BLUE SEAL

Certificate of

Emissions Test Validation

No: 932207-02

The Center for Emissions Research and Analysis has conducted laboratory emissions testing of a 3.5hp Tecumseh lawn mower engine with untreated gasoline and gasoline treated with the Fitch Fuel Catalyst on July 1 and July 13, 1993 and which has demonstrated the following emissions reductions and fuel savings as a result of treatment by the Fitch Fuel Catalyst:

Carbon Monoxide:	48.8%
Hydrocarbons:	38.0%
Nitrogen Oxides:	11.1%
Fuel Consumption:	36.5%

The testing was performed in accordance with the Society of Automotive Engineers (SAE) J1088 test procedure and the California Air Resources Board Raw Gas Method (RGM) test procedure. This emissions data is a valid representation of the emissions from the specific engine tested.

Process Tested:

Make: Advanced Power Systems International, Inc.
Model: In-Tank Fitch Fuel Catalyst
Test Engine: 3 year old 3.5hp Tecumseh Lawn Mower Engine
Model No: SKW 011569 9-22253 X62

This Emissions Test Validation Certificate is issued this 22nd day of July 1993

Lawrence D. Odle

Lawrence D. Odle
Executive Director
The Center for Emissions Research & Analysis
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SUMMARY REPORT

ASSESSMENT OF IN-USE EMISSIONS FROM A GASOLINE POWERED LAWN MOWER ENGINE FUELED WITH GASOLINE AND GASOLINE TREATED WITH THE FITCH FUEL CATALYST

FOR

ADVANCED POWER SYSTEMS INTERNATIONAL, INC.

July 22, 1993

CENTER PROJECT #91-003

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ASSESSMENT OF IN-USE EMISSIONS FROM A GASOLINE POWERED LAWN MOWER ENGINE FUELED WITH GASOLINE AND GASOLINE TREATED WITH THE FITCH FUEL CATALYST - SUMMARY REPORT

Executive Summary

Advanced Power Systems International, Inc. has contracted the Center for Emissions Research & Analysis (the Center) to independently evaluate the effect of the Fitch Fuel Catalyst on in-use emissions and fuel consumption of lawn mower engines. The study is being performed by the Center on a representative cross section of gasoline powered lawn mowers in use by the public. This summary report presents the results from one such engine. The program will study and report on lawn mower engine population emissions, emission factors, and potential emission credits.

A complete test per SAE and CARB protocol were performed on the lawn mower engine. Emissions and fuel consumption data were recorded and stored for compilation and analysis.

Results show a significant decrease of fuel consumption and emissions of carbon monoxide, hydrocarbons, and nitrogen oxides as a result of fuel treatment with the Fitch Fuel Catalyst.

1.0 TEST EQUIPMENT AND PROCEDURES

The test facility and equipment used for the project include a small engine dynamometer test system and a raw gas emissions measurement system. Included with these systems is all instrumentation, control and data acquisition equipment necessary to control and record the test parameters and conditions.

1.1 Small Engine Dynamometer Test System

The small engine dynamometer test system is the combination of equipment necessary to interface, measure, and control small engine conditions. The system is composed of dynamometer loading and control components, mechanical mounting and interfaces, fuel supply and flow measuring equipment, and the data acquisition and control system.

The small engine testing dynamometer system and associated equipment is contained in and adjacent to a dynamometer test chamber. The test chamber materials and method of construction are designed to provide reasonable sound insulation and dampening, and to provide the necessary ventilation and utilities to support the small engine test equipment requirements. The test chamber is 16' x 16' with a standard height ceiling. The room has twin access doors at one end for equipment and personnel access with a double pane window on an adjacent side. The test chamber has sufficient exhaust and make-up air capacity to handle removal of engine exhaust air flows and to provide general test chamber room ventilation. The air exhaust system is of industrial type low heat appliance exhaust duct and roof fan with a minimum 2500 scfm capacity. The exhaust duct inlet at the test chamber provides branch access connections for two 5 inch diameter flexible ducts to exhaust direct sources such as engine exhaust (up to 60 scfm engine exhaust @ 1000 Deg F with up to ten to one dilution air, 660 scfm @ 150 Deg F mixture). Makeup air is provided from vents/ducting to the surrounding facility.

The dynamometer components consist of the eddy current dynamometer loading device, speed and torque instrumentation, cable set and control system. The dynamometer used for this project is a Vibrometer WB 115- V twenty horsepower (15 Kilowatt) horizontal-vertical dynamometer with a Dynacomp DCP 301 control unit and associated cabling. The dynamometer is capable of handling speeds up to 18,000 rpm in the horizontal position (6,000 rpm in the vertical position) and torque up to 50 Newton-meters up to 2865 rpm. Speed is measured by a FT107/M1 differential ferrostat transducer sensing a toothed wheel and the torque is measured with a load cell. The system has a combined accuracy of +/- 1 % for power determination. Since the speed pickup senses pulse frequency it is a principle method for speed determination and does not require calibration. The torque load cell is calibrated with Class F calibration weights. Calibration was performed per the manufacturer specifications. The speed and torque readings were recorded by interfacing the respective control unit outputs to the personal computer-based data acquisition system. The dynamometer loading device is integrated into a test stand to provide a means for mechanical interface to the engines.

The dynamometer test stand is a bench structure that supports the dynamometer loading device and provides a means for interfacing it to the shaft of the small engine. The test stand was fabricated by Application Engineering with the capability to easily change between horizontal and vertical positions. This is necessary to accommodate engines that operate in these different orientations. Included with the test stand are the engine mounting interface plates, drive shaft couplers and drive shaft guard to properly interface the engines to the dynamometer. The test stand includes a hydraulic actuator for changing between the horizontal and vertical orientations.

The dynamometer requires minimum cooling water flow of approximately two gallons per minute. The cooling water must have very low concentrations of dissolved solids, organics and metals. A closed loop cooling water system is used to meet the cooling requirements. The water within the closed system is conditioned to meet the water quality requirements. An air to water heat exchanger is used in the closed loop system to remove the heat from the cooling system.

The engine test protocol requires measurement of the engine fuel flow rate. This was achieved via a Max Machinery Model 213 positive displacement flow meter compatible with hydrocarbon fuels. The meter has a flow range of 1 to 1800 cc/min with a maximum error of +/- 0.75 %. The meter is factory calibrated by the manufacturer. The flow meter was read using a Model 276 analog transmitter interfaced to the data acquisition system. The fuel was supplied by gravity feed from an external fuel tank. The fuel was EPA specification reformulated fuel "A" (RFA). The RFA fuel specification is shown in Table 1. A certificate of analysis was provided by the fuel vendor. Fuel pressure to the engine was adjusted by setting the height of the external fuel tank relative to the engine carburetor to simulate in use fuel supply conditions.

Table 1. Reformulated Fuel "A" Specifications

(Also referred to as EPA Summertime Baseline Gasoline)

API Gravity	57.4
Sulfur, ppm	339
Benzene, %	1.53
RVP, psi	8.7
Octane, R + M/2	87.3
IBP, deg F	91
10 %, deg F	128
50 %, deg F	218
90 %, deg F	330
End Point, deg F	415
Aromatics, %	32.0
Olefins, %	9.2
Saturates, %	58.8

The engine test protocol requires an exhaust mixing chamber of not less than 10 times the maximum engine displacement be used for proper exhaust mixing and exhaust sample acquisition. Protocol requires that the chamber be insulated and contain instruments for wall temperature measurement and have a means of heating it to 175 to 400 C. An exhaust mixing chamber volume of two liters was used for this project. The exhaust mixing chamber wall temperature was monitored with Type K thermocouples. Wall temperature was maintained using external thermal insulation.

In addition to the measurements indicated above, various temperature and pressure readings of the dynamometer test system were measured. These readings include temperatures of ambient air, exhaust gas fuel, and dynamometer cooling water. Pressures that were measured include exhaust gas and ambient barometric pressure. Pressures were measured with Magnehelic 2020C and 2010C differential pressure gauges with accuracy of +/- 0.1 in. water column. Differential pressure gages are calibrated semiannually. Temperatures are measured with Type K thermocouples with an accuracy of +/- 2 deg F. Standard thermocouple calibration curves are used. Atmospheric pressure is measured with an Airguide compensated aneroid barometer, capable of measuring atmospheric pressure to within 0.1 in. Hg. The aneroid barometer is calibrated semiannually. Engine inlet air relative humidity is recorded using a Dickson TH8-7F ambient monitor with an accuracy of +/- 1% for relative humidity and +/- 1 deg F for temperature. Semiannual single point calibration is performed on temperature and relative humidity.

The data acquisition and control system is a personal computer based system using Strawberry Tree ACPC-12-16 and ACAO-12-4 data acquisition and control cards to for digital and analog input and output. The data acquisition and control is implemented with the cards using Workbench data acquisition and control software. The system has the ability to handle sixteen analog inputs, four analog outputs and twenty four digital inputs or outputs. This system was used to record the test parameters and provide the dynamometer set point control.

1.1.1 Small Engine Dynamometer System Equipment List

Dynamometer

- Vibrometer WB115-V Dynamometer - 15 KW capacity with horizontal and vertical orientation capability
- FT107/M1 Speed Pickup
- DCP 301 Control Unit
- Calibration weights, Class F NIST traceable, 10 Kg total with 500 g incremental capability

Test Stand

- Applications Engineering horizontal/vertical test stand
- Hydraulic orientation change system
- Electric start system

Dynamometer Cooling Water System

- 5 gpm capacity
- Closed system utilizing deionized water
- Air/water heat exchanger

Fuel Supply & Measurement System

- Max Machinery Model 213 positive displacement fuel flow meter
- Max Machinery Model 276 analog transmitter
- Max Machinery Model 381-102 filter, 10 micron

Temperature, Pressure, and Relative Humidity

- Type K thermocouples
- Magnehelic 2020C and 2010C differential pressure gauges
- Airguide compensated aneroid barometer
- Dickson TH8-7F ambient monitor

Data Acquisition System

- PC based computer acquisition and control
- Strawberry Tree ACPC-12-16 data I/O card
- Strawberry Tree ACAO-12-4 analog output card with T31 interface panel
- Workbench data acquisition and control software

1.2 Raw Gas Emissions Measurement System

Emissions measurement was performed using the Center's continuous emissions measurement system. This system is a raw gas continuous emissions measurement system that employs state-of-the-art analyzers for CO_2, CO, HC, O_2, and NOx with associated sample conditioning and management equipment. A schematic of the sampling system is shown in Figure 1. The exhaust gas samples were taken from the exit of the exhaust mixing chamber with an integrated sample probe. A separate heated sample line was used for the hydrocarbon (HC) analyzer. The HC analyzer contains an internal sample pump to draw the sample flow. The sample for analysis of the other species was transported through a heated sample line to a Universal Analyzers Model PSC-1060 gas sample conditioning system. The conditioning system removed the moisture from the sample to a 35 deg F dew point. The sample was transported to the analyzer instrument rack where it passed through a Permapure PD-625-12PS membrane as a backup moisture removal and protection system.

The sample enters a distribution manifold where flows are monitored and adjusted using rotameters with integral needle valves before separate flows are directed to each analyzer. All analyzers meet the respective continuous emissions measurement performance specifications of EPA, CARB and SCAQMD in terms of principle of operation and accuracies. Analyzer outputs were recorded by the computer data acquisition system. Appropriate NIST traceable +/- 1% calibration gases for each instrument and range were used. Instruments were calibrated per manufacturers instructions in accordance with the SAE J1088 protocol.

1.2.1 Raw Gas Emissions Measurement System Equipment List

- Universal Analyzers Model PSC-1060 gas sample conditioner (35 deg F dew point)
- Permapure PD-625-12PS membrane dryer
- API Model 200 NOx Analyzer
  (Ranges: 20, 100, 500 and 2500 ppm, low ranges software selectable)
- Horiba Model CMA-331A CO, CO2 and O2 analyzer
  (CO Ranges: 200 and 1000 ppm)
  (CO2 Ranges: 5 and 20 %)
  (O2 Ranges: 10 and 25 %)
- Horiba Model VIA-510 NDIR CO analyzer
  (Ranges: 5000 ppm, 2 %, 10% and 20%, lower ranges software selectable)
- Eagle Monitoring Systems Model EM 7000 total hydrocarbon analyzer
  (Ranges: 100, 1,000, 10,000 and 100,000 ppm)
- Horiba Model 3410SGD-710 10 point gas divider
- Kontron Model 520 8 channel chart recorder
- Air Dimensions model 01329TC sample pump

1.3 Test Procedures

Testing was performed in accordance with the Society of Automotive Engineers (SAE) J1088 Test Procedure and the California Air Resources Board (CARB) Raw Gas Measurement (RGM) Test Procedure.

Three five-minute runs were performed at each of six engine operating modes using EPA spec. gasoline as fuel. The procedures were repeated using the same fuel catalyzed with the Fitch Fuel Catalyst.

For the catalyzed fuel portion of the test, the catalyst was placed in a container of fuel 24 hours prior to the test. The container was mechanically agitated to simulate the vibration of a lawn mower fuel tank.

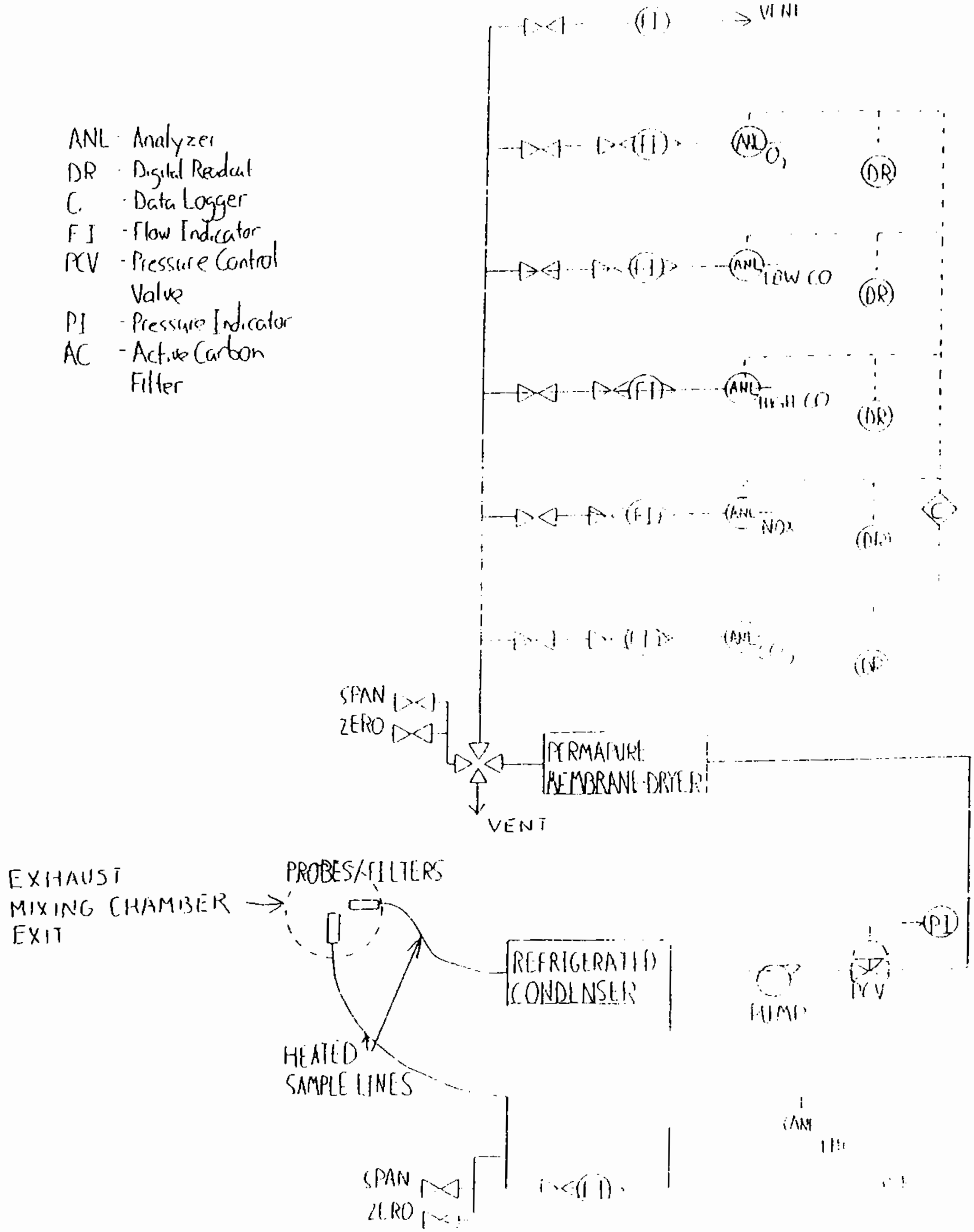
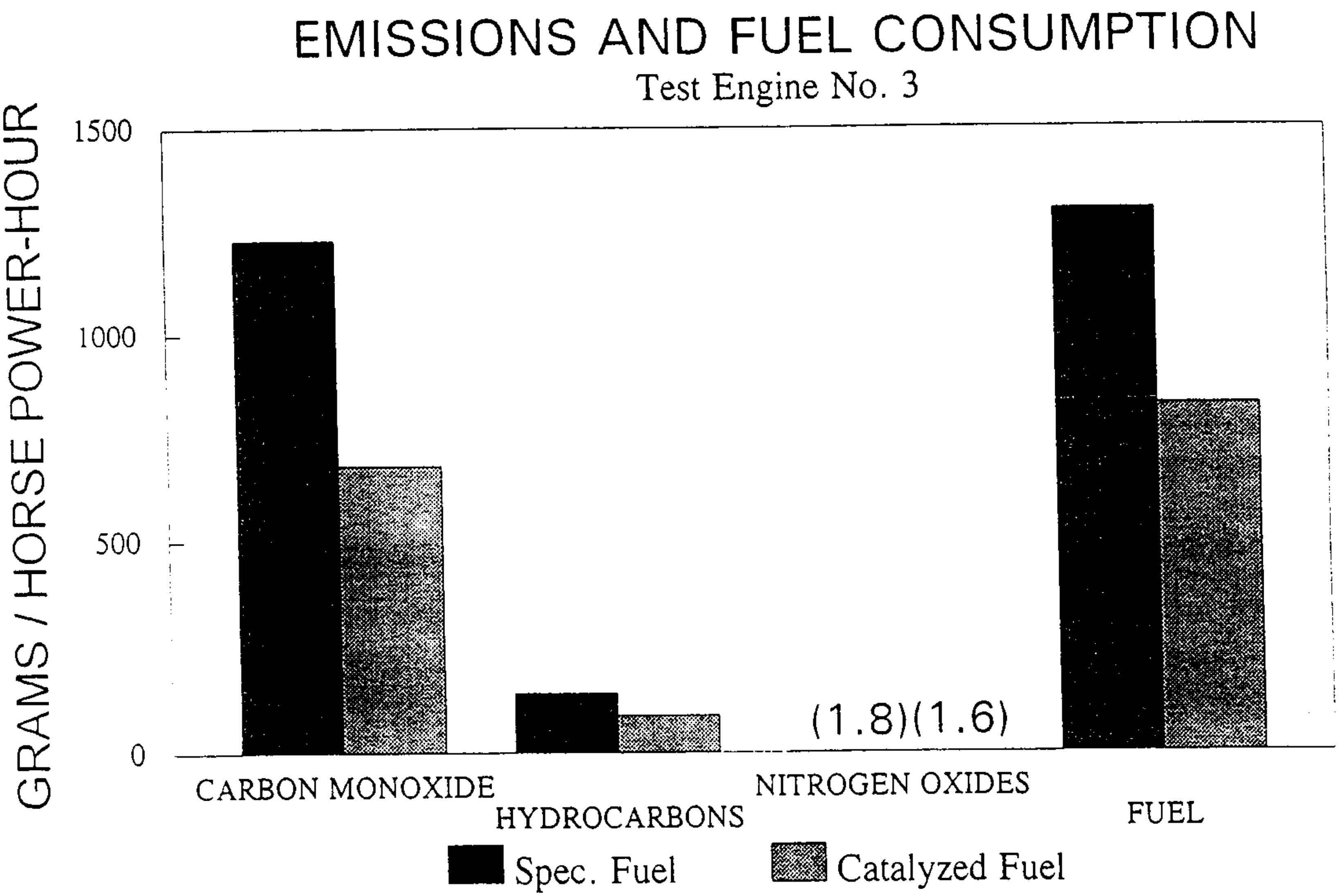


Figure 1. Raw Gas Emissions Measurement System Schematic

2.0 RESULTS

ENGINE #3 (3 year old Tecumseh, 3.5 hp)

	SPEC. FUEL	CATALYZED SPEC. FUEL	% DIFFERENCE
carbon monoxide	**1230 g/hp-hr**	**680 g/hp-hr**	**-48.8%**
hydrocarbons	**142 g/hp-hr**	**88 g/hp-hr**	**-38.0%**
nitrogen oxides	**1.8 g/hp-hr**	**1.6 g/hp-hr**	**-11.1%**
fuel consumption	**1303 g/hp-hr**	**827 g/hp-hr**	**-36.5%**



Tecumseh, 3.5 hp, 3 years old

Center for Emissions Research & Analysis

Project 93-001: Advanced Power Systems International

Lawn Mower #3 (3.5 HP Tecumseh, Approximately 3 years old)

Tested: July 1 and July 13, 1993

TEST DATA SUMMARY*

	SPEED (rpm)	POWER (power)	TORQUE (ft-lb)	FUEL (cc/min)	CO_2 (%)	O_2 (%)	THC (ppm)	NO_x (ppm)	CO (ppm)
MODE 1 (Idle, no load)									
Un-Catalyzed	2198	.218	0.47	12.96	9.41	4.52	16,094	36.7	31,735
Catalyzed	2105	0.189	0.47	12.20	8.64	6.10	11,706	37.0	27,910
MODE 3 (85% Rated Speed, MAX load)									
Un-Catalyzed	2590	2.08	4.23	45.18	7.00	2.28	14,352	88.2	92,423
Catalyzed	2580	2.08	4.23	34.4	8.32	1.96	12,616	162.5	85,456
MODE 4 (85% Rated Speed, 75% MAX load)									
Un-Catalyzed	2589	1.68	3.41	40.11	7.01	2.35	14,619	69.5	93,302
Catalyzed	2581	1.53	3.11	22.86	8.17	2.31	12,562	115.9	83,417
MODE 5 (85% Rated Speed, 50% MAX load)									
Un-Catalyzed	2589	1.27	2.58	39.29	7.80	2.23	14,390	75.6	87,145
Catalyzed	2579	1.08	2.20	16.47	8.20	3.66	10,663	101.5	65,551
MODE 6 (85% Rated Speed, 25% MAX load)									
Un-Catalyzed	2589	0.58	1.17	28.94	8.02	2.36	13,762	81.5	76,822
Catalyzed	2581	0.48	0.98	15.40	7.80	5.12	16,183	50.9	55,501
MODE 7 (85% Rated Speed, MIN load)									
Un-Catalyzed	2589	0.70	1.42	16.00	8.3	3.52	22,414	29.7	59,413
Catalyzed	2581	0.52	1.05	12.81	7.8	5.03	17,139	45.5	56,939

* Test data presented as averages of three 5-minute test runs per mode