.00			19.45 grams/hour
				Refuel	P2	6/22/01				11.13			3.9	2.86 grams/gallon
Generator	02	68 Homelite	0.125	Basic	P2	9/07/01	0.25	0.75						
		XL-A115												
		2 stroke												
Generator	03	02 Coleman	5.0	Basic	P2	5/15/02	1.85	13.64						
		PL0545005												
		4 stroke		Runloss	P2	5/28/02			1.80		1.00			1.80 grams/hour
Forklift	01	95 Komatsu	12.6	Basic	P2	10/08/01	13.54	47.28						
		FG30G-11		After Repair	P2	10/17/01	10.55	24.61						
		4 stroke												
				Runloss (AR)	P2	10/23/01			1.83		1.00	6.9		0.27 grams/mile Rebuilt Carb
Forklift	02	87 Toyota	8.0	Basic	P2	10/16/01	7.43	24.74						
		2FG25-10579												
		4 stroke		Runloss	P2	10/16/01			195.14		1.00	6.2		31.47 grams/mi
				Runloss (AR)	P2	10/25/01			7.38		1.00	6.2		1.19 grams/mi Replaced PCV to manifold hose

Table 8 - Recreational Marine Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Personal Water Craft	01	92 Yamaha Wave Runner III 2 stroke	10.5	Basic	P2	10/18/01	5.71	13.93						
Personal Water Craft	02	91 Bombardier Sea-Doo XP 2 stroke	10.0	Basic	P2	10/19/01	7.22	23.69						
Personal Water Craft	03	01 Yamaha Wave Runner 2 stroke	4.8	Basic	P2	10/31/01	1.55	6.76						
Out Board	01	77 Evinrude 66054 2 stroke	6.6	Basic	P2	11/07/01	6.14	19.63						
	02	01 Mercury	31.0	Basic	P2	3/13/03	4.91	26.76						Day 1
		Opti-Max				3/14/03		25.72						Day 2
		4 stroke				3/15/03		25.35						Day 3
				Refuel	P2	3/20/03				89.35			27.17	3.28 grams/gal
	03	00 Johnson RJ90PLSSE 4 stroke	35.0	Basic	P2	3/25/03	13.224	49.86						
Stern Drive	01	77 Schuster	11.0	Basic	P2	11/20/01	29.56	63.34						
		Jet Boat		After Maint	P2	11/30/01	15.95	48.04						After Maint
		4 stroke												
				Weather 1	P2	1/04/02	14.70	43.22						Initial
				Weather 2	P2	1/09/02	14.20	41.47						end week 1
				Weather 3	P2	1/17/02	14.19	42.12						end week 2
				Weather 4	P2	1/24/02	14.51	45.69						end week 3

Table 8 - Recreational Marine Summary

Category	#	Year Make Model	Tank gal.	Sequence	Fuel	Start Date	HLS gms	DHB gms	RLS gms	Refuel gms	Dur. hrs	Dist. mi	gal.	Note
Stern Drive	02	98 Yahama EXT 1200W 2 stroke	35	Basic	P2	12/11/01	10.09	37.49						
Stern Drive	03	02 GM 4.3 GL 4 stroke	29	Level 100%	P2	4/08/03	3.31	18.13						
				Level 75%	P2	4/15/03	4.13	22.64						
				Basic	P2	4/02/03	3.66	22.99						
				Level 25%	P2	4/11/03	5.81	34.43						
				Refuel	P2	4/17/03				88.98			27.43	3.25 grams/gal

IV. Discussion

The scope of this contract was limited to testing of a variety of equipment under controlled conditions. Analysis of the results was excluded. Some results, however, merit comment.

Mower 04 demonstrates the ability of a small liquid leak to overwhelm vapor driven evaporative affects. The 24.0 gram as-received result on this unit was triple the next highest result observed. The cause of this level was attributed to a liquid leak.

Mower 07 resulted in unexpectedly high running loss emissions. This was later determined to be caused by open crankcase venting. In 1995 federal regulations required a closed crankcase in this class of equipment. This unit was manufactured in 1994. Most manufacturers equipped their engines with positive crankcase ventilation (PCV) before this requirement was enacted, but Mower 07 was an exception to the rule.

Generator 01 and 03 were of similar size and fuel tank capacity. Generator 01 was mounted in a fully enclosed cabinet, apparently to reduce noise levels and for cosmetic appearance. Generator 03 was mounted in an open tubular frame. Generator 01 test results for the Hot Soak and Running Loss tests reflect the higher fuel temperatures that would be expected with its enclosed design.

Generator 03's plastic fuel tank, on the other hand, apparently drove diurnal emissions to twice the level observed with Generator 01's metal fuel tank. Generator 01's shielding could also have attenuated the ambient temperatures observed in the fuel tank.

The recreational marine craft yielded very high diurnal emissions. The results are, however, in proportion with the fuel tank capacities of the equipment tested. The 30+ gallon fuel tanks were the largest of any tested in this program.

V. Summary and Conclusions

The primary purpose of this effort was to collect evaporative emissions data on a variety of off-road equipment using enhanced procedures recently developed for on-road vehicles. Attempts to develop an improved off-road equipment emissions inventory was specifically excluded from the scope of work of the agreement.

The original matrix of equipment was modified during the course of testing. A number of changes were incorporated at the direction of ARB staff. The original cost and technical proposal assumed that all lawn and garden equipment would be supplied by the test sponsors. A limited sample was supplied, and ATL was instructed to procure the remaining units. The cost of trips and equipment procurement resulted in a reduction in the total number of pieces tested. Limited testing of California Phase III fuel was included in the original request for proposal. This was later eliminated. Additional test slots were provided for demonstration of evaporative emission control devices. Multiple tests were performed on one lawn mower with prototype control equipment, and other pieces of equipment were tested before and after restorative maintenance to absorb some of the slots. ARB staff requested that ATL procure and test two gasoline-powered forklifts during the course of the program. No forklifts were originally specified. Winter grade fuel was supplied, and tests were performed using that fuel and nonstandard temperatures. These tests were not originally included.

A running dialogue was maintained with the test sponsors to reconcile the scope of the original work and the work actually being performed. The work presented in this report displays the results of that interchange.

Data gathered during the program has been supplied to the ARB emission factor modeling group for analysis and incorporation in the OFFROAD model.

From the perspective of a laboratory operator that normally performs testing of new certification on-road vehicles, the difference between uncontrolled off-road equipment and those vehicles being produced to achieve current and future regulations is remarkable. Lawn and Garden equipment with less than one quart of fuel tank capacity are generating substantially more evaporative hydrocarbon emissions than modern cars and trucks, on both a per use and per day basis. It appears as if substantial reductions in the atmospheric hydrocarbon emission inventory are available through the control of evaporative emissions from this diverse class of equipment. Much of research in evaporative emission control methods and technologies has already been performed for on-road vehicles. It appears as if this technology can be applied to off-road equipment. It also appears as if some relatively simple steps, such as utilizing low permeation materials and eliminating open venting of the fuel tank, can result in significant reductions. Numerous questions, however, remain concerning relative cost, relative contribution to the inventory, safety, and public acceptance.

VI. Recommendations

This program provides initial results on a wide variety of equipment using current methods for measurement of evaporative emissions. These results, particularly in combination with other studies of exhaust emissions and ongoing efforts to create an accurate census of in-use equipment, provide a basis for creating a much improved hydrocarbon emissions inventory. The improved inventory provides a critical tool for comparison of various strategies for achieving healthful air quality levels. This inventory development should be pursued.

It is apparent that substantial reductions in evaporative emissions are available from the wide variety of equipment included in the off-road classification, but equally apparent that careful consideration will be required to fairly and effectively select which controls to implement.

Acronyms

ARB – Air Resources Board

ATL - Automotive Testing Laboratories, Inc.

ATV – All Terrain Vehicle

CalRFG2 – California Phase II Reformulated Gasoline

CalRFG3 – California Phase III Reformulated Gasoline

CFR – Code of Federal Regulations

CO – Carbon Monoxide

CO_2 – Carbon Dioxide

DHB – Diurnal Heat Build

FID – Flame Ionization Detector

HC – Hydrocarbon

HLS – Hot Loss Soak

ISO – International Standards Organization

PCV – Positive Crankcase Ventilation

PpmC – parts per million Carbon

PWC – Personal Water Craft

RFP – Request for Proposal

RFG – Reformulated Gasoline

RLS – Running Loss

RPM – Revolutions per Minute

RVP – Reid Vapor Pressure

SHED - Sealed Housing for Evaporative Determination

THC – Total Hydrocarbon

UDDS – Urban Dynamometer Driving Schedule

VW – Volkswagen

Appendices

Appendix I - Equipment Description

Equipment Type	Number	Year	Manufacturer	Model	Engine Size	Fuel Tank Capacity	Fuel Tank Material	Stroke	Power Rating
Lawnmower	Mow01	1999	Toro	20040 SR-2105		0.5 Gal	Plastic	4	6.5 HP
	Mow02	1999	Murray	20111X192A		0.1875 Gal	Metal	4	3.5 HP
	Mow03	2001	Scotts	OVRM120	195 cc	0.375 Gal	Plastic	4	6.5 HP
	Mow04	1989	Toro	20511		0.25 Gal	Plastic	4	
	Mow05	1990	Toro	22036		0.5 Gal	Metal	2	4.5 HP
	Mow06	1973	Builders Best	F111C	148 cc	0.25 Gal	Metal	4	3.5 HP
	Mow07	1994	Sears	917.38359		0.5 Gal	Plastic	4	4.5 HP
	Mow08	2001	Honda	Harmony II HRT216	161 cc	.29 Gal	Plastic	4	5.5 HP
Edge Trimmer	Trim01		Ryobi	970R		0.125 Gal	Plastic	4	
	Trim02	1999	Stihl	FS80	25 cc	0.125 Gal	Plastic	2	
	Trim03		McCulloch	40003102		0.125 Gal		2	
	Trim04	2000	Makita USA Inc.	EM4251	24.5 cc	0.264 Gal	Plastic	4	1.1 HP
Leaf Blower	Leaf01	2000	Echo	PB-231LN	22.8 cc	0.16 Gal	Plastic	2	
	Leaf02	1999	John Deere	UT08087	25 cc	0.25 Gal	Plastic	2	
Chainsaw (Hedge Trimmer)	Saw01		Echo	HC-1500	21.2 cc	0.08 Gal	Plastic	2	
Chainsaw	Saw02	1989?	McCulloch	60001620	2.0 CID	.0625 Gal	Plastic	2	

Appendix I - Equipment Description

Equipment Type	Number	Year	Manufacturer	Model	Engine Size	Fuel Tank Capacity	Fuel Tank Material	Stroke	Power Rating
Dirt Bike	DB01	1982	Honda	XR200R	199cc	2.4 Gal	Plastic	4	
	DB02	2000	Kawasaki	KX250	249cc	2.2 Gal	Plastic	2	42HP
	DB03	1984	Suzuki	RM125	124cc	2.0 Gal	Plastic	2	
	DB04	2001	Yamaha	WR250F	249cc	3.2 Gal	Plastic	4	
All Terrain Vehicles	ATV01	1983	Honda	Odyssey FL250	248cc	3.0 Gal	Metal	2	
	ATV02	2001	Yamaha	Banshee YFZ350N-W	347 cc	3.2 Gal	Plastic	2	
	ATV03	2001	Suzuki	Quadrunner LT-F250	246 cc	3.2 Gal	Plastic	4	
	ATV04	1988	Kawasaki	Bayou KLF220	215 cc	2.6 Gal	Plastic	4	
Generator	Gen01	1995	Honda	EX5500	359 cc	4.4 Gal	Metal	4	12 HP
	Gen02	1968	Homelite	XL-A115		0.125 Gal	Metal	2	
	Gen03	2002	Coleman	PL0545005	305 cc	5.0 Gal	Plastic	4	10 HP
Forklift	FL01	1995	Komatsu	FG30G-11		12.6 Gal	Metal	4	61 HP
	FL02	1987	Toyota	2FG25-10579		8.0 Gal	Metal	4	52 HP

Appendix I - Equipment Description

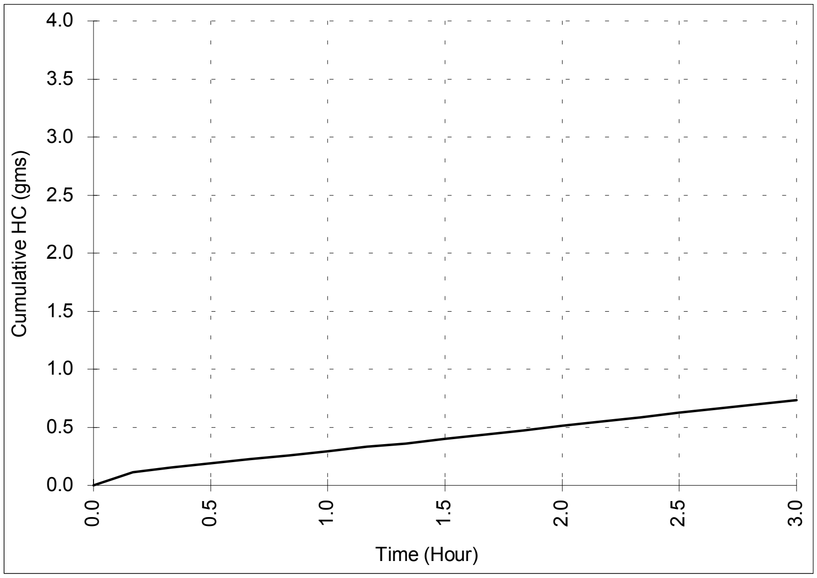
Equipment Type	Number	Year	Manufacturer	Model	Engine Size	Fuel Tank Capacity	Fuel Tank Material	Stroke	Power Rating
Personal Water Craft	PWC01	1992	Yamaha	Wave Runner III	650 cc	10.5 Gal	Plastic	2	
	PWC02	1991	Bombardier	Sea-Doo XP	580 cc	10 Gal	Plastic	2	
	PCW03	2001	Yamaha	Super Jet (SJ700AZ)	701 cc	4.8 Gal	Plastic	2	73 HP
Outboard Motor	OB01	1977	Evinrude	66054		N/A	N/A	2	6 HP
Tank	OBFT01	1989	Chilton	P6M	N/A	6.6 Gal	Plastic	N/A	N/A
	OB02	2001	Mercury	Opti-Max	2.5L	31 Gal	Plastic	4	150 HP
	OB03	2000	Johnson	RJ90PLSSE	105.4 ci	35 Gal	Plastic	4	90 HP
Stern Drive Boat	STRN01	1972	Schuster	Jet Boat	455 ci	11 Gal	Metal	4	
Stern Drive Boat	STRN02	1998	Yahama	EXT 1200W		35 Gal	Plastic	2	270 HP
Stern Drive Boat	STRN03	2002	Volvo	Penta	4.3L	29 Gal	Plastic	4	190 HP

Appendix II
Continuous Results

Equipment: MOW01
1999 Toro 20040 SR-2105; 4 stroke

Sequence: HS/Diurnal

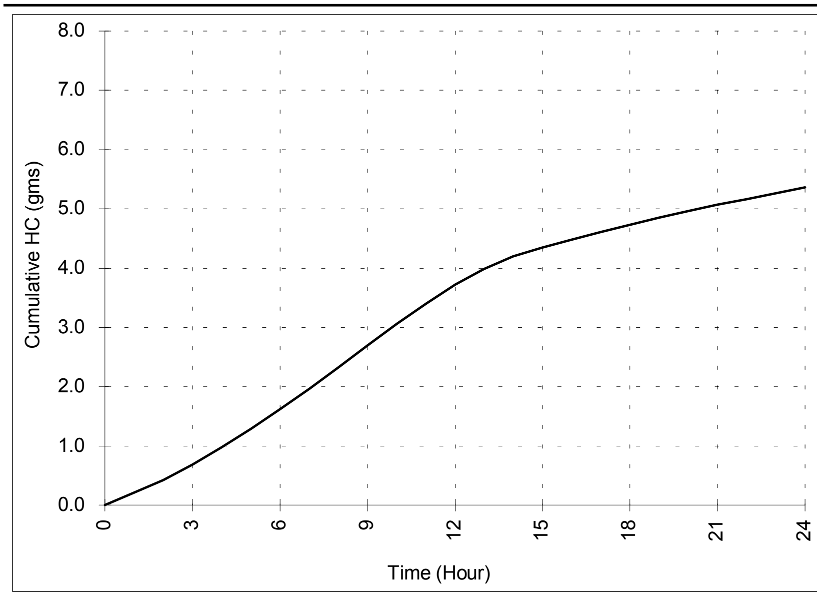
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.74

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

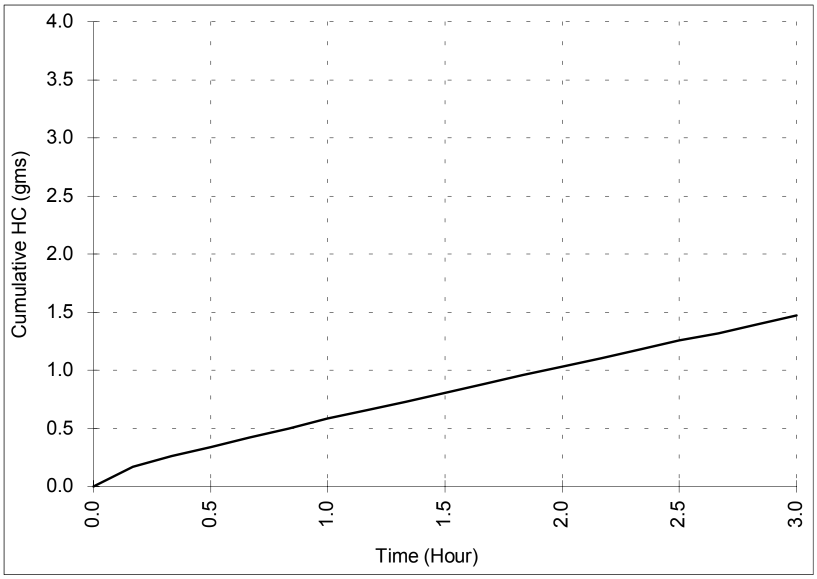
Test	Fuel	Grams
Diurnal		5.36

Appendix II
Continuous Results

Equipment: MOW02
1999 Murray 20111X192A; 4 stroke

Sequence: HS/Diurnal

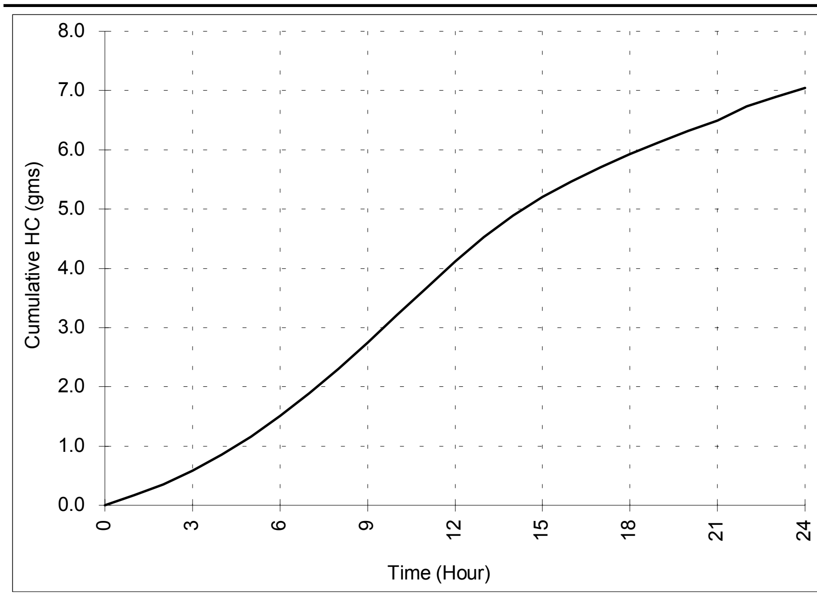
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.47

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

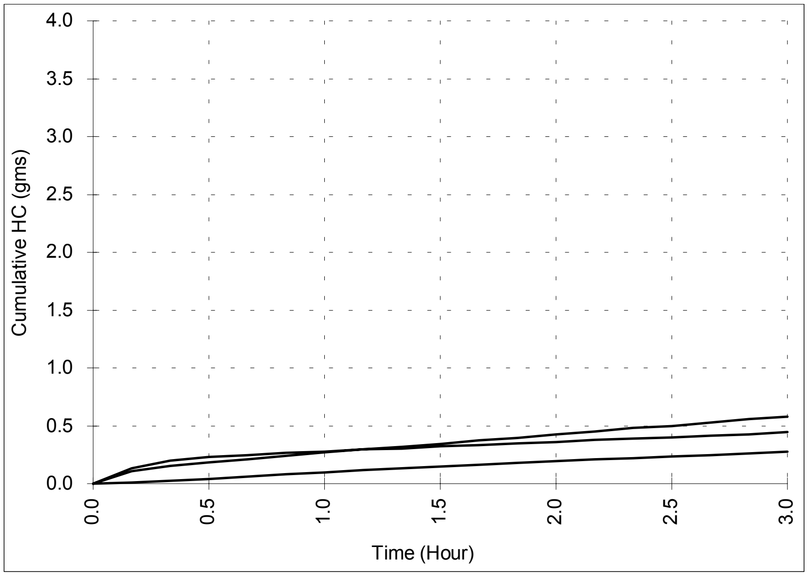
Test	Fuel	Grams
Diurnal	Summer	7.05

Appendix II
Continuous Results

Equipment: MOW03
2001 Scotts OVRM120; 4 stroke

Sequence: HS/Diurnal

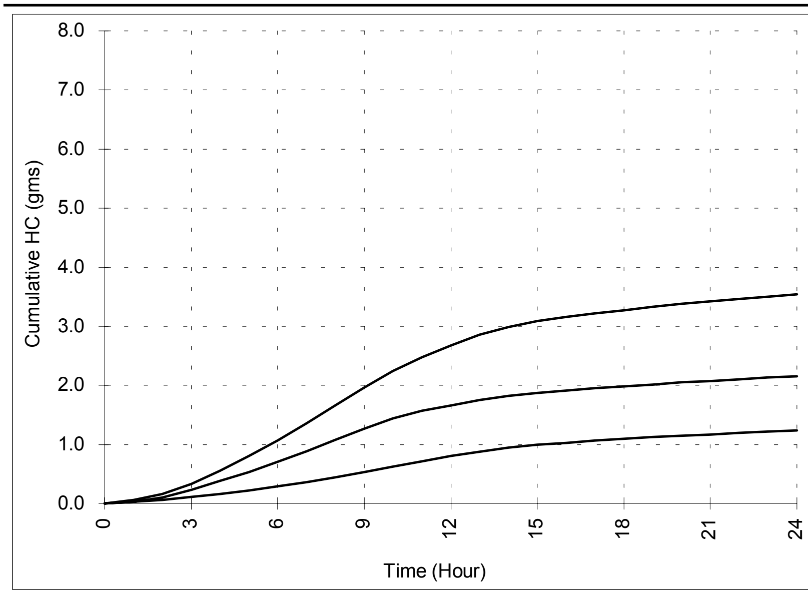
HOT SOAK EVAPORATIVE EMISSIONS TEST



Emission Control
System Strategy Tests

Test	Fuel	Grams
Std. Tank	Summer	0.58
Spc. Tank	Summer	0.44
Tank/valve	Summer	0.28

DIURNAL EVAPORATIVE EMISSIONS TEST



Emission Control
System Strategy Tests

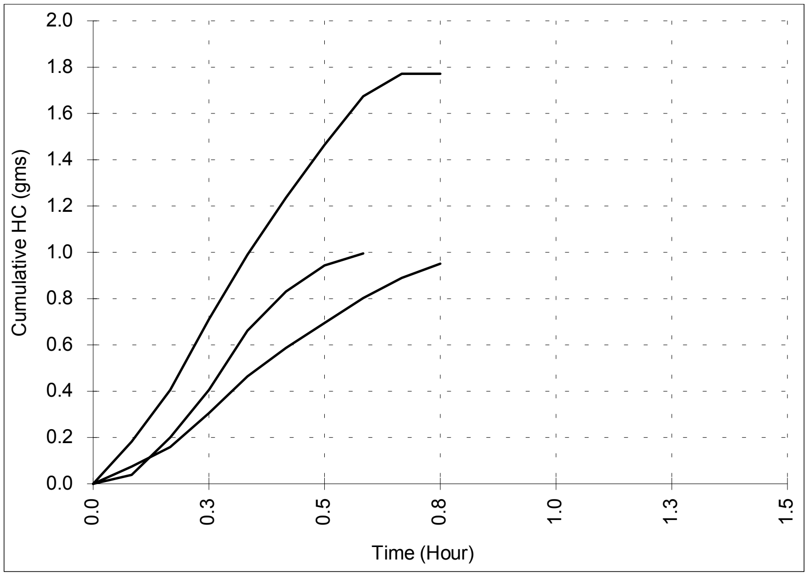
Test	Fuel	Grams
Std. Tank	Summer	3.54
Spc. Tank	Summer	2.15
Tank/valve	Summer	1.23

Appendix II
Continuous Results

Equipment: MOW03
2001 Scotts OVRM120; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Emission Control
System Strategy Tests

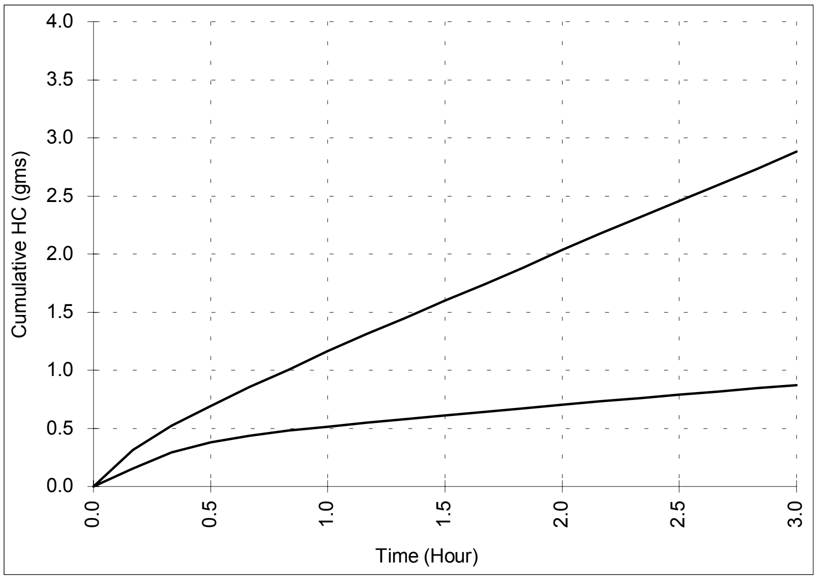
Test	Fuel	Grams
Std. Tank	Summer	1.77
Spc. Tank	Summer	0.95
Tank/valve	Summer	0.99

Appendix II
Continuous Results

Equipment: MOW04

Sequence: HS/Diurnal

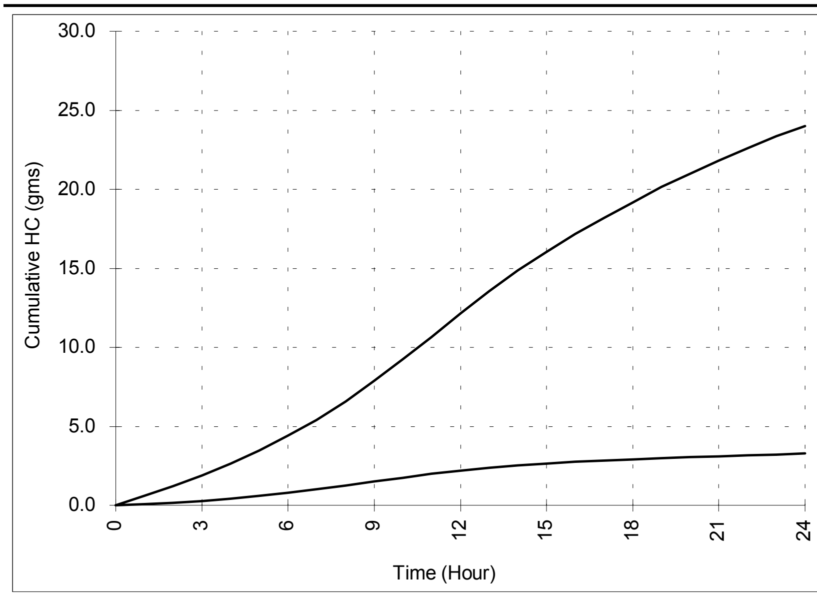
HOT SOAK EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

Test	Fuel	Grams
Before	Summer	2.88
After	Summer	0.87

DIURNAL EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

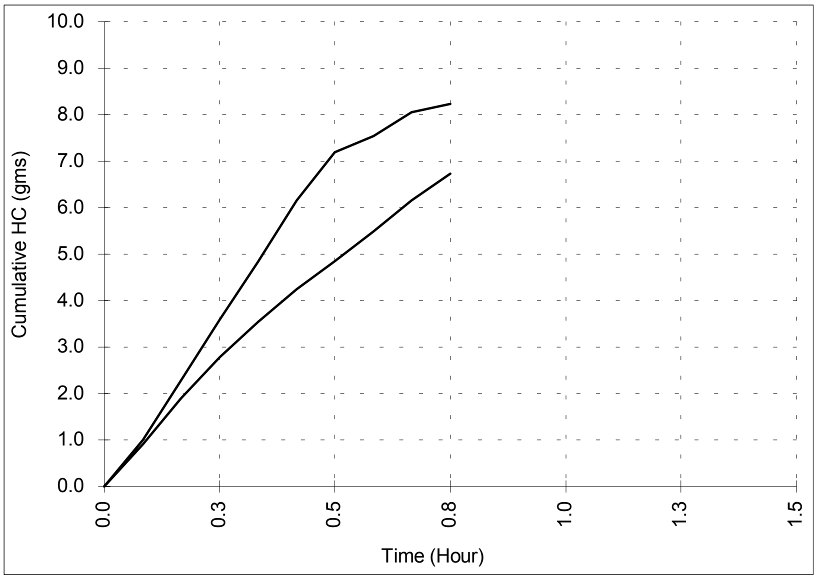
Test	Fuel	Grams
Before	Summer	23.99
After	Summer	3.28

Appendix II
Continuous Results

Equipment: MOW04

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

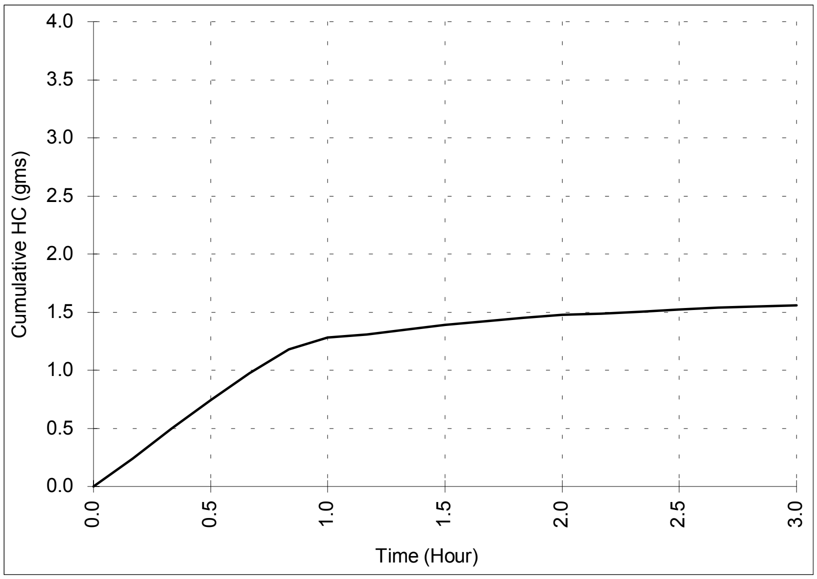
Test	Fuel	Grams
Before	Summer	8.23
After	Summer	6.73

Appendix II
Continuous Results

Equipment: MOW05
1990 Toro 22036; 2 stroke

Sequence: HS/Diurnal

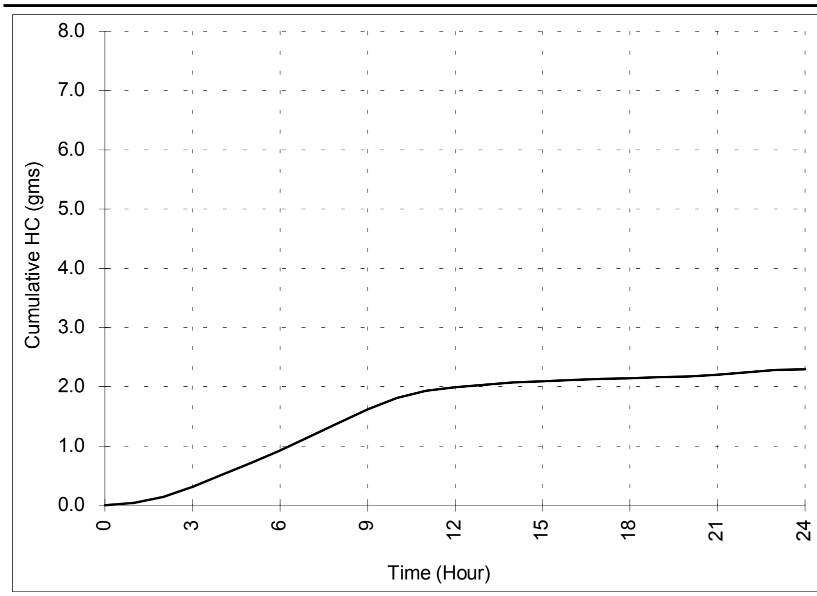
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.56

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

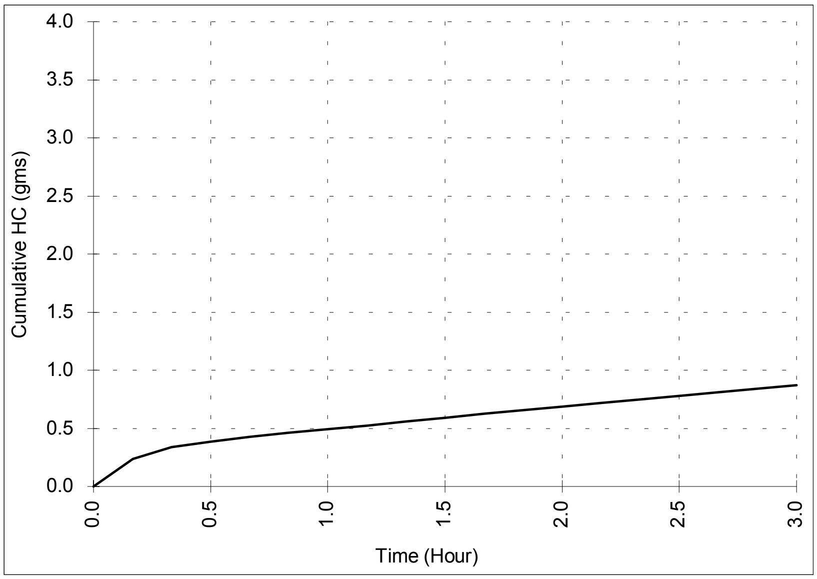
Test	Fuel	Grams
Diurnal	Summer	2.30

Appendix II
Continuous Results

Equipment: MOW06
1973 Builders Best F111C; 4 stroke

Sequence: HS/Diurnal

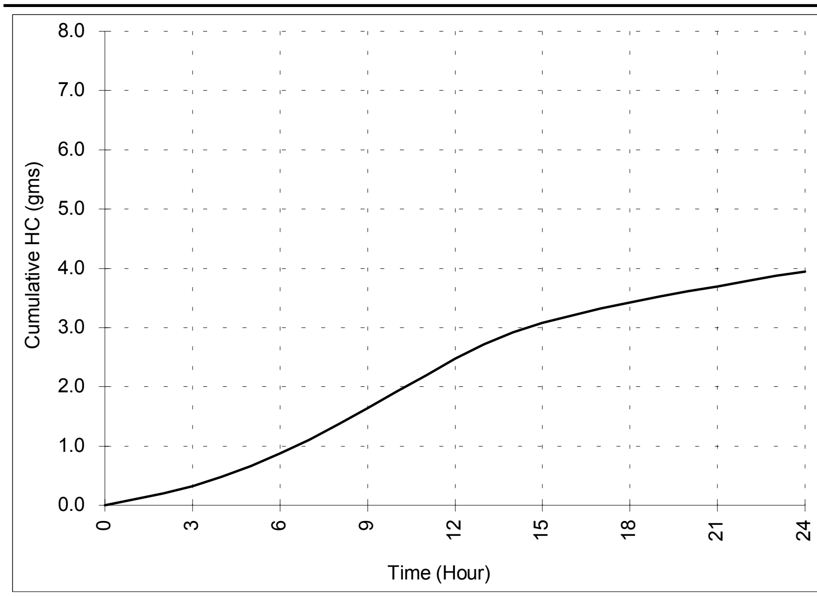
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.87

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

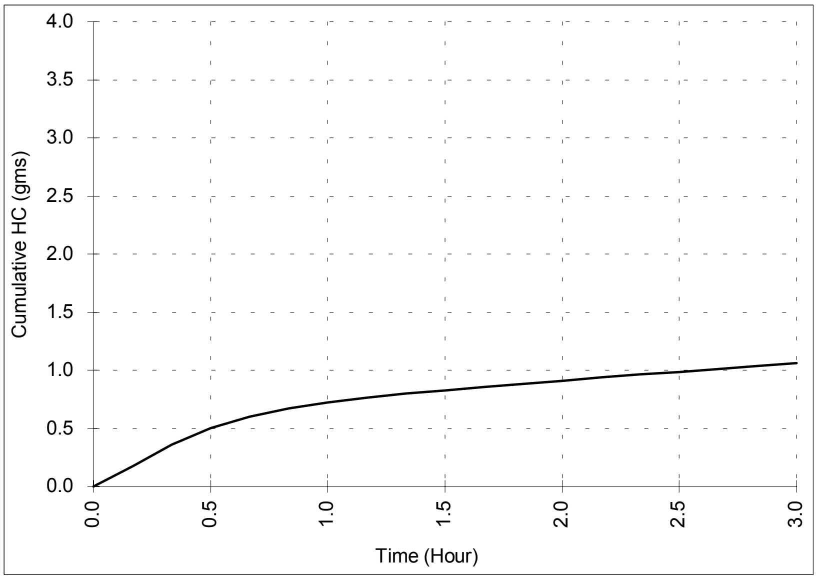
Test	Fuel	Grams
Diurnal	Summer	3.94

Appendix II
Continuous Results

Equipment: MOW07
1994 Sears 917.38359; 4 stroke

Sequence: HS/Diurnal

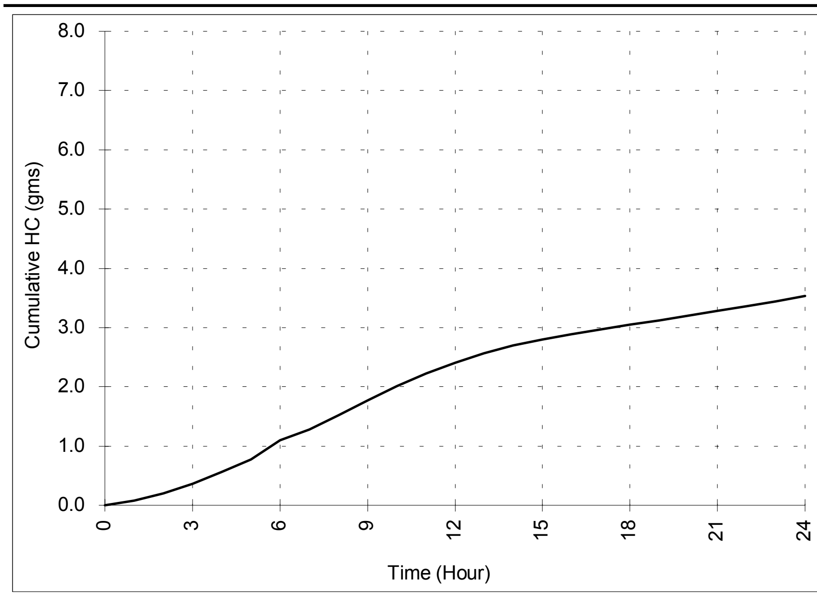
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.06

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

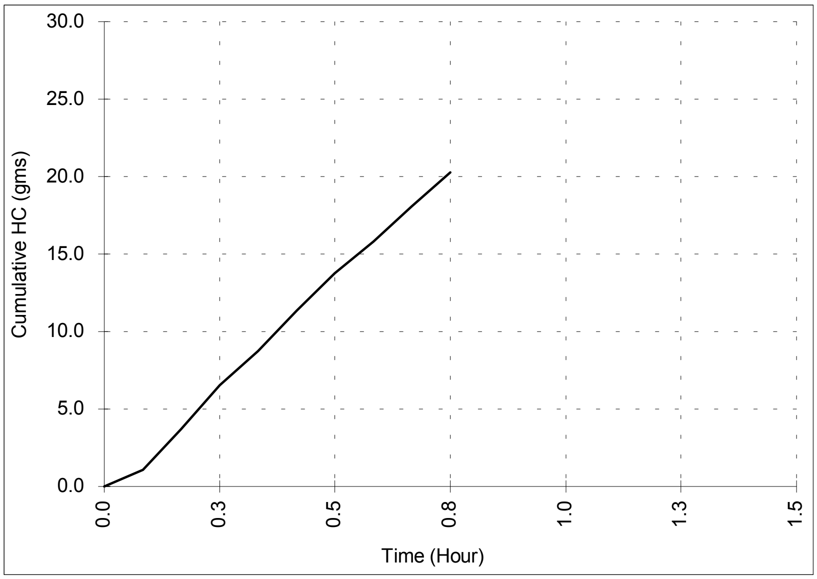
Test	Fuel	Grams
Diurnal	Summer	3.54

Appendix II
Continuous Results

Equipment: MOW07
1994 Sears 917.38359; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

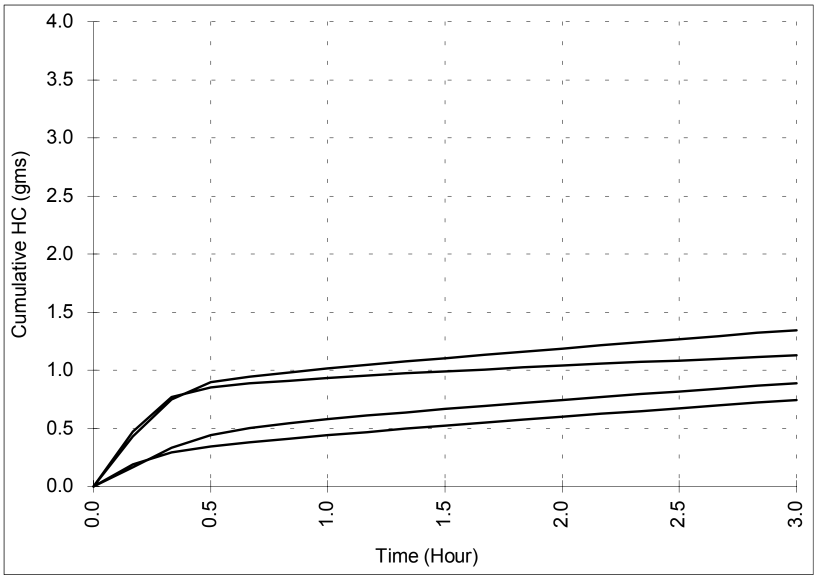
Test	Fuel	Grams
Run Loss	Summer	20.27

Appendix II
Continuous Results

Equipment: MOW08
2000 Honda Harmony II HRT216; 4 stroke

Sequence: HS/Diurnal

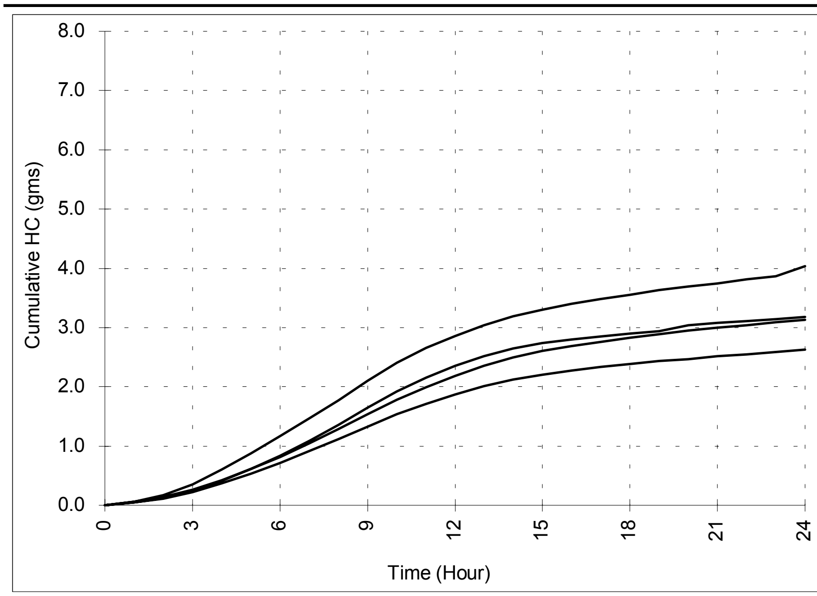
HOT SOAK EVAPORATIVE EMISSIONS TEST



Temperature/RVP
Sensitivity Tests

Test	Fuel	Grams
65-105	Summer	0.89
65-105	Summer	0.75
65-105	Winter	1.13
50-90	Winter	1.34

DIURNAL EVAPORATIVE EMISSIONS TEST



Temperature/RVP
Sensitivity Tests

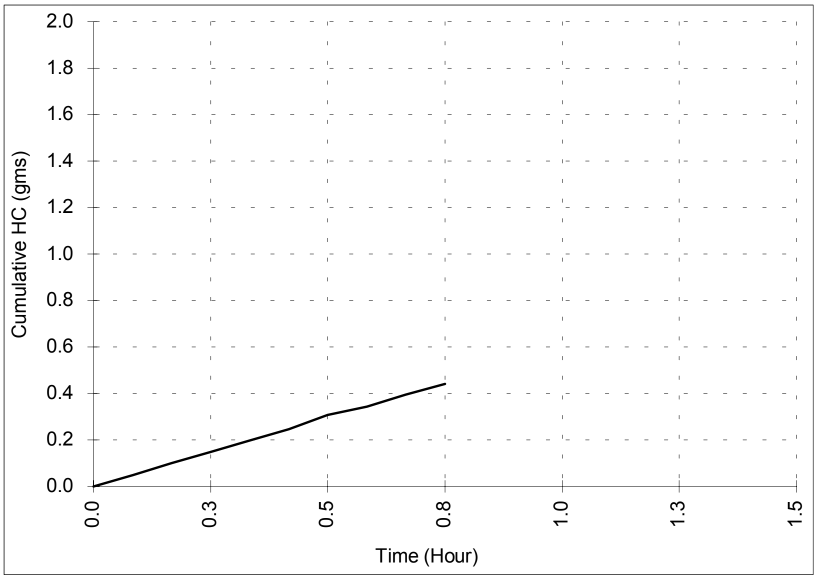
Test	Fuel	Grams
65-105	Summer	3.18
65-105	Summer	3.13
65-105	Winter	4.03
50-90	Winter	2.63

Appendix II
Continuous Results

Equipment: MOW08
2000 Honda Harmony II HRT216; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

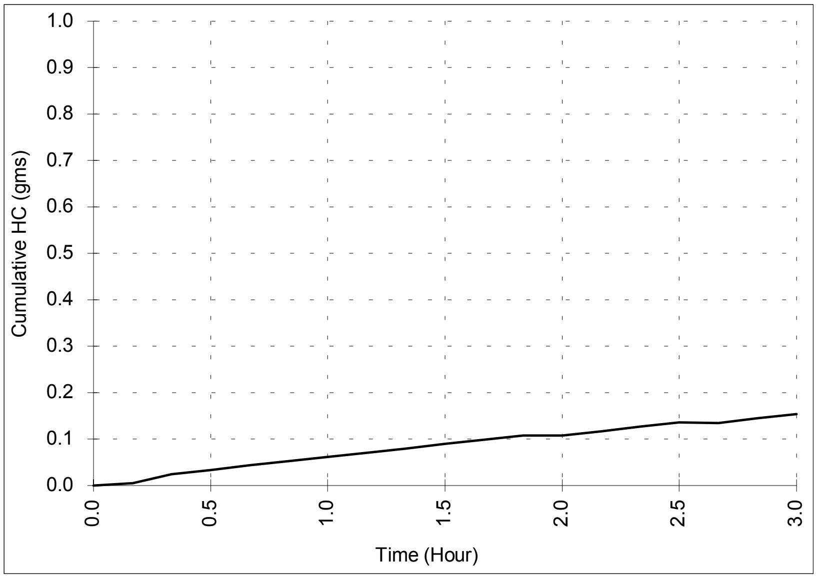
Test	Fuel	Grams
Run Loss	Summer	0.44

Appendix II
Continuous Results

Equipment: TRIM01
Ryobi 970R; 4 stroke

Sequence: HS/Diurnal

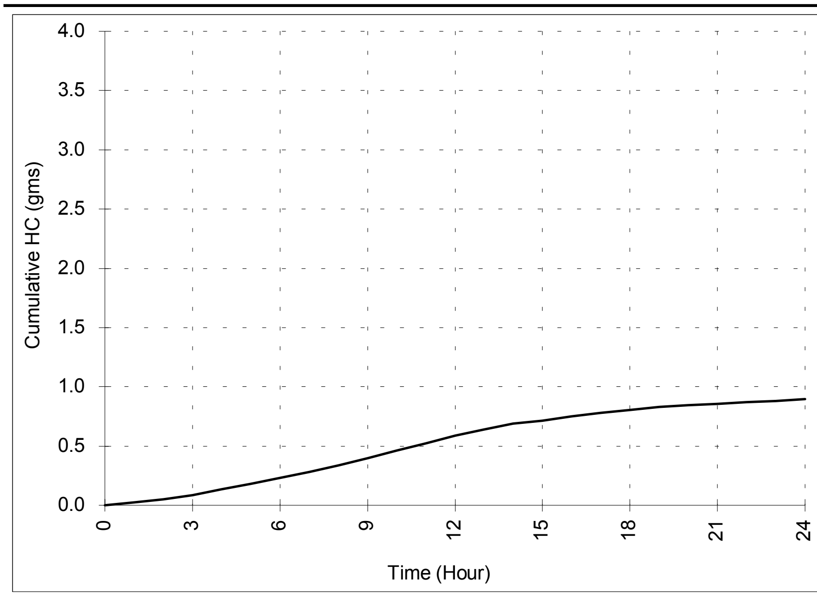
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.15

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

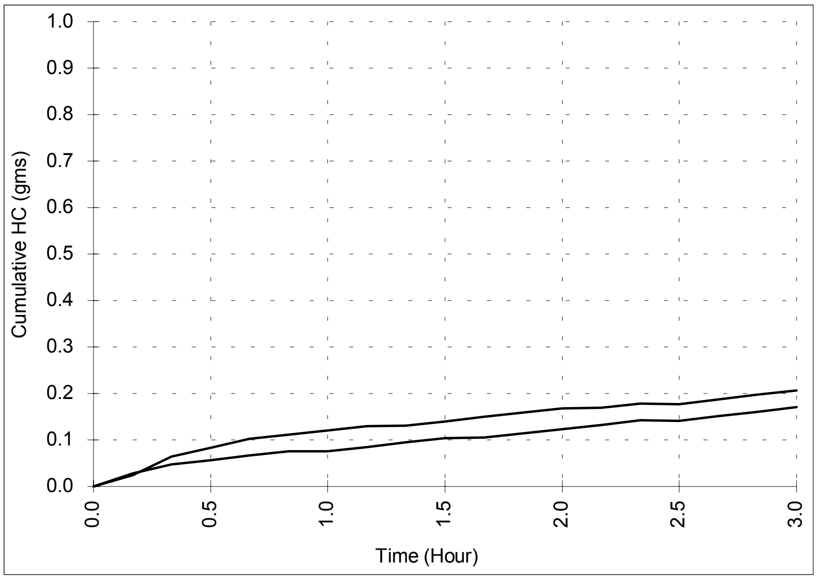
Test	Fuel	Grams
Diurnal	Summer	0.89

Appendix II
Continuous Results

Equipment: TRIM02
1999 Stihl FS80; 2 stroke

Sequence: HS/Diurnal

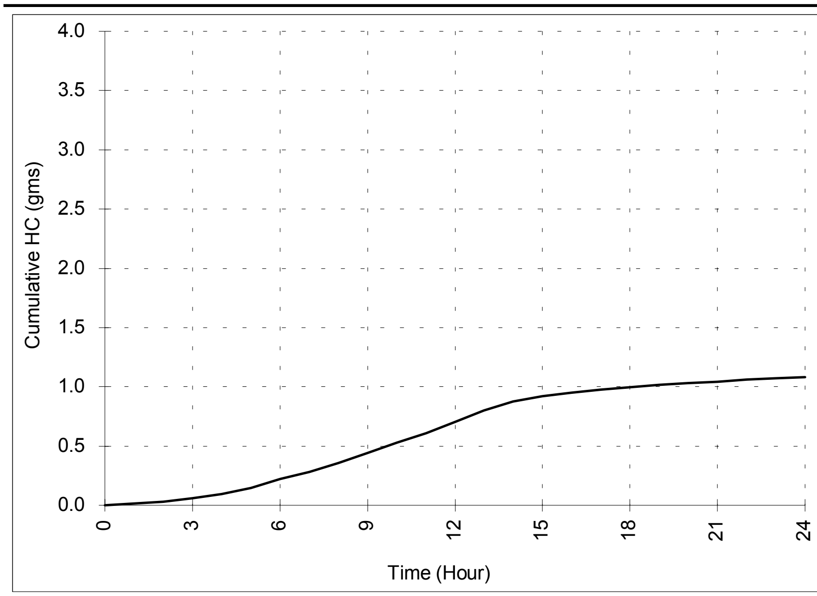
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.21
HS	Summer	0.17

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

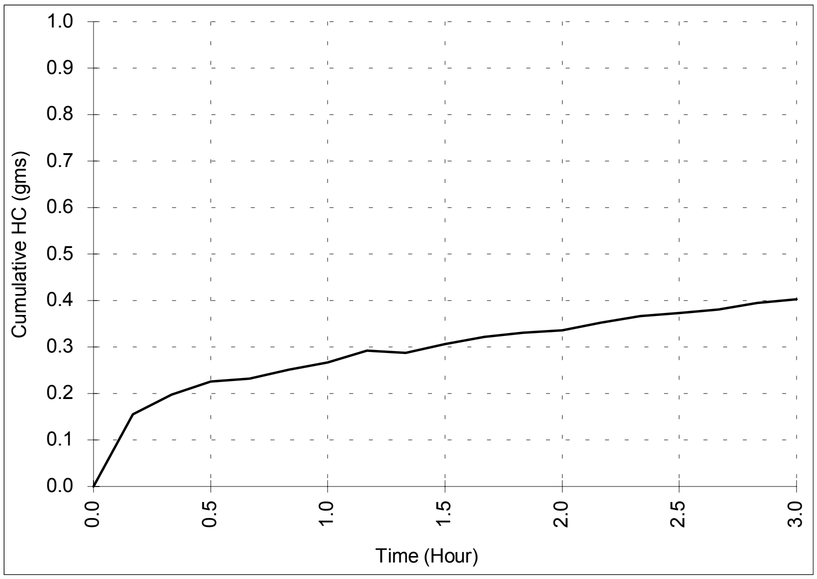
Test	Fuel	Grams
Diurnal	Summer	------
Diurnal	Summer	1.08

Appendix II
Continuous Results

Equipment: TRIM03
McCulloch 40003102; 2 stroke

Sequence: HS/Diurnal

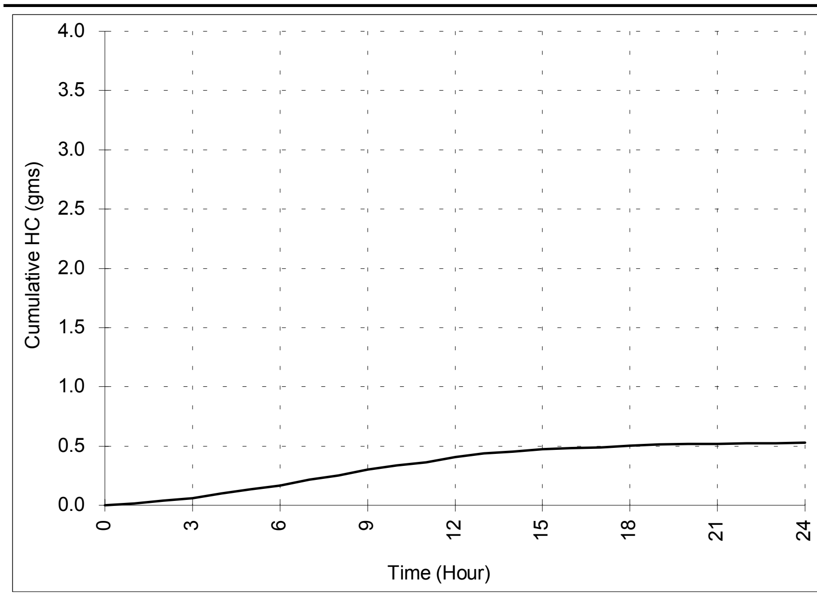
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.40

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

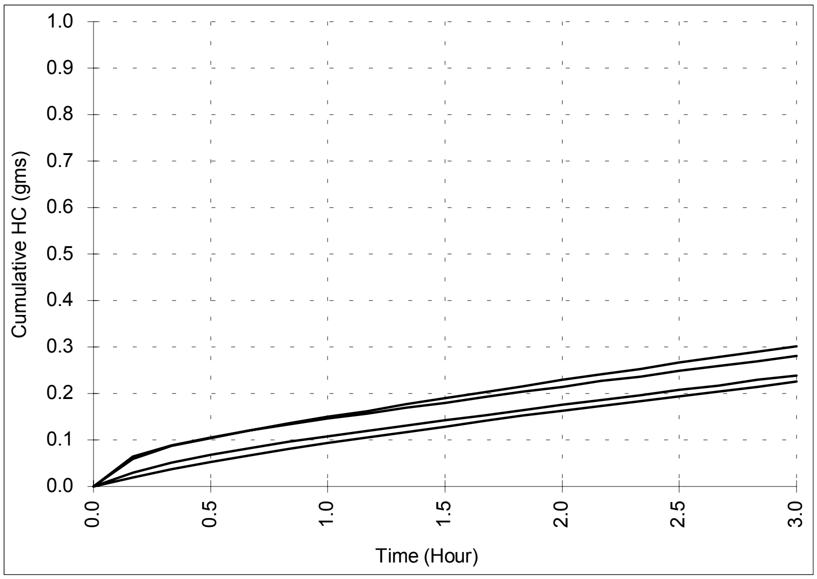
Test	Fuel	Grams
Diurnal	Summer	0.53

Appendix II
Continuous Results

Equipment: TRIM04
2000 Makita USA Inc. EM4251; 4 stroke

Sequence: HS/Diurnal

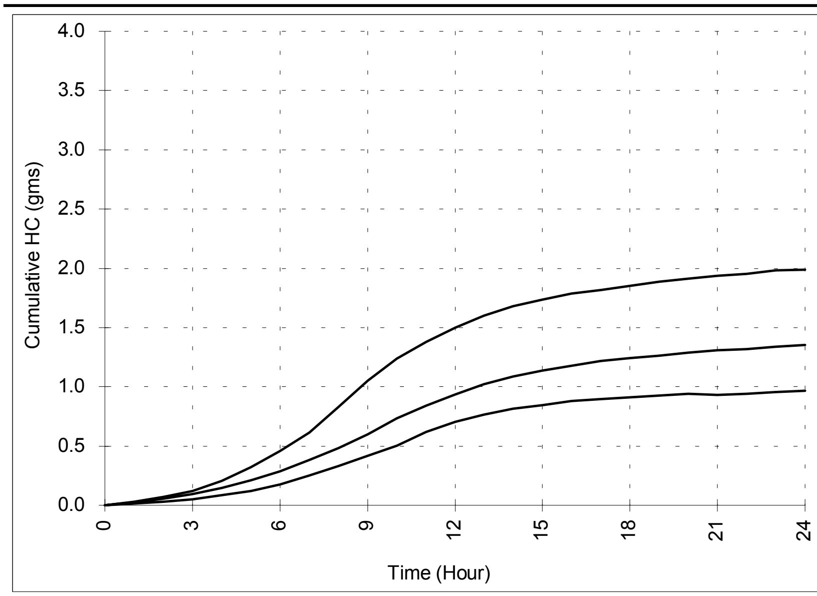
HOT SOAK EVAPORATIVE EMISSIONS TEST



Temperature/RVP
Sensitivity Tests

Test	Fuel	Grams
65-105	Summer	0.23
65-105	Winter	0.24
50-90	Winter	0.30
50-90	Winter	0.28

DIURNAL EVAPORATIVE EMISSIONS TEST



Temperature/RVP
Sensitivity Tests

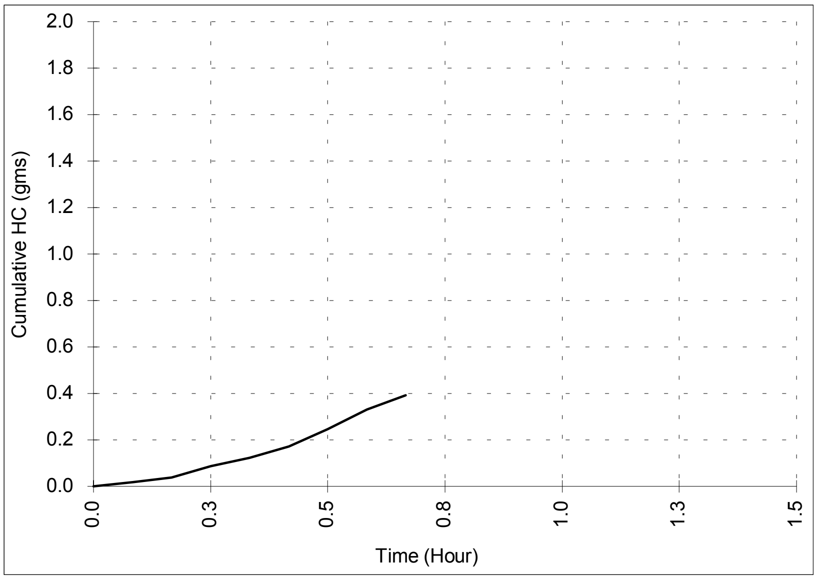
Test	Fuel	Grams
65-105	Summer	1.35
65-105	Winter	1.99
50-90	Winter	------
50-90	Winter	0.97

Appendix II
Continuous Results

Equipment: TRIM04
2000 Makita USA Inc. EM4251; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

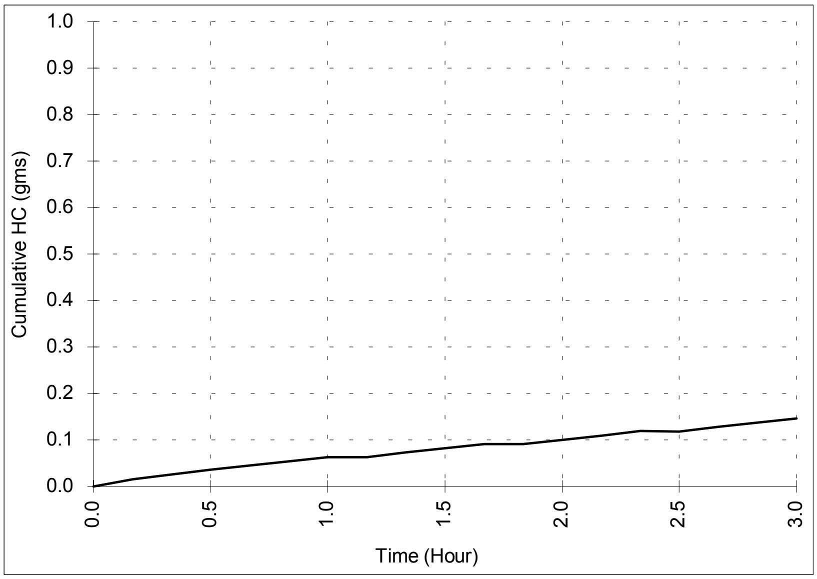
Test	Fuel	Grams
Run Loss	Summer	0.39

Appendix II
Continuous Results

Equipment: HEDGE_TRIM01
Echo HC-1500; 2 stroke

Sequence: HS/Diurnal

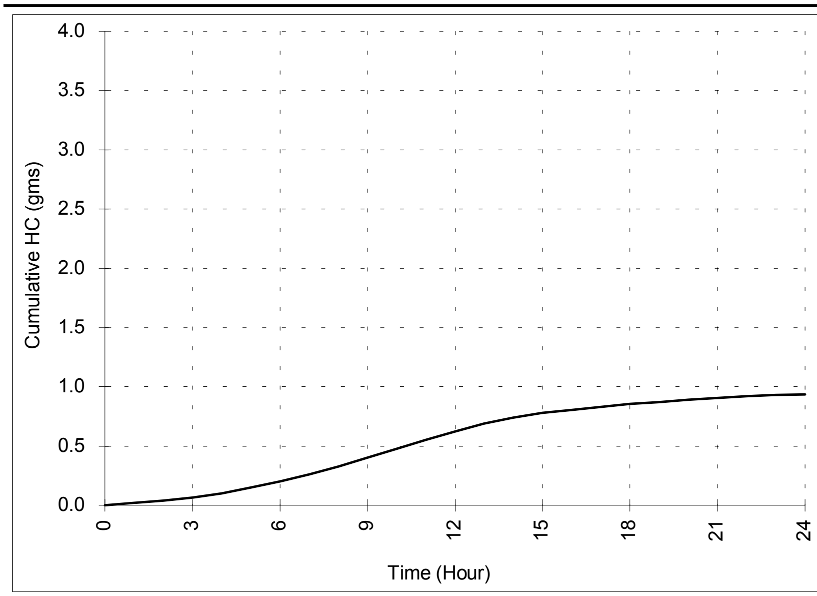
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.15

DIURNAL EVAPORATIVE EMISSIONS TEST



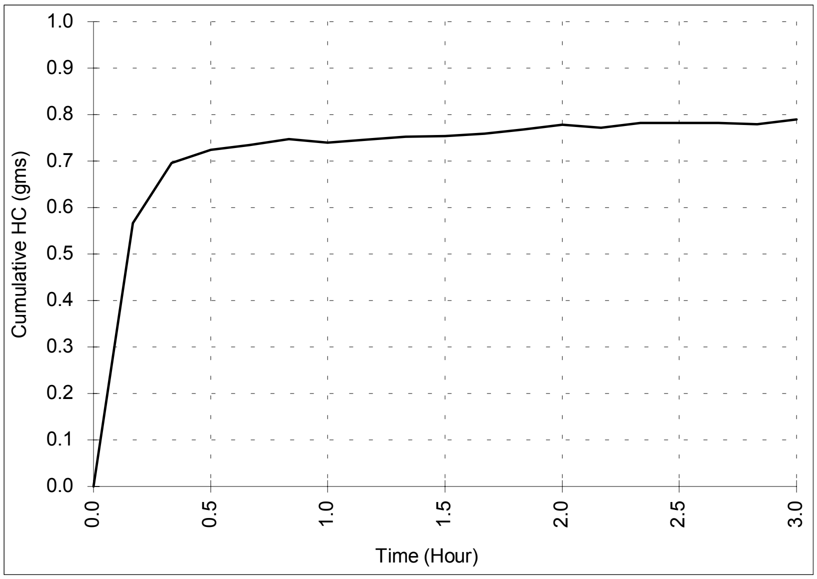
Diurnal Tests

Test	Fuel	Grams
Diurnal	Summer	0.94

Equipment: SAW02
1989 McCulloch 60001620; 2 stroke

Sequence: HS/Diurnal

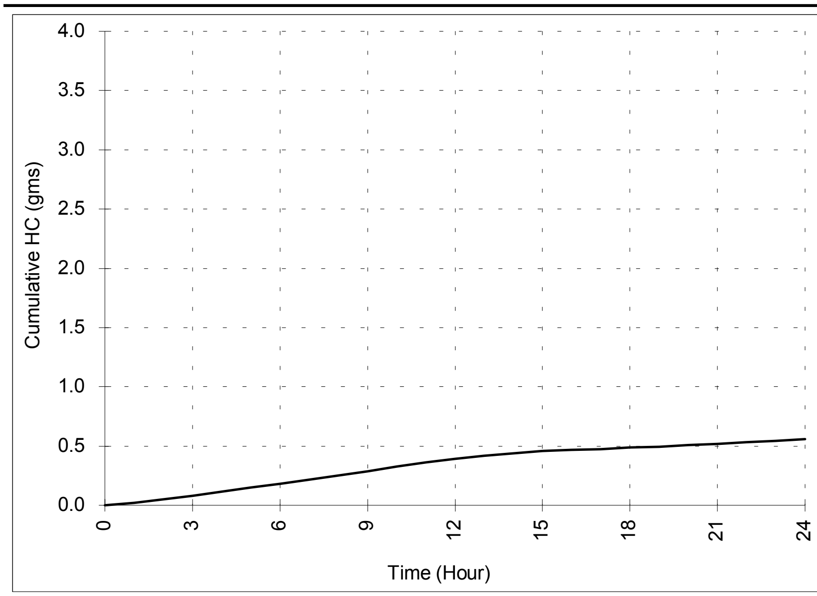
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.79

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

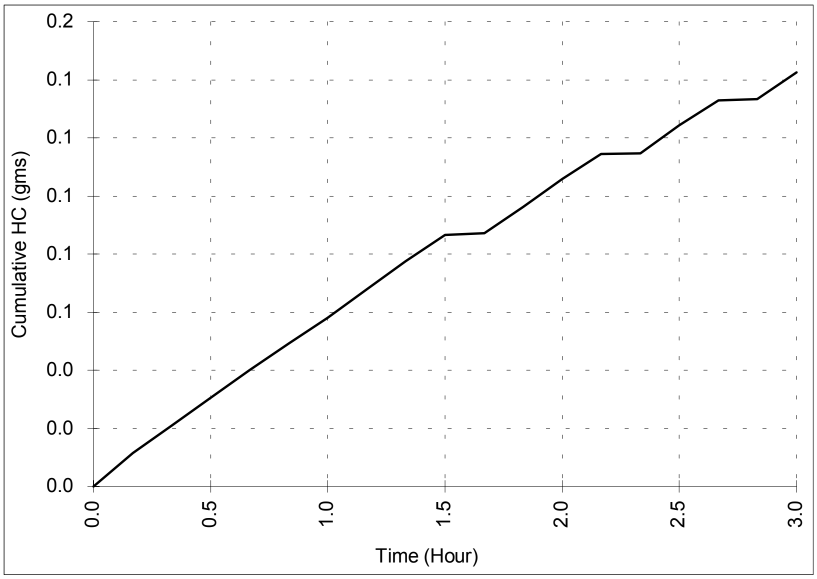
Test	Fuel	Grams
Diurnal	Summer	0.56

Appendix II
Continuous Results

Equipment: LEAF01
2000 Echo PB-231LN; 2 stroke

Sequence: HS/Diurnal

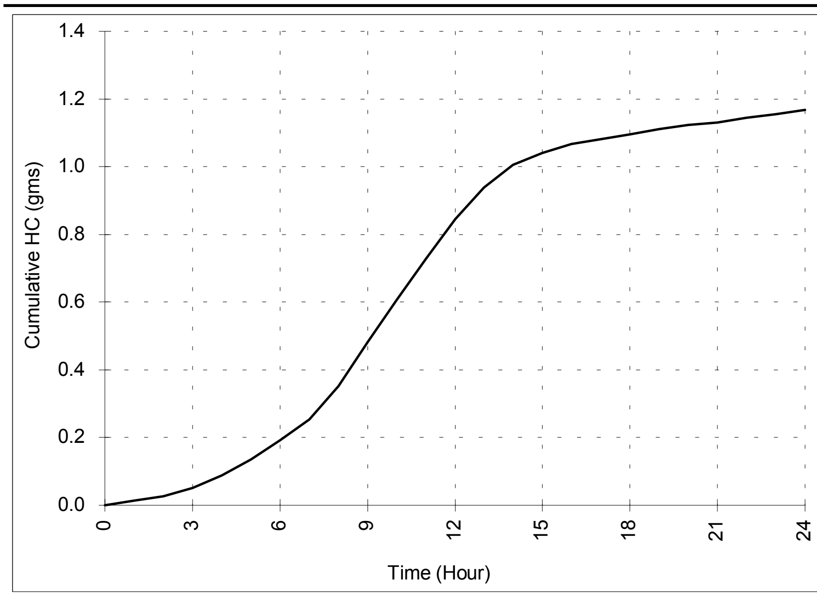
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.14

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

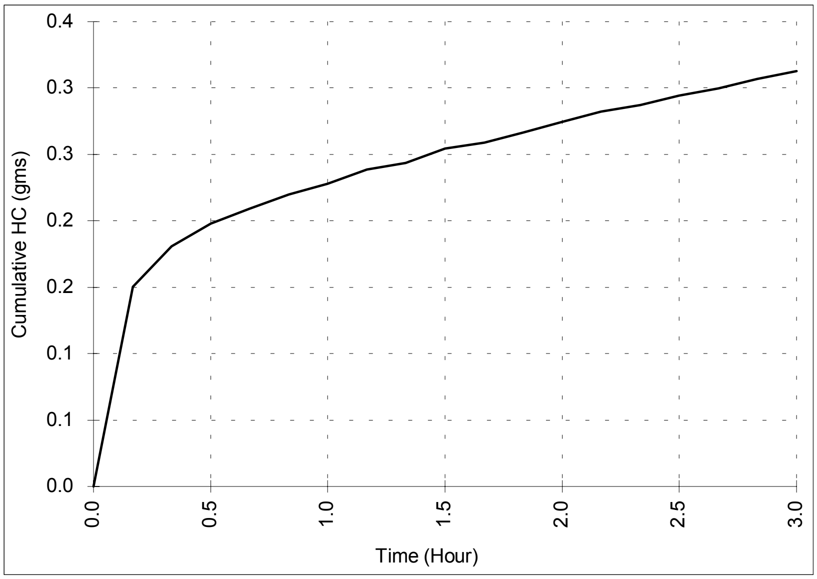
Test	Fuel	Grams
Diurnal	Summer	1.17

Appendix II
Continuous Results

Equipment: LEAF02
1999 John Deere UT08087; 2 stroke

Sequence: HS/Diurnal

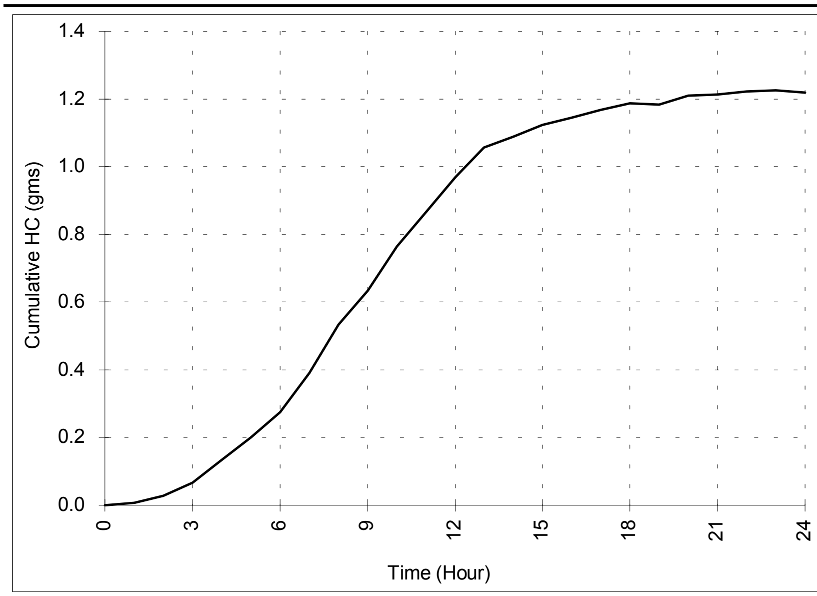
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.31

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

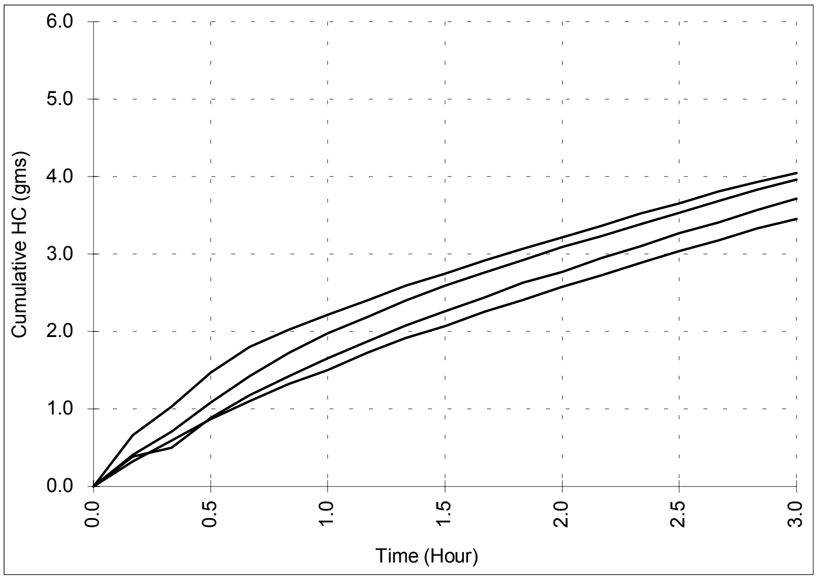
Test	Fuel	Grams
Diurnal	Summer	1.22

Appendix II
Continuous Results

Equipment: DB01
1982 Honda XR200R; 4 stroke

Sequence: HS/Diurnal

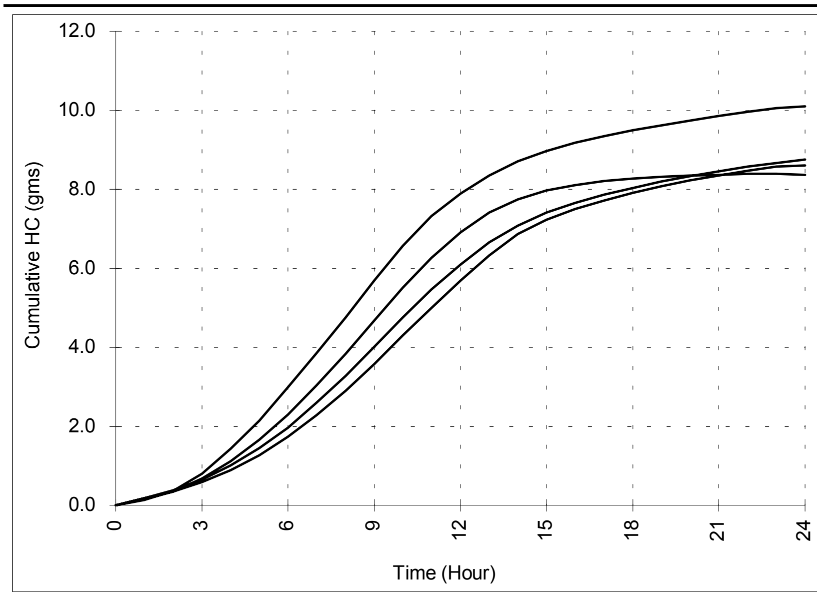
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

Level	Fuel	Grams
100%	Summer	3.71
75%	Summer	3.45
50%	Summer	3.96
25%	Summer	4.05

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

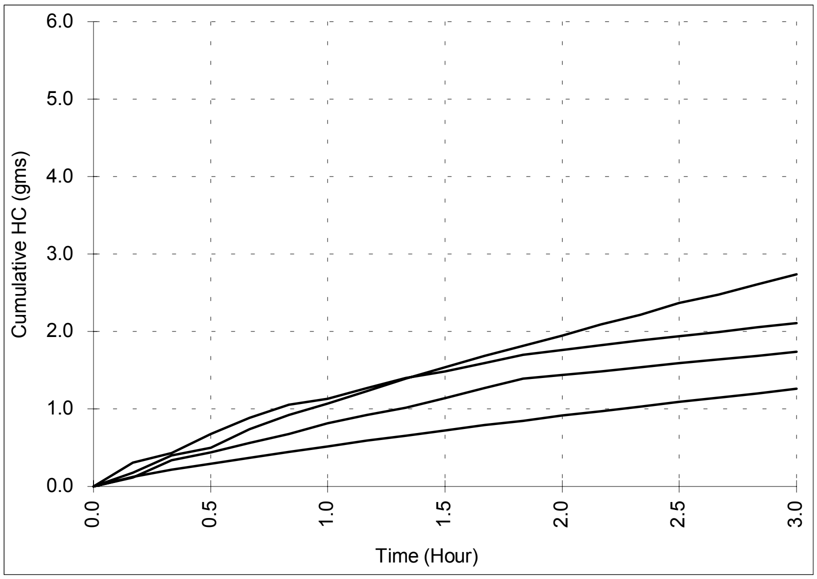
Level	Fuel	Grams
100%	Summer	8.60
75%	Summer	8.75
50%	Summer	8.36
25%	Summer	10.10

Appendix II
Continuous Results

Equipment: DB01
1982 Honda XR200R; 4 stroke

Sequence: HS/Diurnal

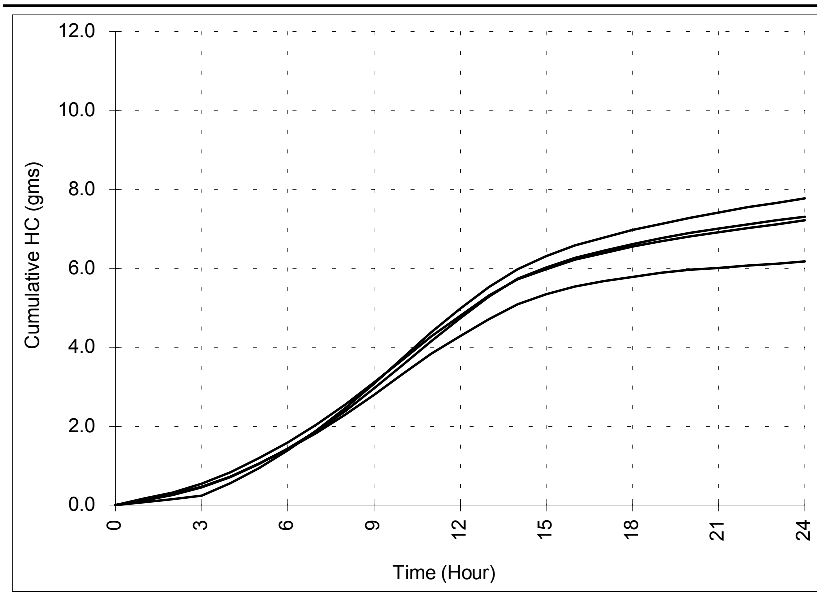
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tests

Week	Fuel	Grams
Initial	Summer	1.26
Week 1	Summer	2.74
Week 2	Summer	1.74
Week 3	Summer	2.10

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tests

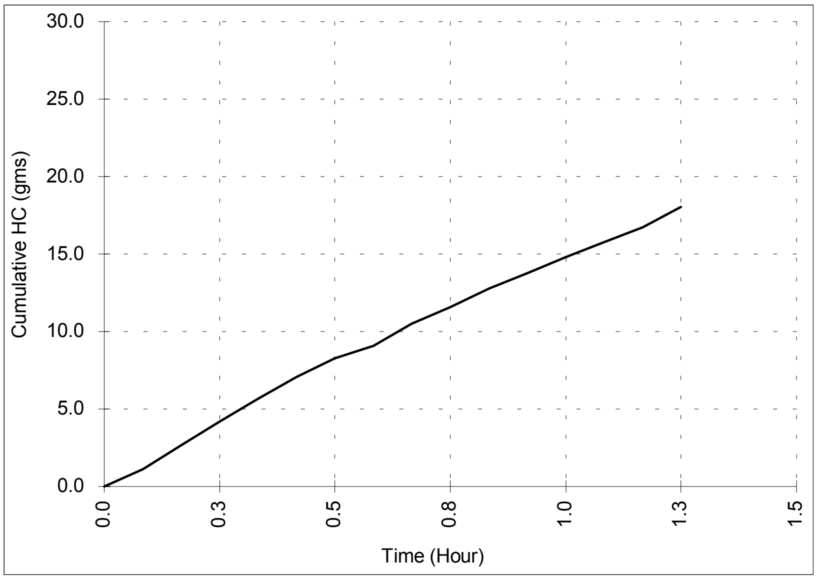
Week	Fuel	Grams
Initial		7.31
Week 1		7.21
Week 2		6.17
Week 3		7.78

Appendix II
Continuous Results

Equipment: DB01
1982 Honda XR200R; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

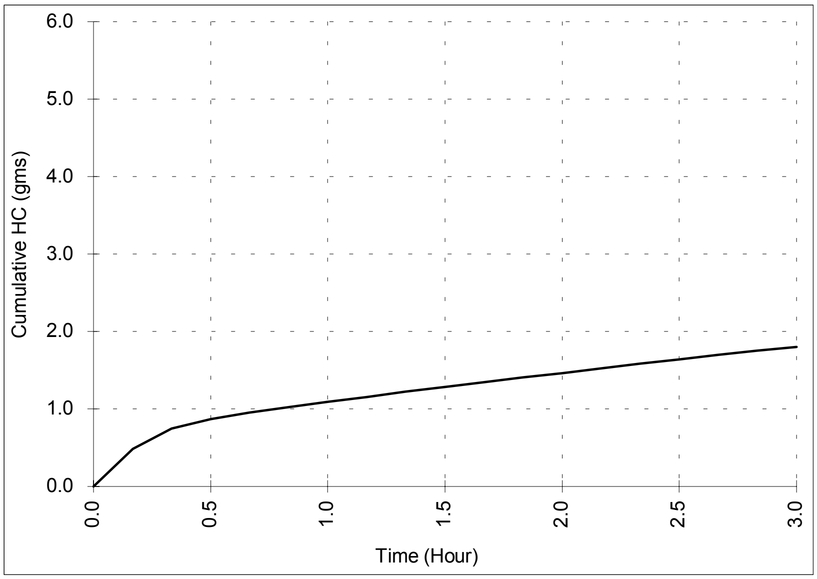
Test	Fuel	Grams
Run Loss	Summer	18.02

Appendix II
Continuous Results

Equipment: DB02
2000 Kawasaki KX250; 2 stroke

Sequence: HS/Diurnal

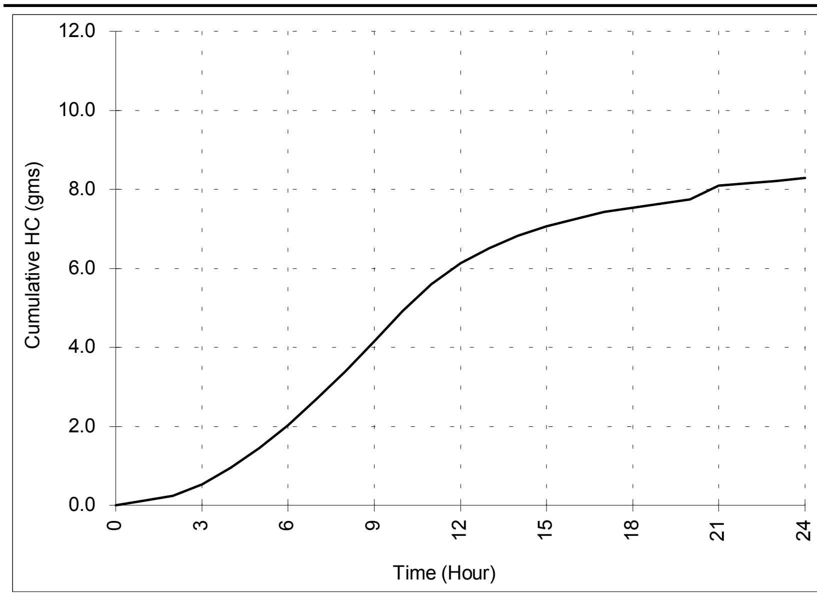
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.80

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

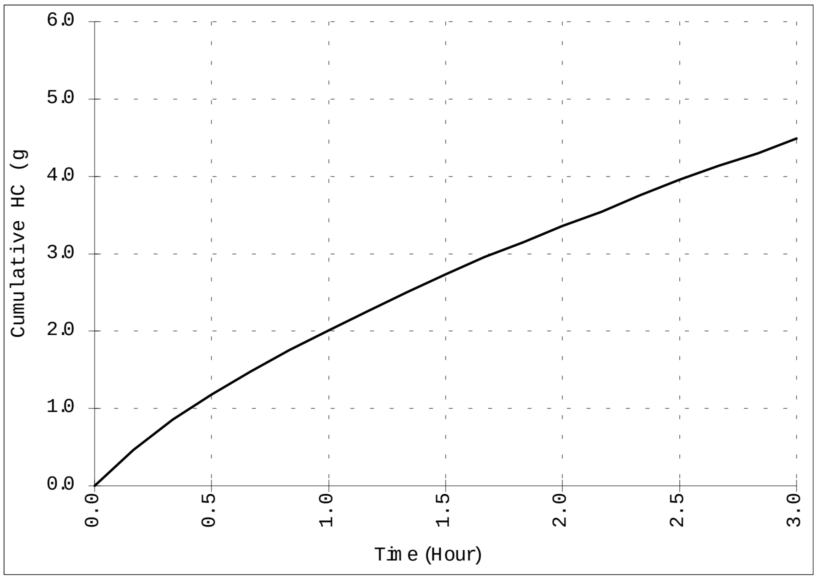
Test	Fuel	Grams
Diurnal	Summer	8.29

Appendix II
Continuous Results

Equipment: DB03
1984 Suzuki RM125; 2 stroke

Sequence: HS/Diurnal

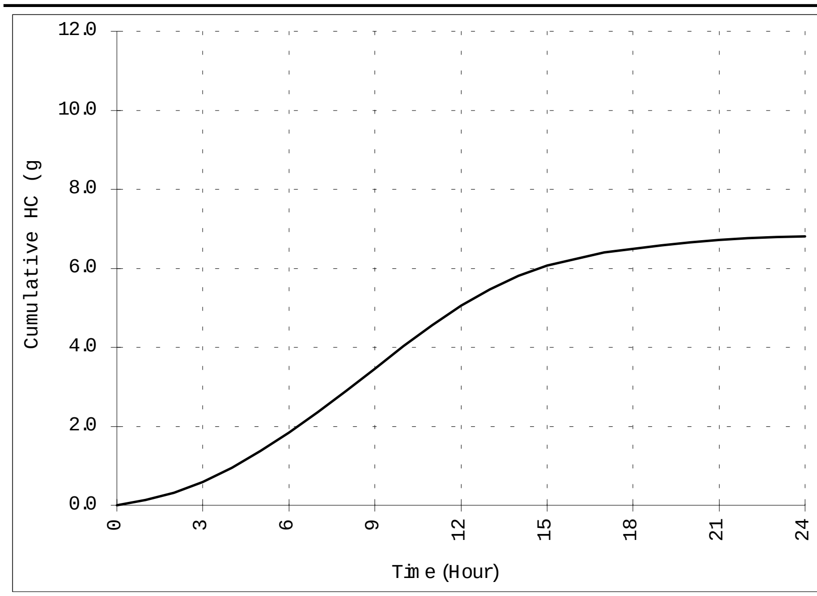
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	4.49

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

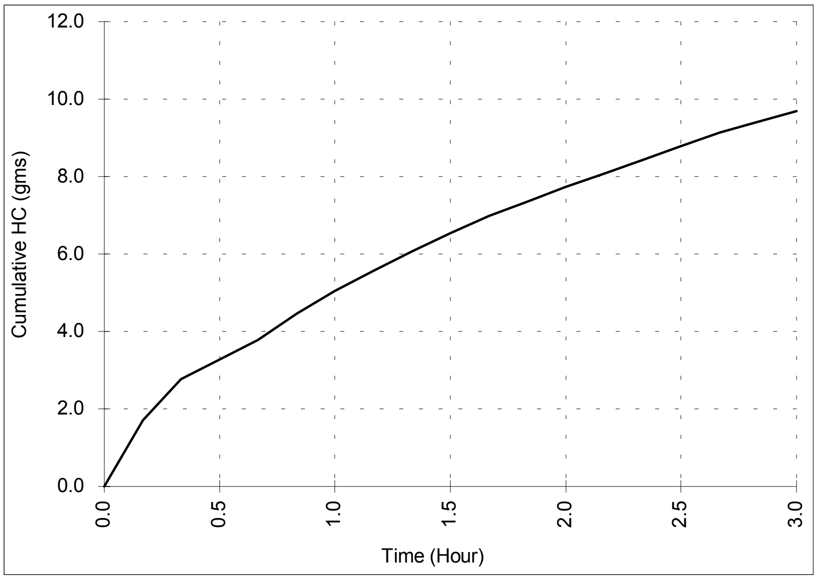
Test	Fuel	Grams
Diurnal	Summer	6.81

Appendix II
Continuous Results

Equipment: DB04
2001 Yamaha WR250F; 4 stroke

Sequence: HS/Diurnal

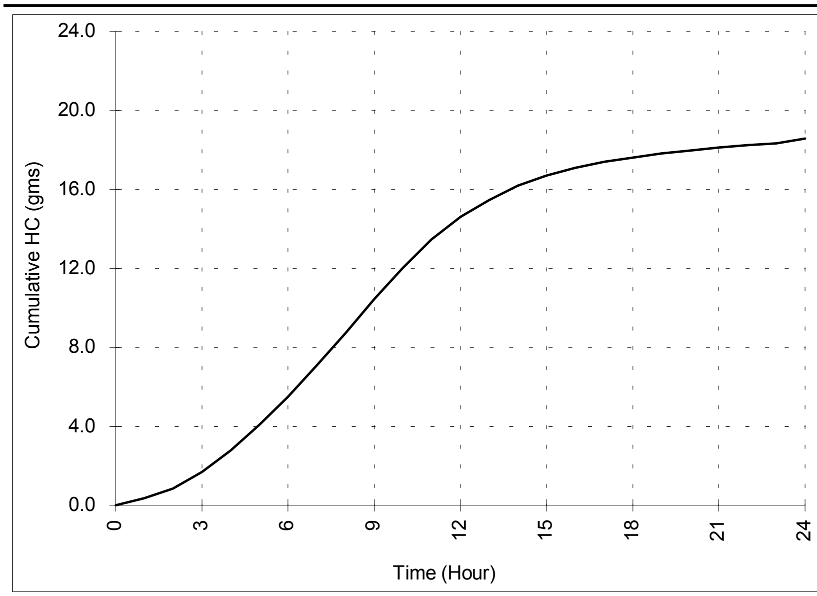
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	9.70

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

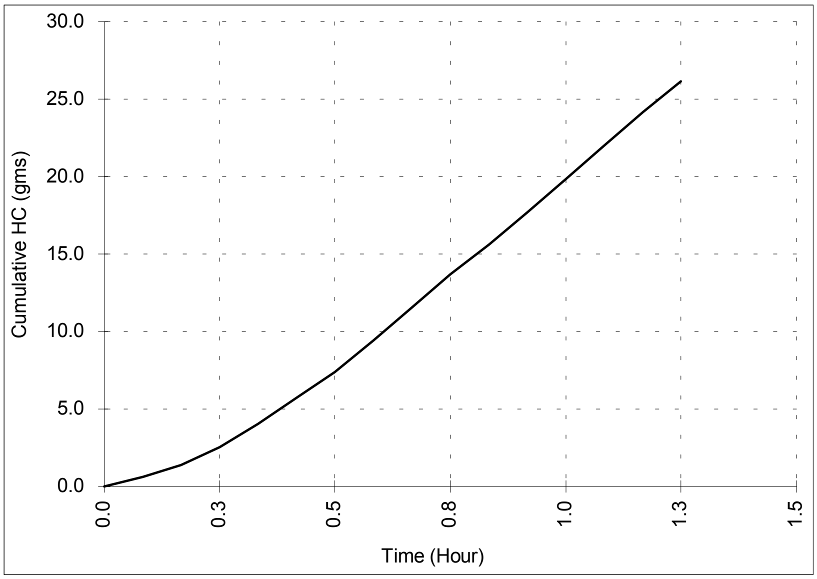
Test	Fuel	Grams
Diurnal	Summer	18.57

Appendix II
Continuous Results

Equipment: DB04
2001 Yamaha WR250F; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

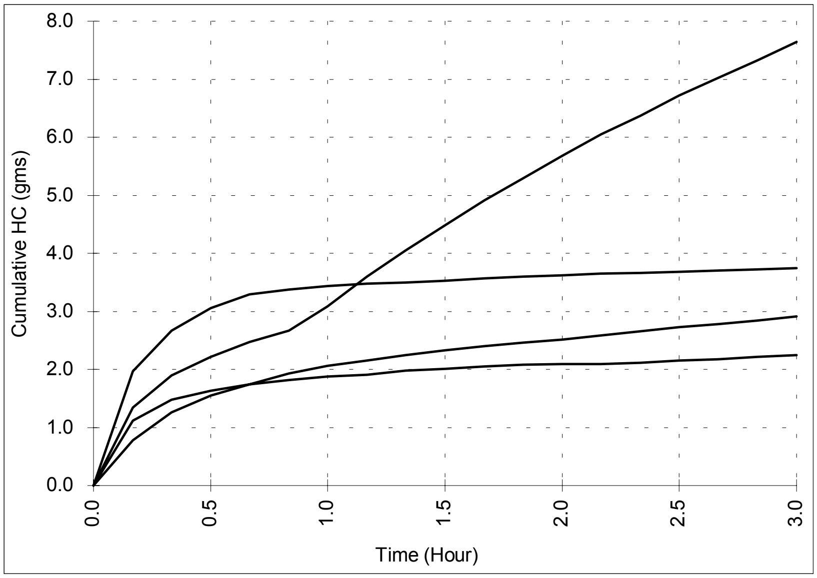
Test	Fuel	Grams
Run Loss	Summer	26.16

Appendix II
<u>Continuous Results</u>

Equipment: ATV01
1983 Honda Odyssey FL250; 2 stroke

Sequence: HS/Diurnal

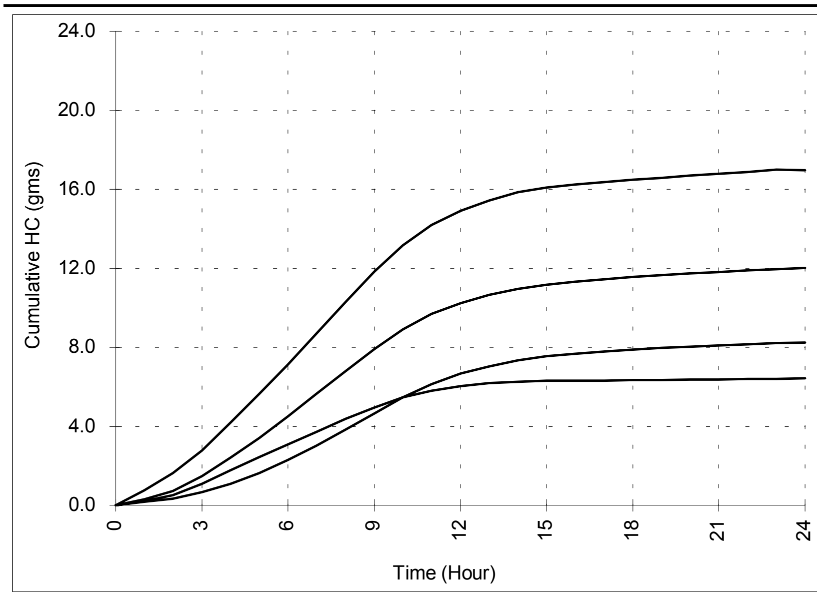
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

Level	Fuel	Grams
100%	Summer	7.64
75%	Summer	3.74
50%	Summer	2.24
25%	Summer	2.91

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

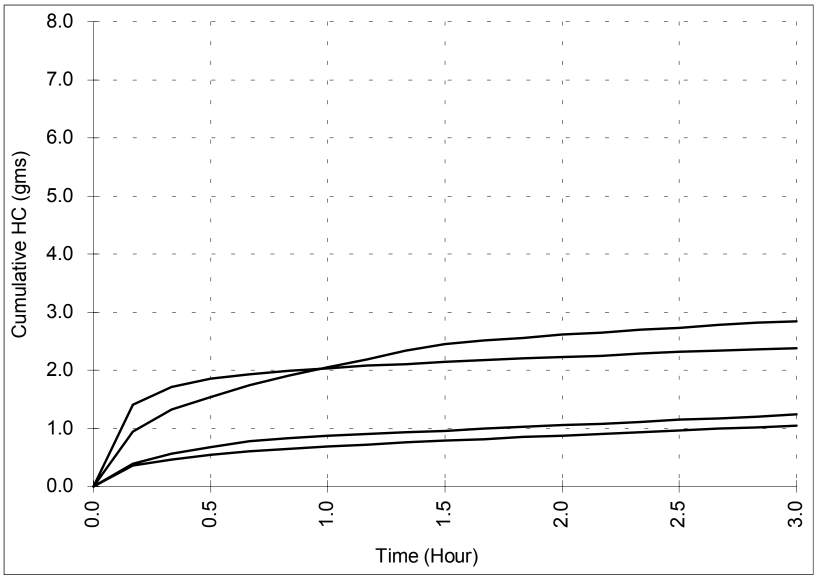
Level	Fuel	Grams
100%	Summer	8.25
75%	Summer	12.02
50%	Summer	16.98
25%	Summer	6.43

Appendix II
Continuous Results

Equipment: ATV01
1983 Honda Odyssey FL250; 2 stroke

Sequence: HS/Diurnal

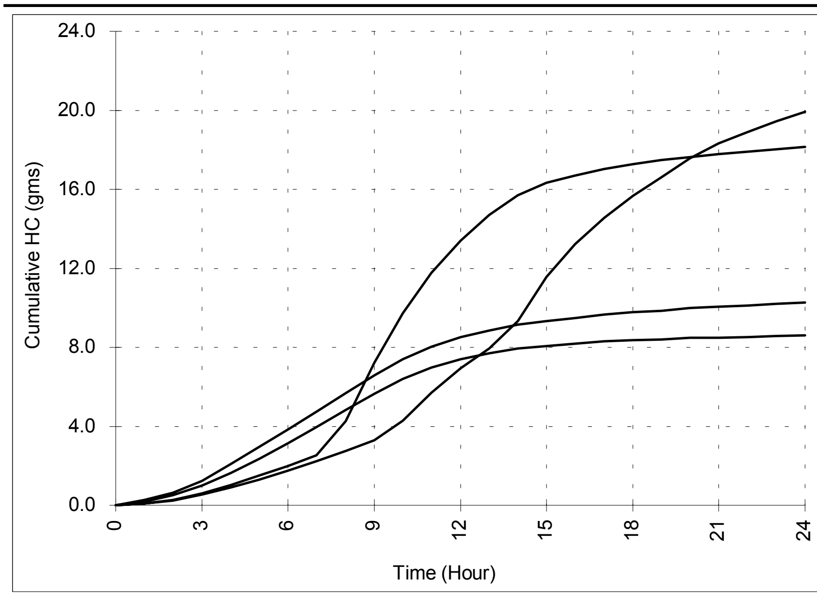
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tests

Week	Fuel	Grams
Initial	Summer	2.84
Week 1	Summer	2.38
Week 2	Summer	1.24
Week 3	Summer	1.04

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tests

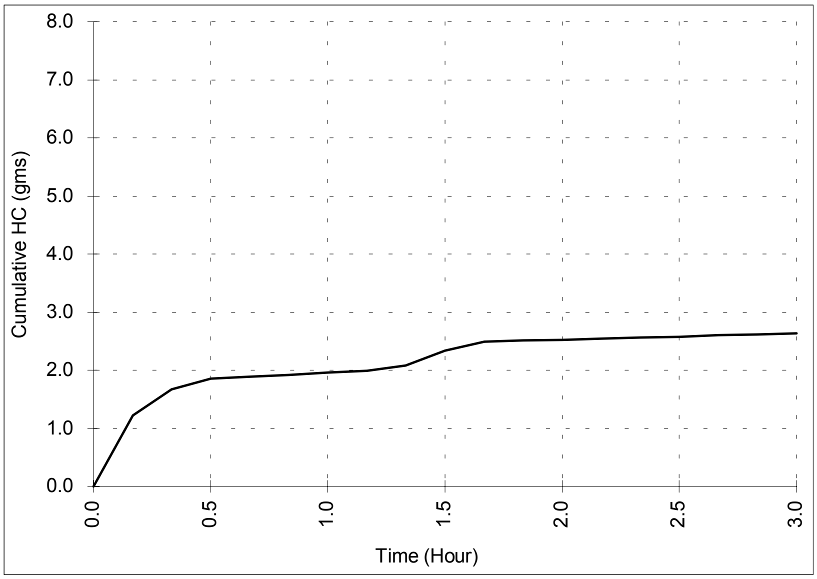
Week	Fuel	Grams
Initial	Summer	19.93
Week 1	Summer	18.13
Week 2	Summer	10.28
Week 3	Summer	8.59

Appendix II
<u>Continuous Results</u>

Equipment: ATV02
2001 Yamaha Banshee YFZ350N-W; 2 stroke

Sequence: HS/Diurnal

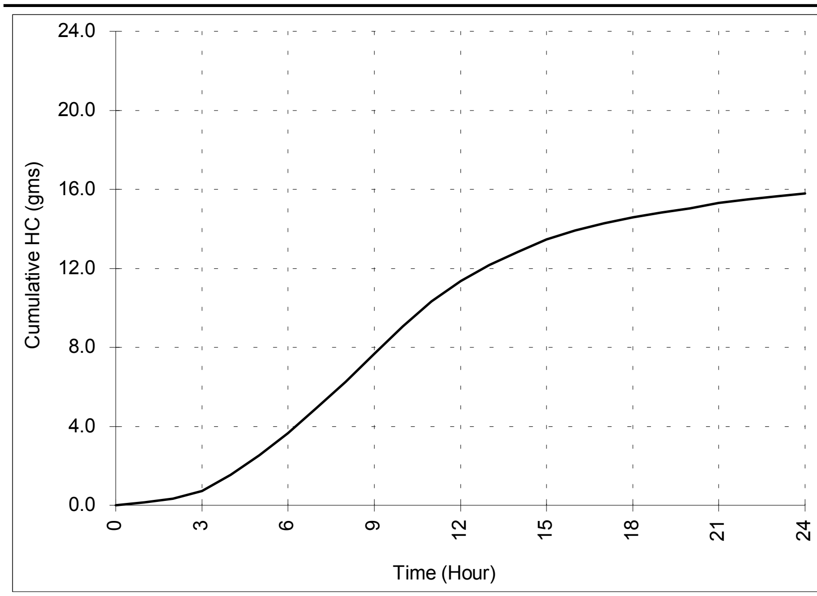
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	2.64

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

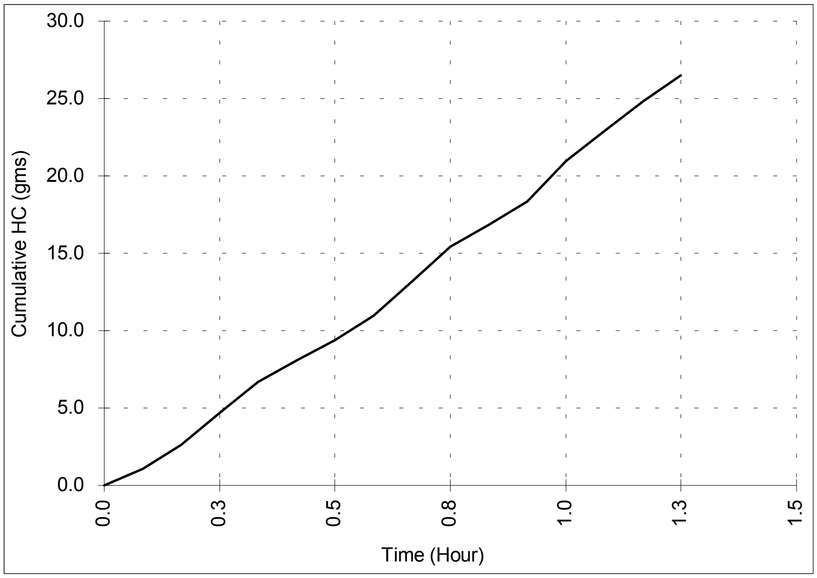
Test	Fuel	Grams
Diurnal	Summer	15.79

Appendix II
Continuous Results

Equipment: ATV02
2001 Yamaha Banshee YFZ350N-W; 2 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

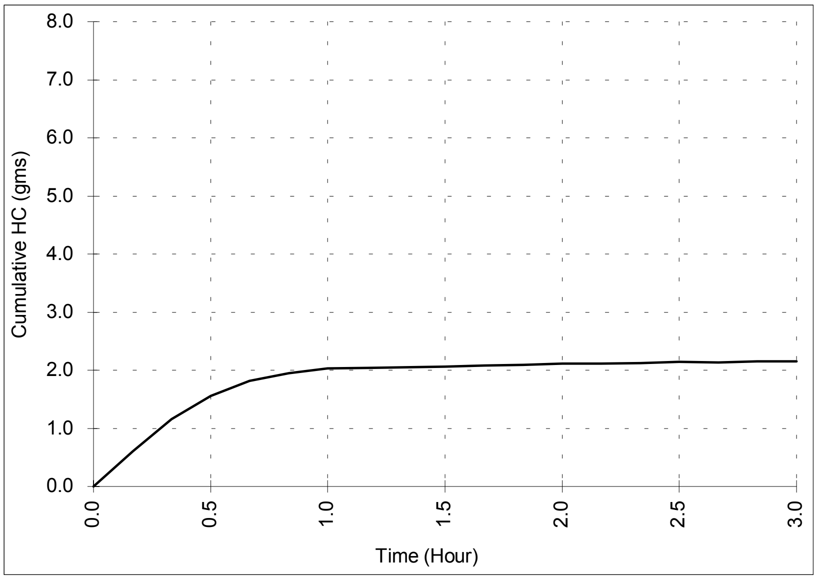
Test	Fuel	Grams
Run Loss	Summer	26.48

Appendix II
Continuous Results

Equipment: ATV03
2001 Suzuki Quadrunner LT-F250; 4 stroke

Sequence: HS/Diurnal

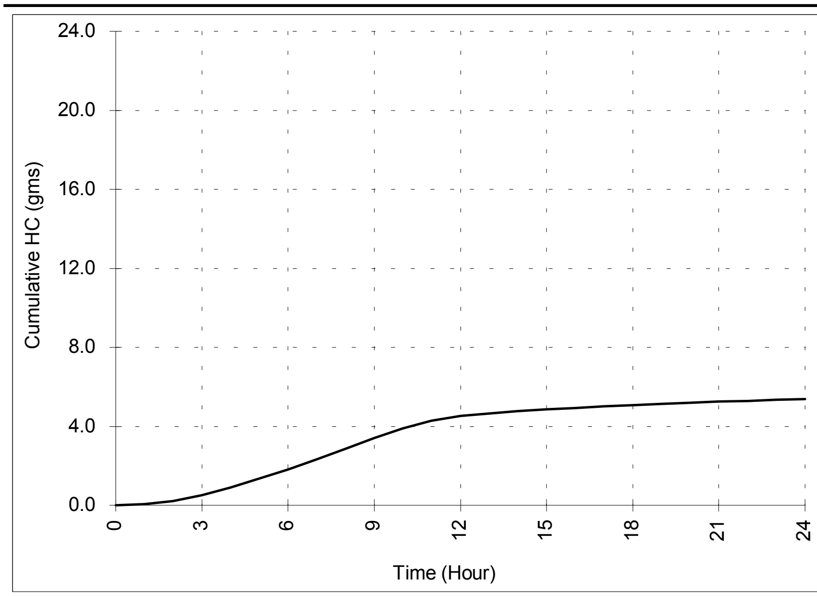
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	2.16

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

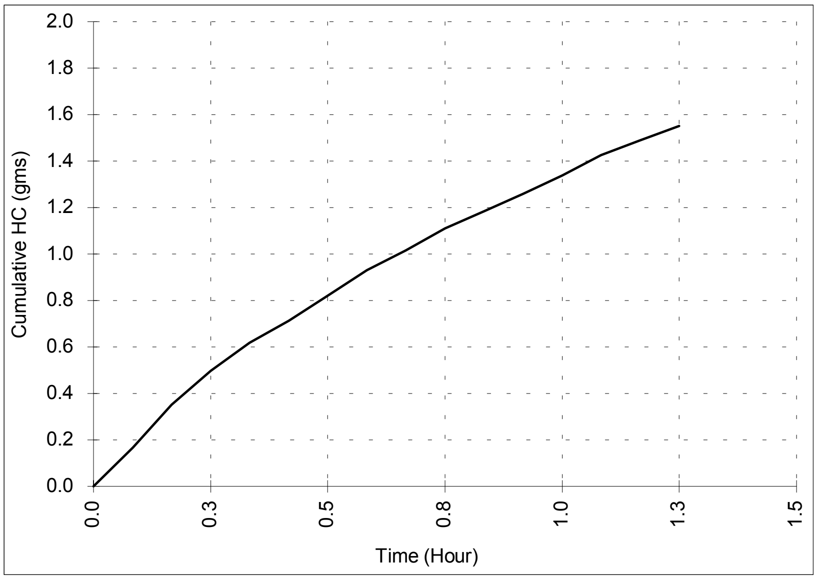
Test	Fuel	Grams
Diurnal	Summer	5.36

Appendix II
Continuous Results

Equipment: ATV03
2001 Suzuki Quadrunner LT-F250; 4 stroke

Sequence: Runloss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

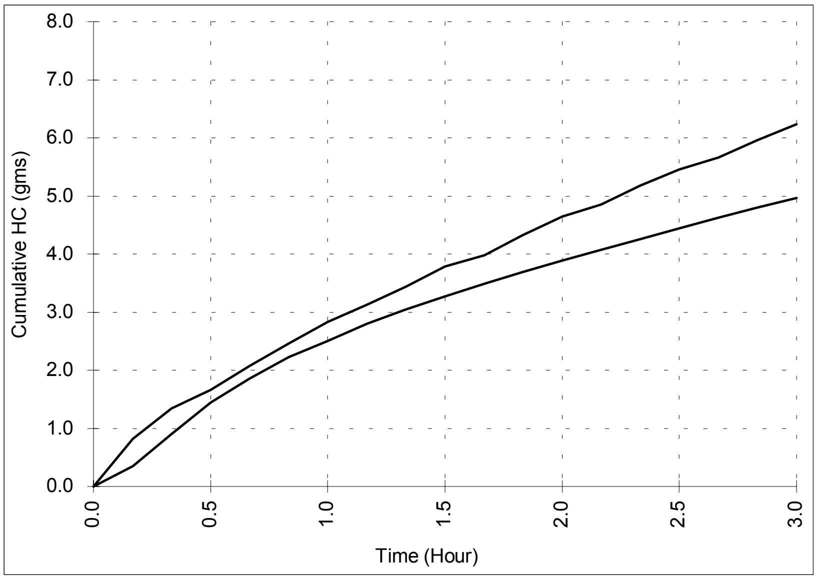
Test	Fuel	Grams
Run Loss	Summer	1.55

Appendix II
Continuous Results

Equipment: ATV04
1988 Kawasaki Bayou KLF220; 4 stroke

Sequence: HS/Diurnal

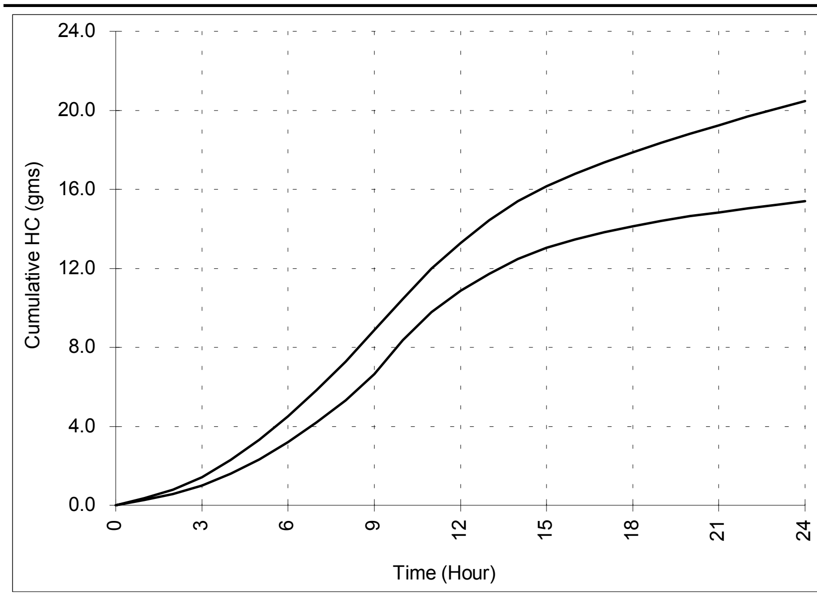
HOT SOAK EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

Test	Fuel	Grams
Before	Summer	6.24
After	Summer	4.96

DIURNAL EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

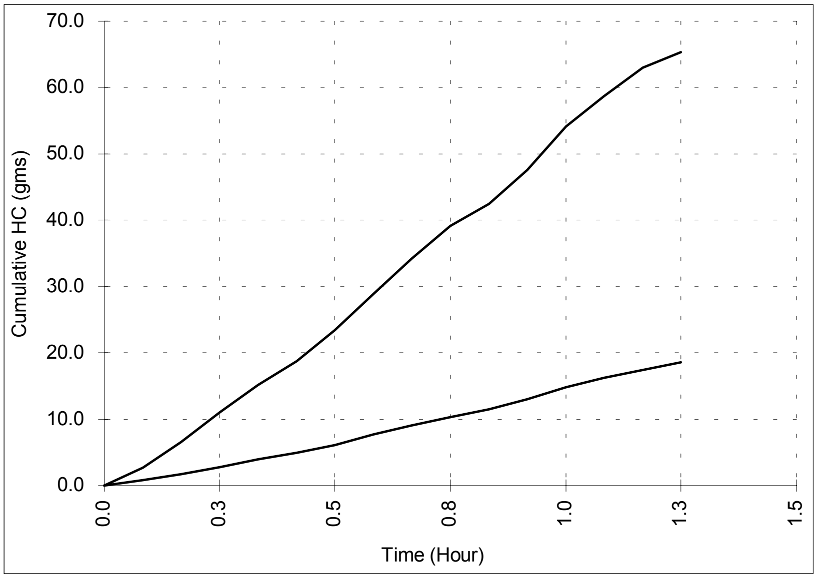
Test	Fuel	Grams
Before	Summer	20.48
After	Summer	15.40

Appendix II
Continuous Results

Equipment: ATV04
1988 Kawasaki Bayou KLF220; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

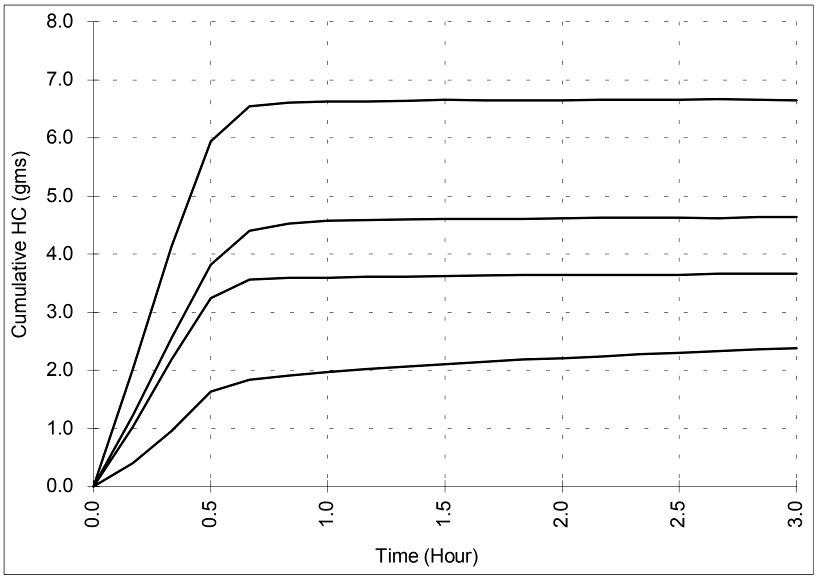
Test	Fuel	Grams
Before	Summer	65.36
After	Summer	18.54

Appendix II
Continuous Results

Equipment: GEN01
1995 Honda EX5500; 4 stroke

Sequence: HS/Diurnal

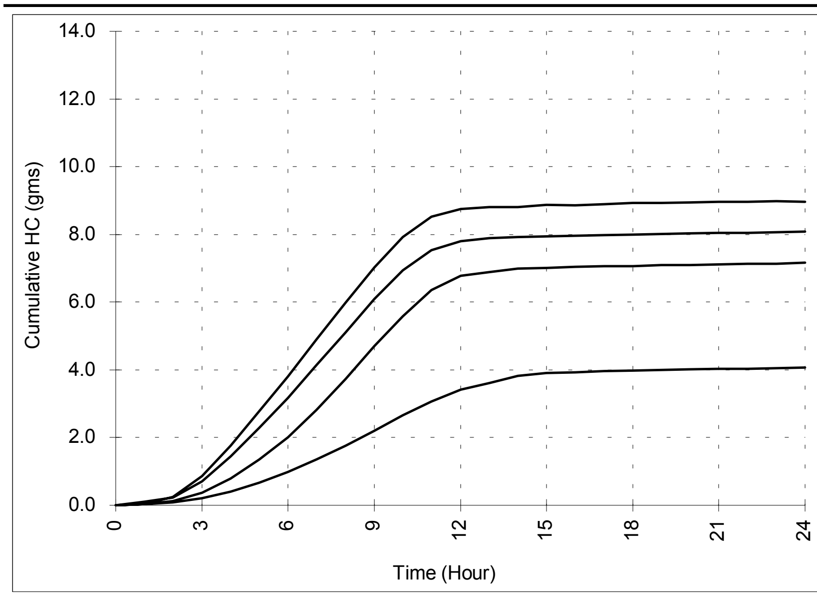
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

Level	Fuel	Grams
100%	Summer	2.38
75%	Summer	3.66
50%	Summer	4.64
25%	Summer	6.65

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

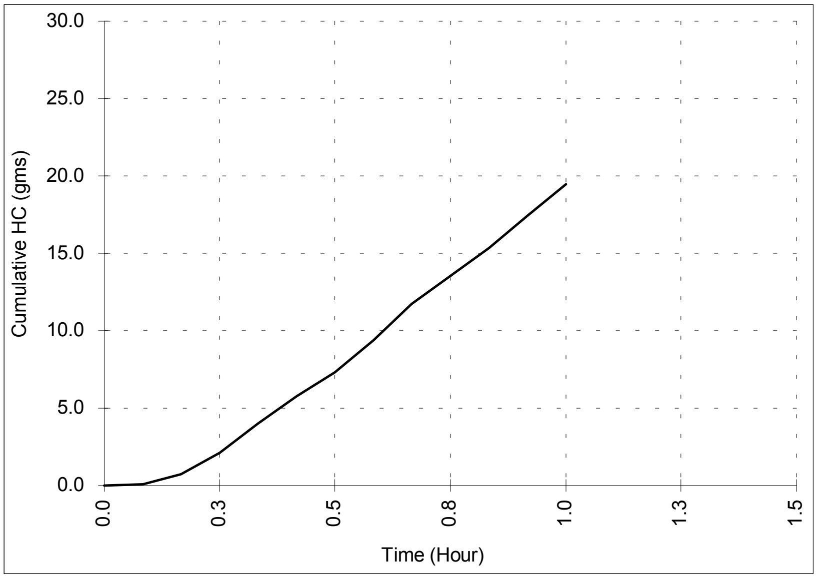
Level	Fuel	Grams
100%	Summer	4.06
75%	Summer	7.16
50%	Summer	8.08
25%	Summer	8.96

Appendix II
Continuous Results

Equipment: GEN01
1995 Honda EX5500; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

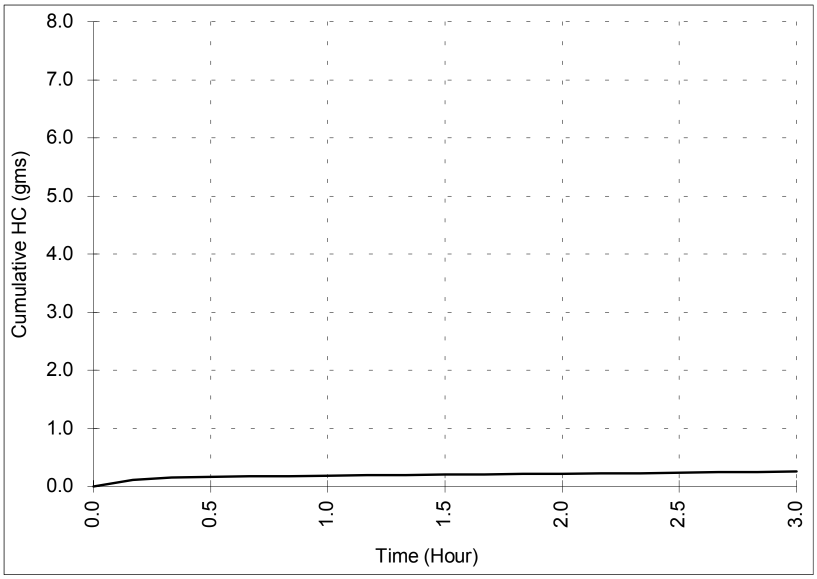
Test	Fuel	Grams
Run Loss	Summer	19.45

Appendix II
Continuous Results

Equipment: GEN02
1968 Homelite XL-A115; 2 stroke

Sequence: HS/Diurnal

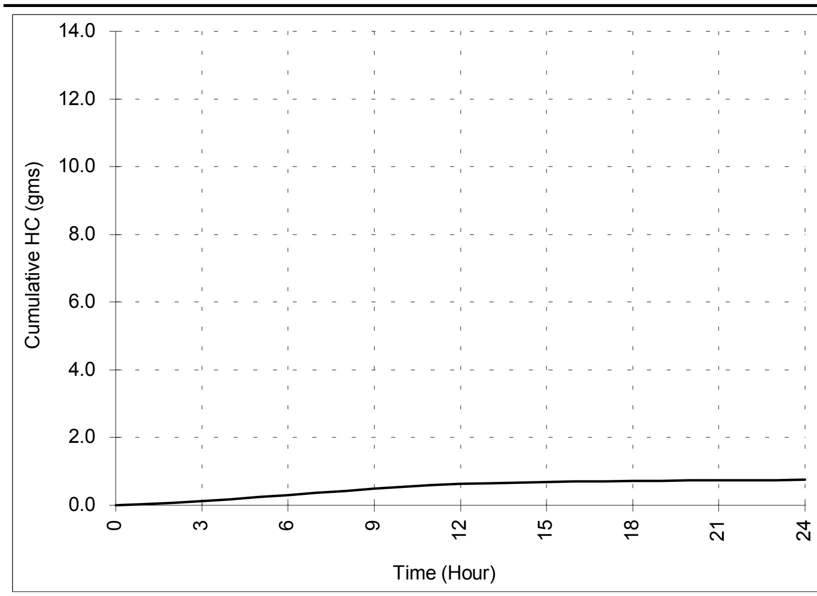
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	0.25

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

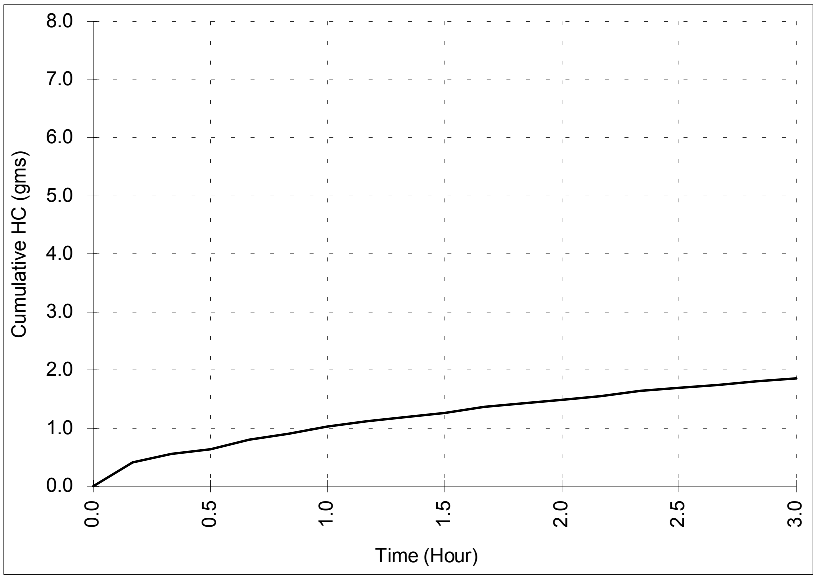
Test	Fuel	Grams
Diurnal	Summer	0.75

Appendix II
<u>Continuous Results</u>

Equipment: GEN03
2002 Coleman PL0545005; 4 stroke

Sequence: HS/Diurnal

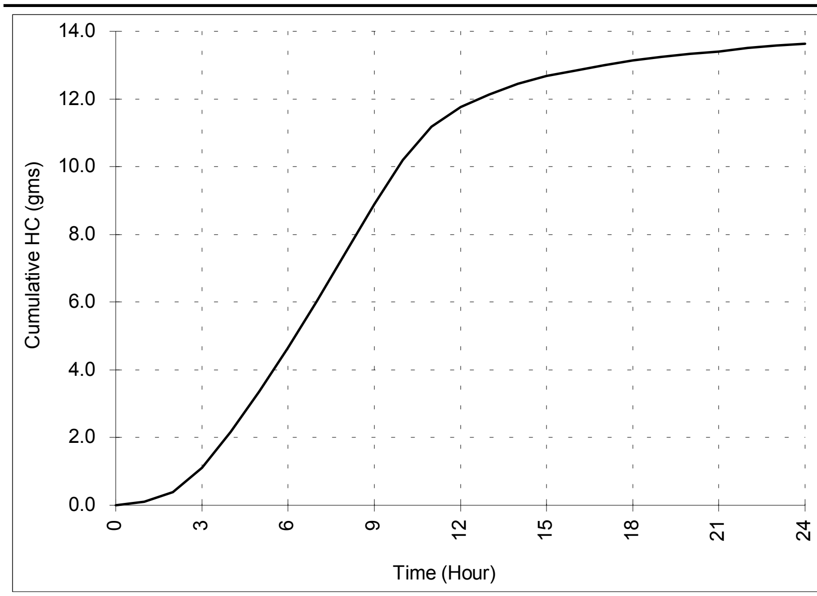
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.85

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

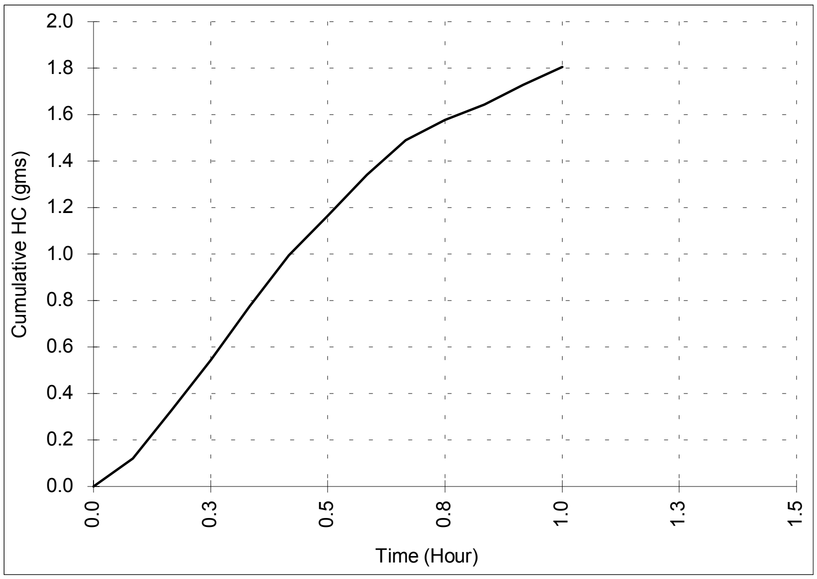
Test	Fuel	Grams
Diurnal	Summer	13.64

Appendix II
Continuous Results

Equipment: GEN03
2002 Coleman PL0545005; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

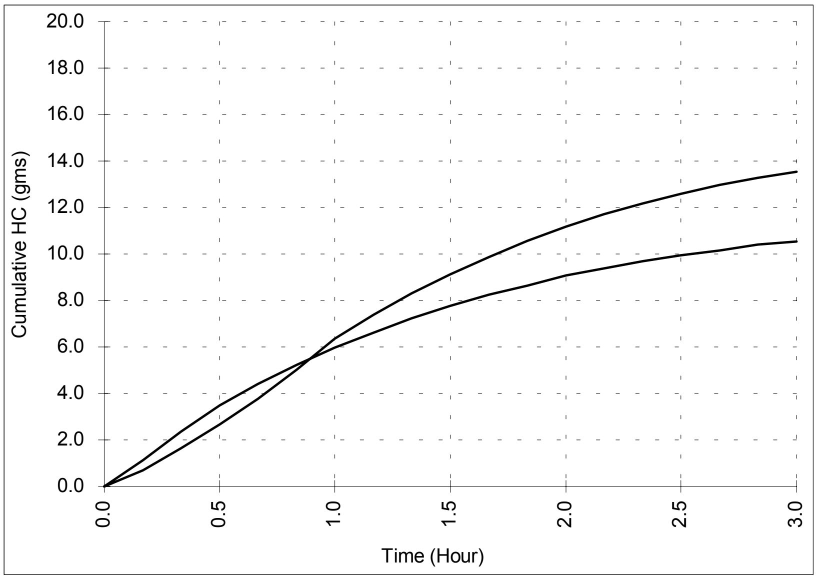
Test	Fuel	Grams
Run Loss	Summer	1.80

Appendix II
Continuous Results

Equipment: FORK01
1995 Komatsu FG30G-11; 4 stroke

Sequence: HS/Diurnal

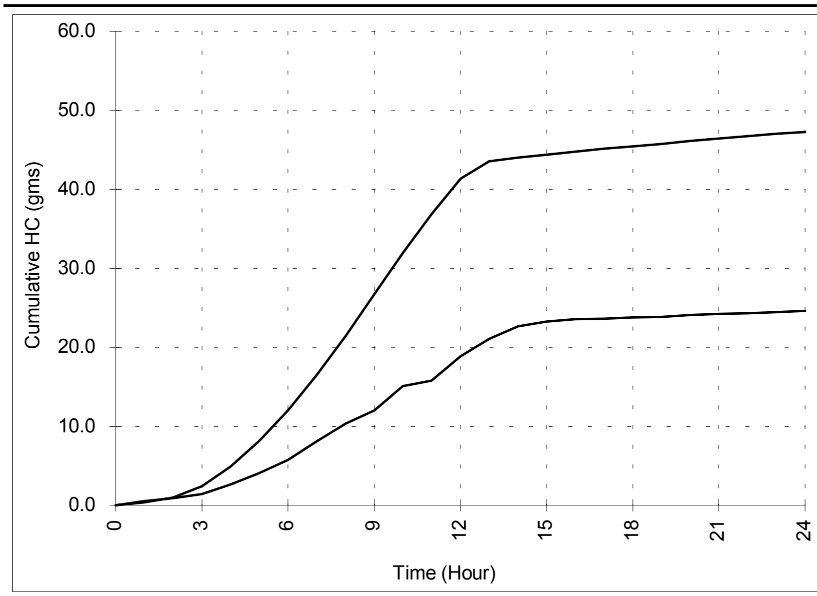
HOT SOAK EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

Test	Fuel	Grams
Before	Summer	13.54
After	Summer	10.55

DIURNAL EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

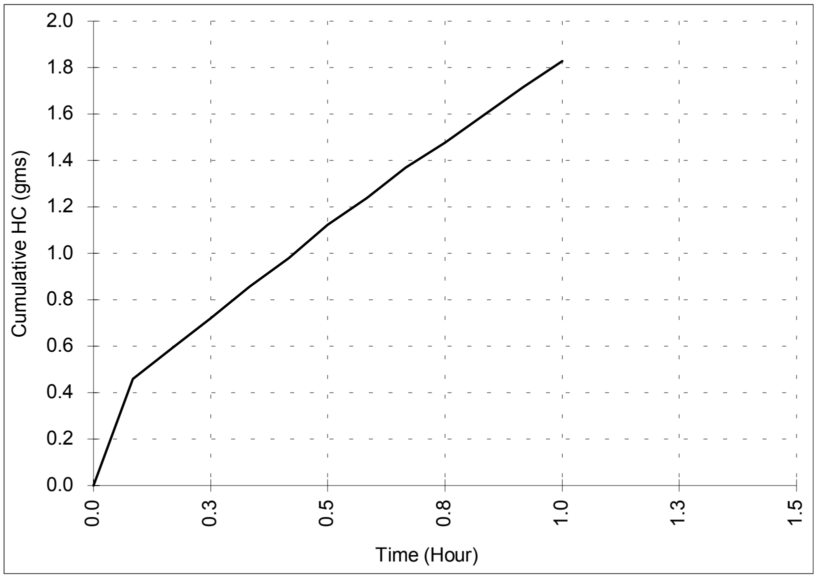
Test	Fuel	Grams
Before	Summer	47.28
After	Summer	24.61

Appendix II
Continuous Results

Equipment: FORK01
1995 Komatsu FG30G-11; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Run Loss Tests

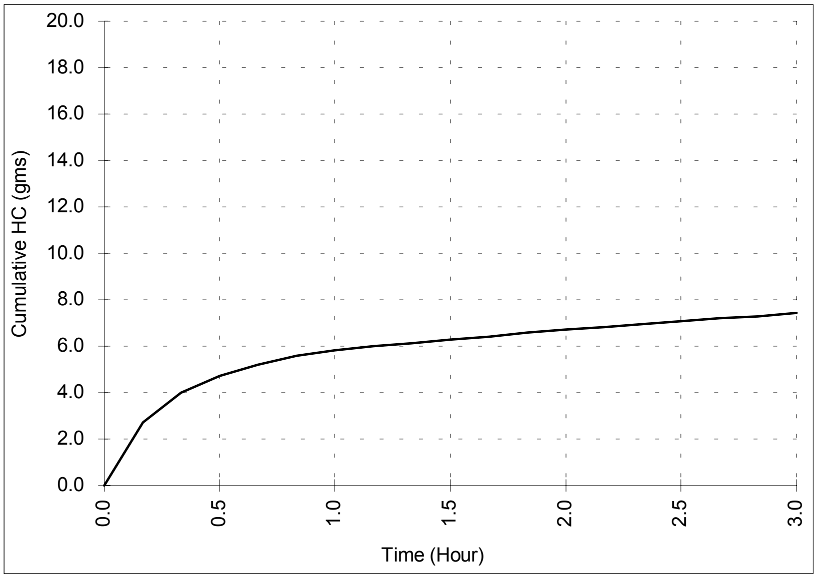
Test	Fuel	Grams
Run Loss	Summer	1.83

Appendix II
Continuous Results

Equipment: FORK02
1987 Toyota 2FG25-10579; 4 stroke

Sequence: HS/Diurnal

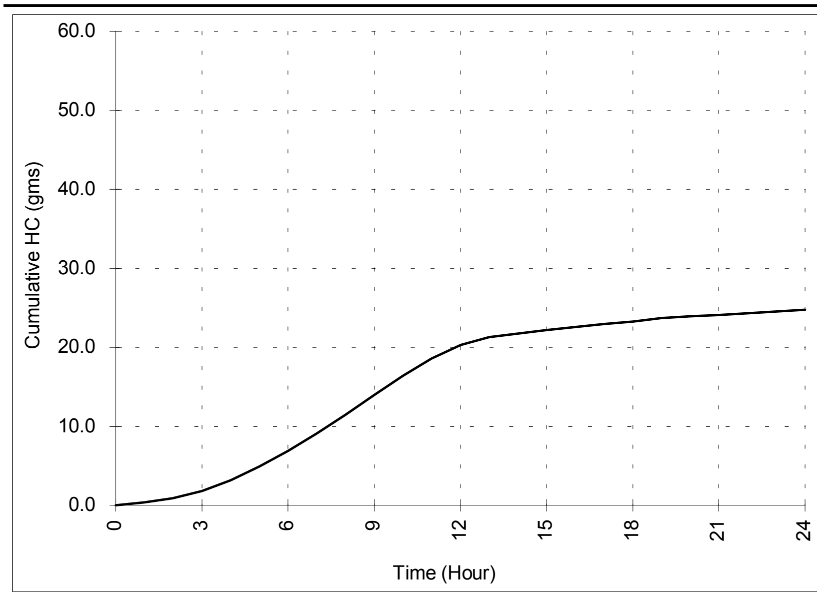
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	7.43

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

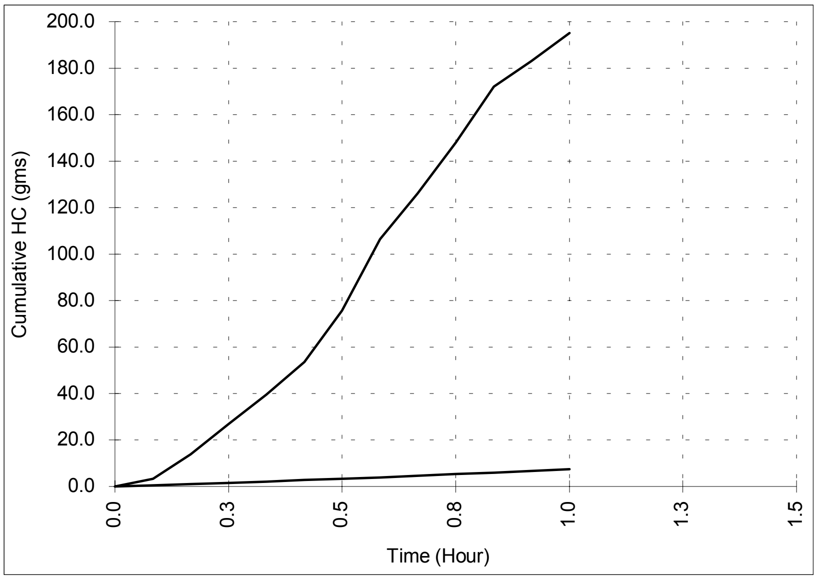
Test	Fuel	Grams
Diurnal	Summer	24.74

Appendix II
Continuous Results

Equipment: FORK02
1987 Toyota 2FG25-10579; 4 stroke

Sequence: Run Loss

RUN LOSS EVAPORATIVE EMISSIONS TEST



Befor & After Repair Tests

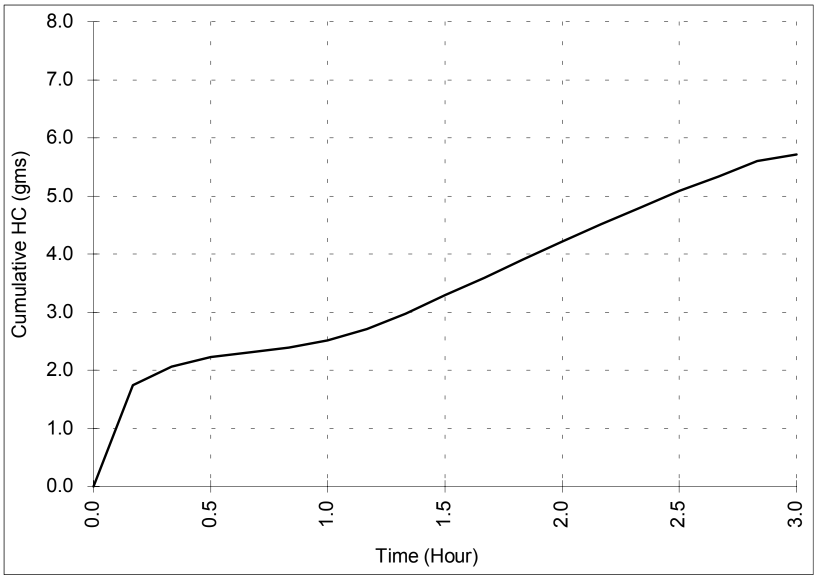
Test	Fuel	Grams
Before	Summer	195.14
After	Summer	7.38

Appendix II
Continuous Results

Equipment: PWC01
1992 Yamaha Wave Runner III; 2 stroke

Sequence: HS/Diurnal

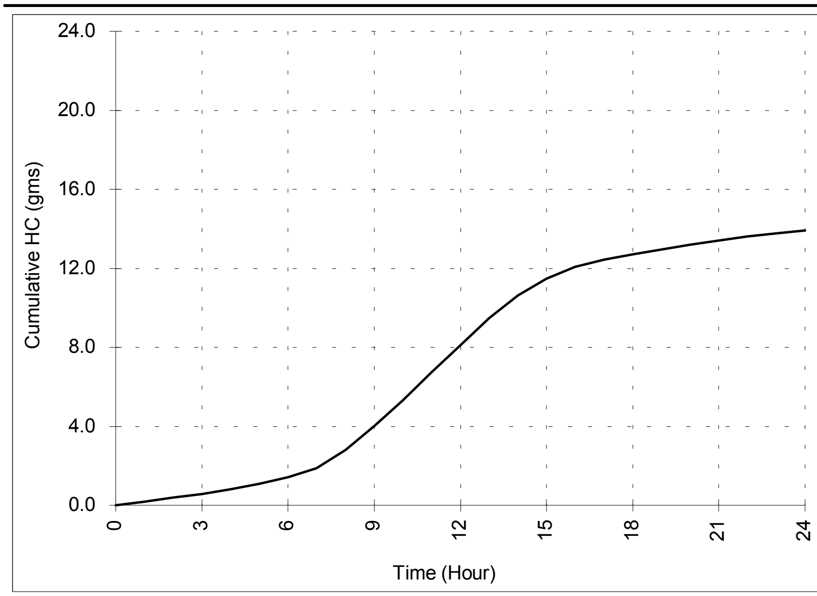
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	5.71

DIURNAL EVAPORATIVE EMISSIONS TEST



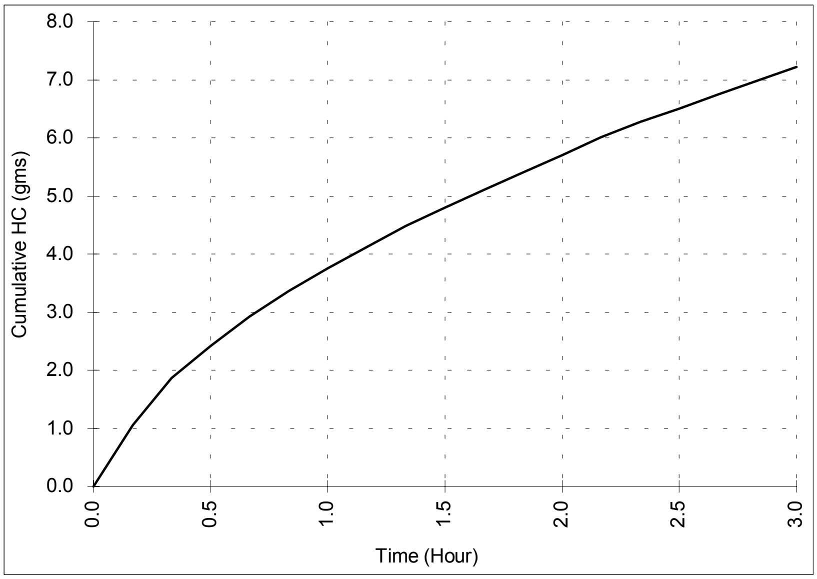
Diurnal Tests

Test	Fuel	Grams
Diurnal	Summer	13.93

Equipment: PWC02
1991 Bombardier Sea-Doo XP; 2 stroke

Sequence: HS/Diurnal

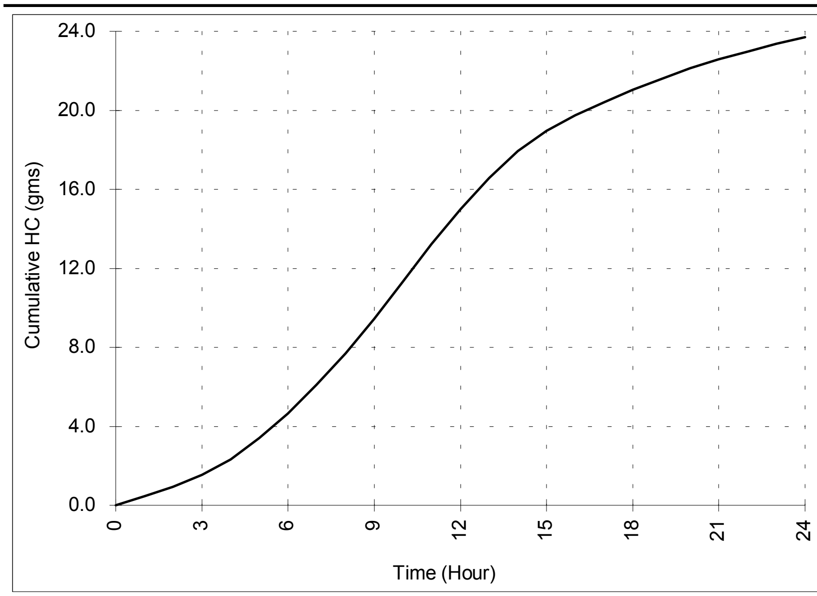
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	7.22

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

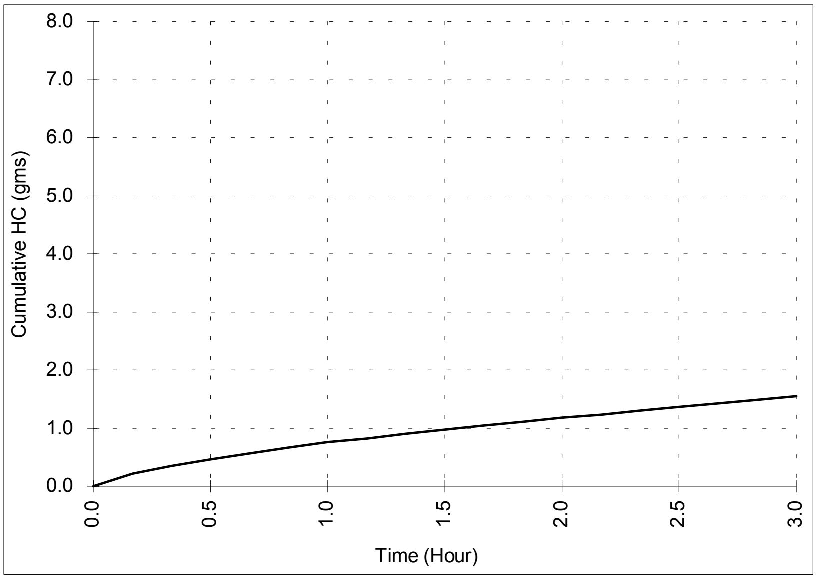
Test	Fuel	Grams
Diurnal	Summer	23.69

Appendix II
Continuous Results

Equipment: PWC03
2001 Yamaha Super Jet (SJ700AZ); 2 stroke

Sequence: HS/Diurnal

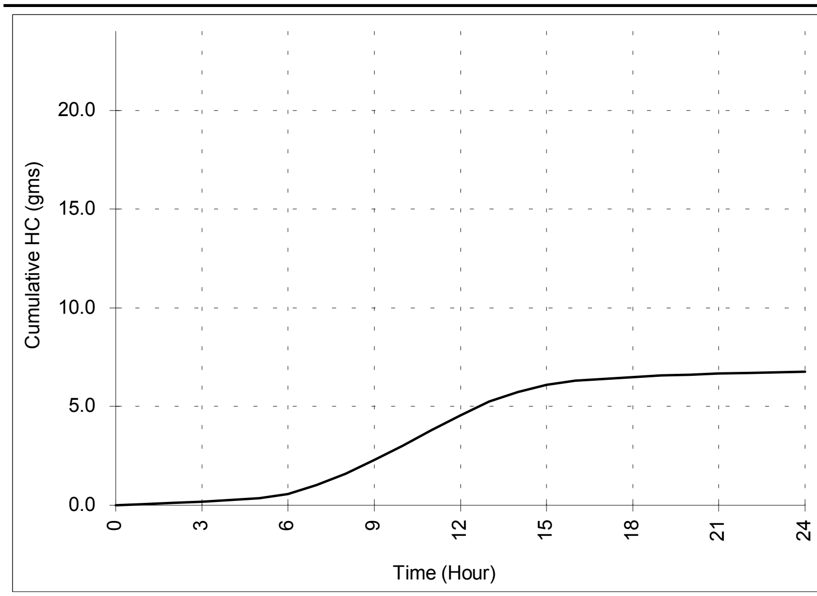
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	1.55

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

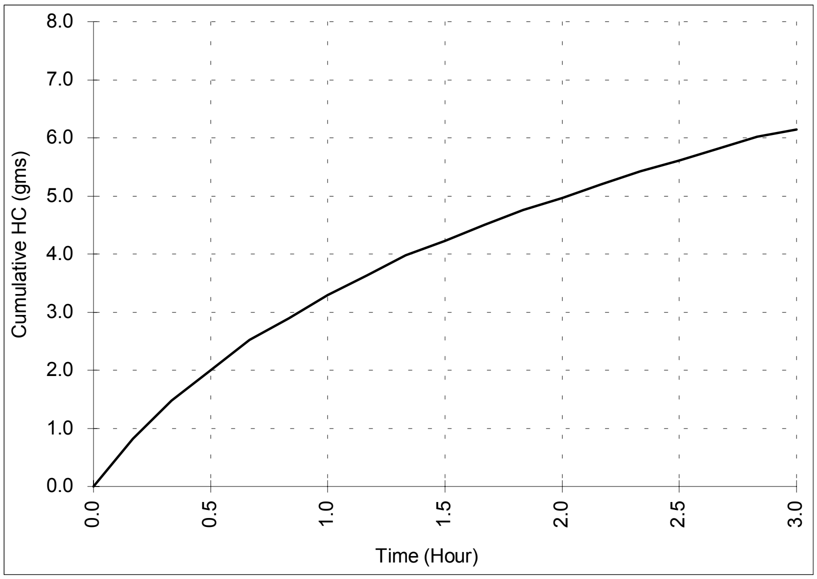
Test	Fuel	Grams
Diurnal	Summer	6.76

Appendix II
Continuous Results

Equipment: OB01
1977 Evinrude 66054; 2 stroke

Sequence: HS/Diurnal

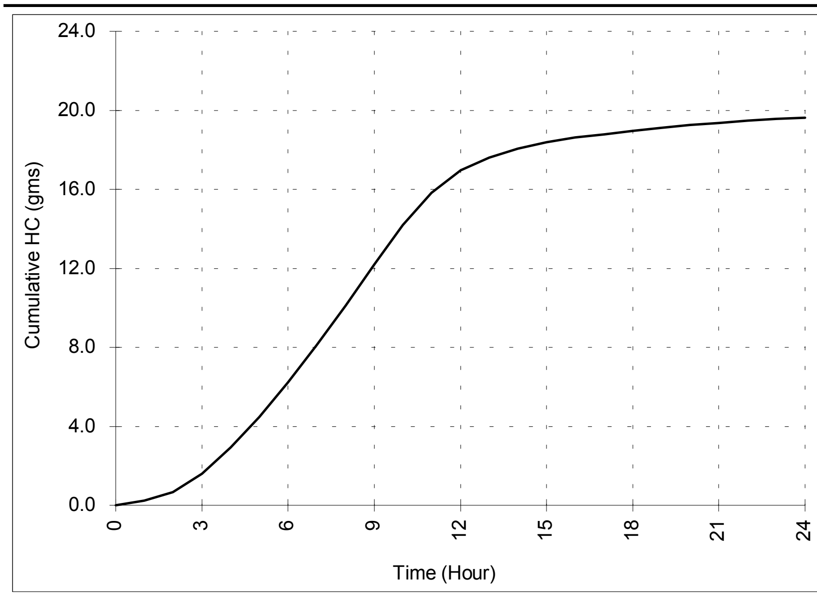
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	6.14

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

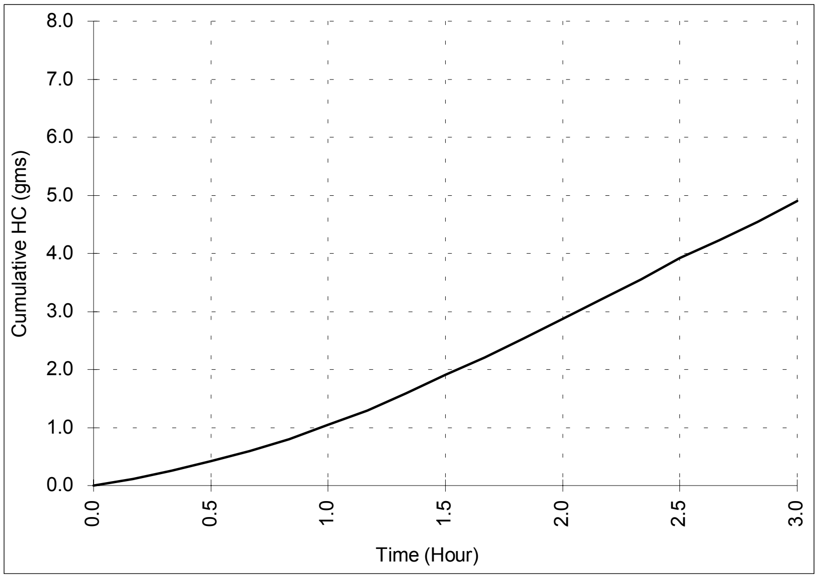
Test	Fuel	Grams
Diurnal	Summer	19.63

Appendix II
Continuous Results

Equipment: OB02
2001 Mercury Opti-Max; 4 stroke

Sequence: HS/Diurnal

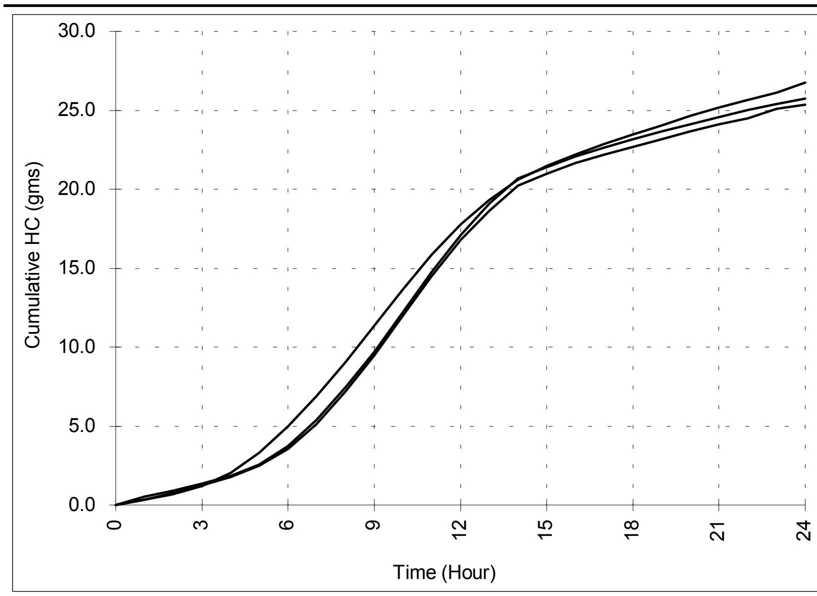
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	4.91

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

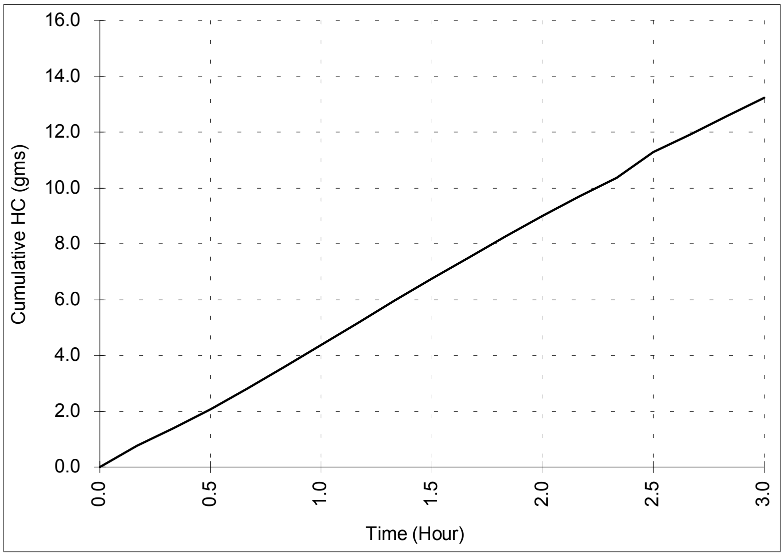
Test	Fuel	Grams
Diurnal	Summer	26.76
Day2	Summer	25.72
Day3	Summer	25.35

Appendix II
Continuous Results

Equipment: OB03
2000 Johnson RJ90PLSSE; 4 stroke

Sequence: HS/Diurnal

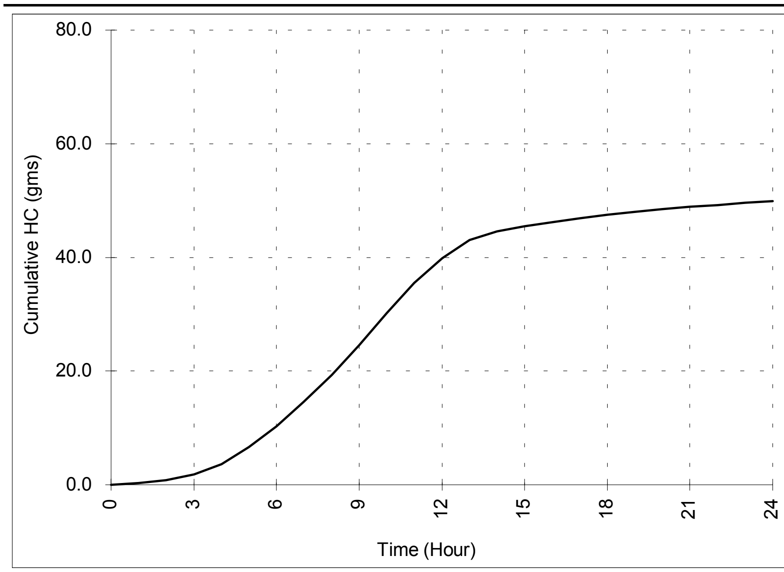
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	13.22

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

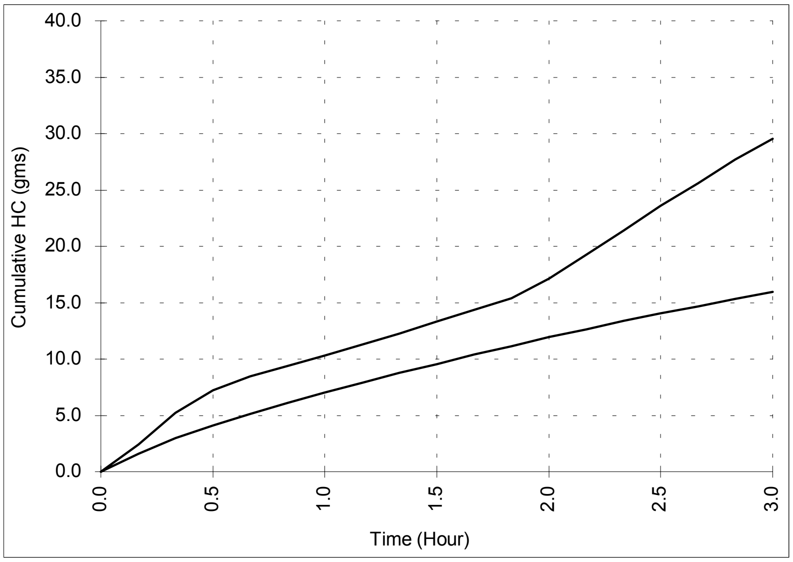
Test	Fuel	Grams
Diurnal	Summer	49.86

Appendix II
Continuous Results

Equipment: STRN01
1972 Schuster Jet Boat; 4 stroke

Sequence: HS/Diurnal

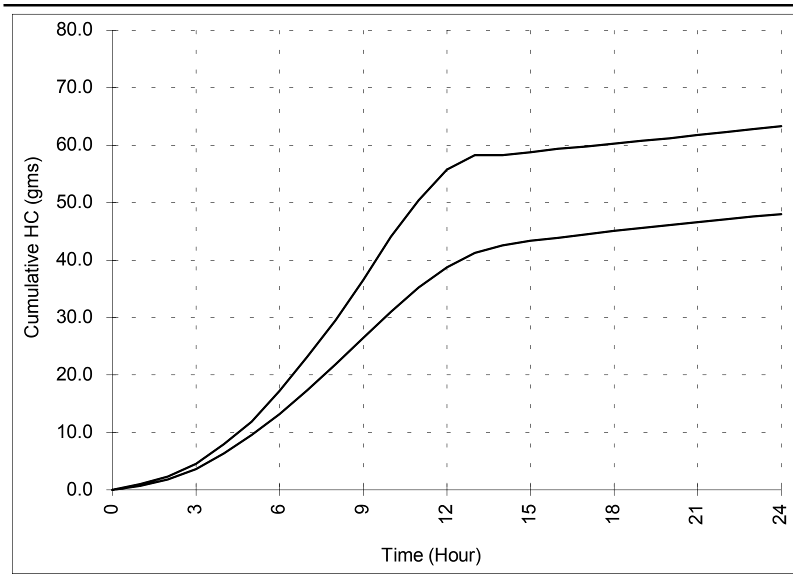
HOT SOAK EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

Test	Fuel	Grams
Before	Summer	29.56
After	Summer	15.95

DIURNAL EVAPORATIVE EMISSIONS TEST



Before & After Repair Tests

Test	Fuel	Grams
Before	Summer	63.34
After	Summer	48.04

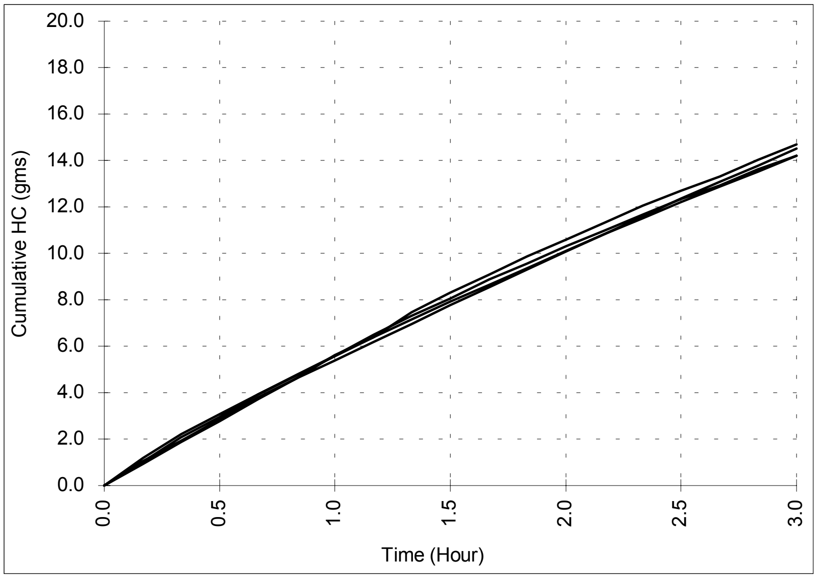
Appendix II

Continuous Results

Equipment: STRN01
1972 Schuster Jet Boat; 4 stroke

Sequence: HS/Diurnal

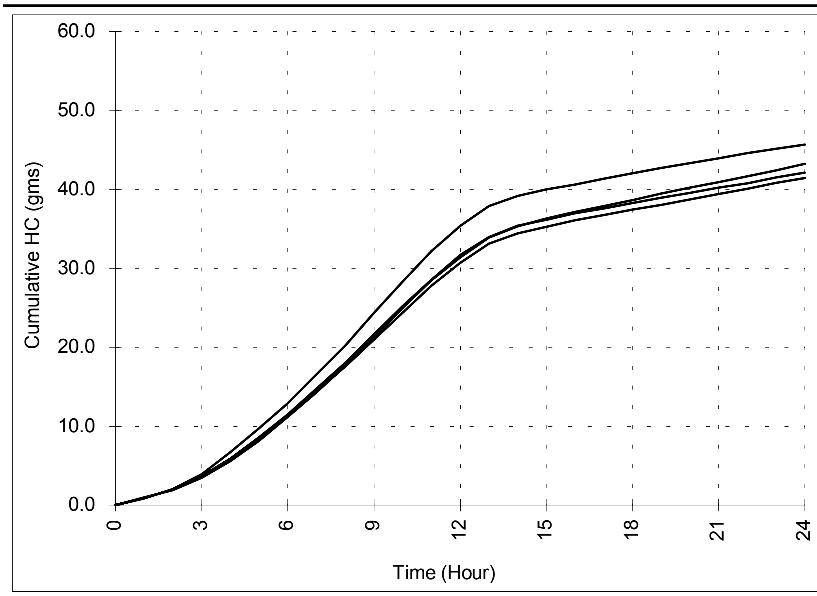
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tessts

Week	Fuel	Grams
Initial	Summer	14.70
Week 1	Summer	14.20
Week 2	Summer	14.19
Week 3	Summer	14.51

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Weathering Tessts

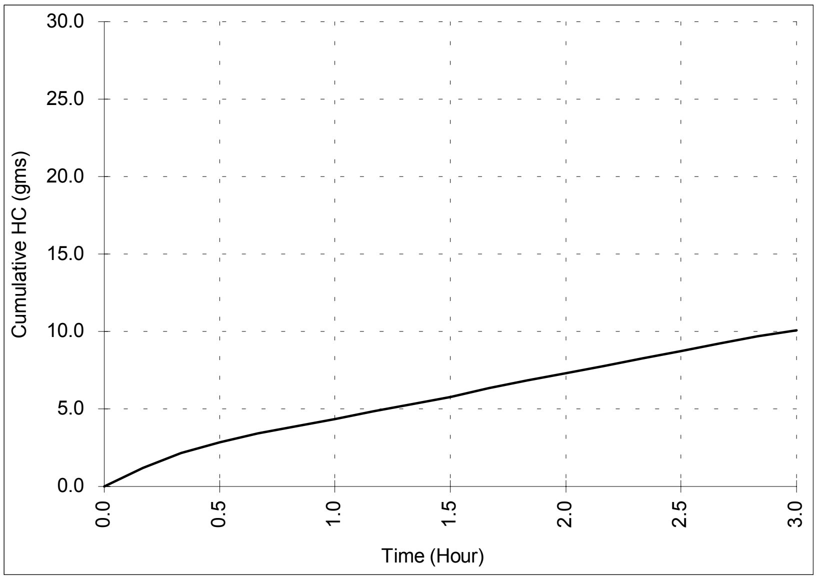
Week	Fuel	Grams
Initial	Summer	43.22
Week 1	Summer	41.47
Week 2	Summer	42.12
Week 3	Summer	45.69

Appendix II
Continuous Results

Equipment: STRN02
1998 Yahama EXT 1200W; 2 stroke

Sequence: HS/Diurnal

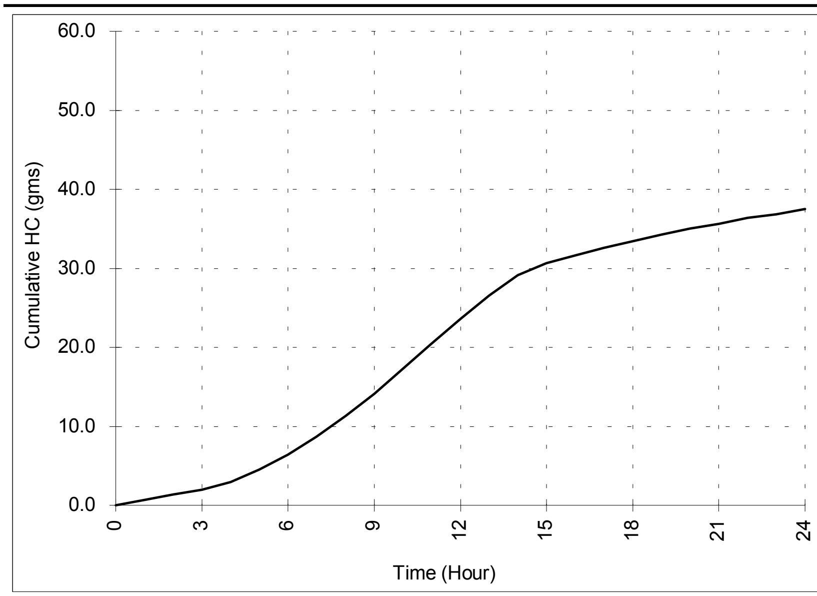
HOT SOAK EVAPORATIVE EMISSIONS TEST



Hot Soak Tests

Test	Fuel	Grams
HS	Summer	10.09

DIURNAL EVAPORATIVE EMISSIONS TEST



Diurnal Tests

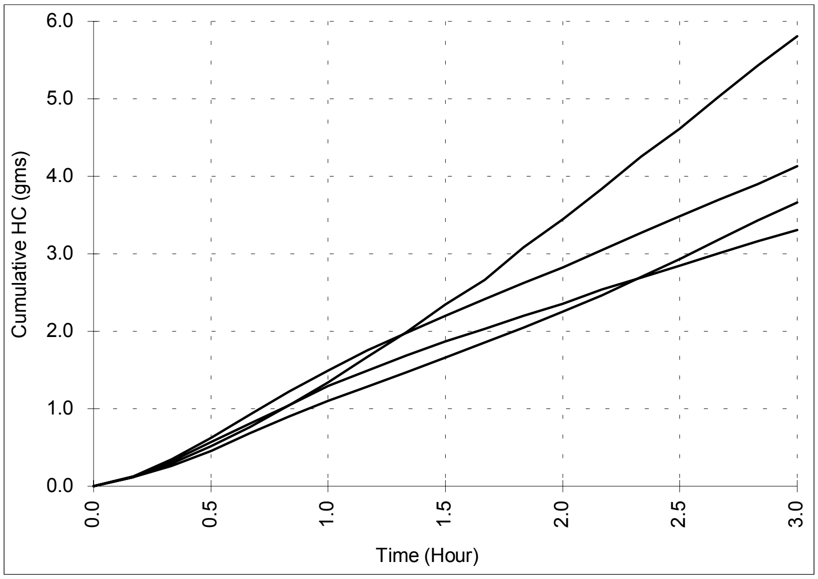
Test	Fuel	Grams
Diurnal	Summer	37.49

Appendix II
Continuous Results

Equipment: STRN03
2002 GM 4.3 GL; 4 stroke

Sequence: HS/Diurnal

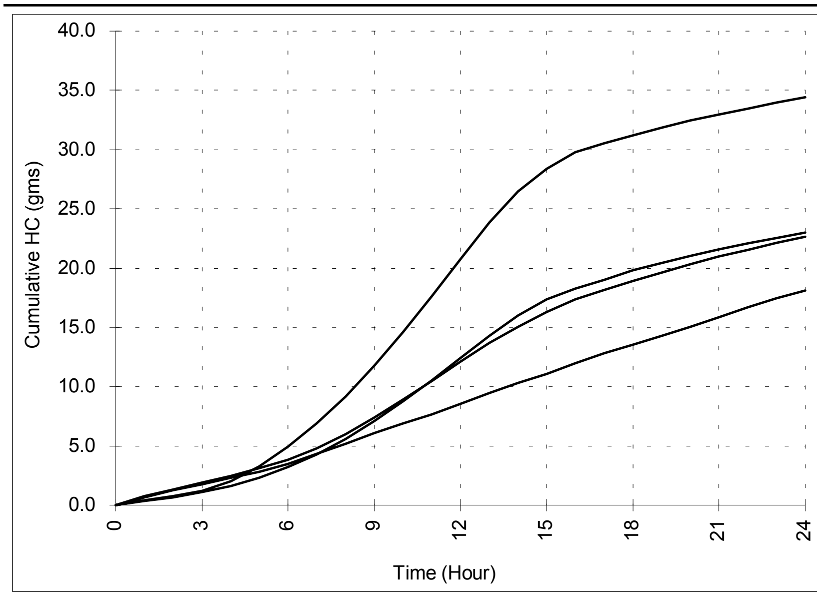
HOT SOAK EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

Level	Fuel	Grams
100%	Summer	3.31
75%	Summer	4.13
50%	Summer	3.66
25%	Summer	5.81

DIURNAL EVAPORATIVE EMISSIONS TEST



Fuel Level Tests

Level	Fuel	Grams
100%	Summer	18.13
75%	Summer	22.64
50%	Summer	22.99
25%	Summer	34.43