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EVALUATION OF A PROPORTIONAL SAMPLER FOR AUTOMOTIVE EXHAUST EMISSIONS

Environmental Sciences Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
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by

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ABSTRACT

A test program was conducted to evaluate a proportional sampler for use in automotive exhaust gas emissions research. Automobile emissions test results obtained using the proportional sampler were compared with results obtained using the conventional constant volume sampler.

Measurements obtained using the proportional sampler for hydrocarbons, carbon monoxide, nitrogen oxides, and carbon dioxide are within 19, 46, 20, and 14 percent, respectively, of measurements obtained using the constant volume sampler. Such differences render the proportional sampler unacceptable as a quantitative research tool.

Inability of the exhaust gas flow meter to accurately measure pulsating exhaust flow is cited as the principal cause of error in the proportional sampler.

SECTION 1

INTRODUCTION

Light duty vehicle exhaust emission standards are expressed in units of mass per vehicle mile traveled. The current emissions certification procedure used in the United States utilizes a chassis dynamometer, a constant volume sampler, and a set of exhaust gas analyzers. With these three basic blocks of equipment, automobile exhaust emissions can be generated, representatively sampled, and measured.

The constant volume sampler (CVS) technique is well known and its essential features are described in the Federal Register (1). Vehicle exhaust gases are ducted into a CVS where the gases are cooled by dilution air prior to sampling. Dilution ratios are significantly high to minimize water condensation within the sampler and to minimize unwanted chemical reactions. The combined exhaust plus diluent flow rate is maintained constant in order to simplify both sampling and computational requirements.

From strictly a research point of view, the CVS, although reliable and accurate, suffers from two primary drawbacks: it is a large, awkward piece of equipment having virtually no mobility, and it dilutes the raw exhaust sample resulting in low gas specie concentrations. Frequently in research work it becomes desirable to examine the emission of non-regulated gases having raw exhaust concentrations near the threshold sensitivity level. In such cases the requirement for exhaust gas dilution becomes an unacceptable drawback.

One alternative mass measurement technique utilizes a proportional sampler for sampling raw exhaust gas. As the name implies, the proportional sampler samples raw exhaust at a flow rate proportional to the total exhaust gas flow rate. The concept of proportional sampling was first employed in the early sixties with the development of a device which sampled automobile exhaust at a rate proportional to the measured air-flow into the carbureter (2). This technique had as its best feature the capability of sampling the vehicle during actual real world operation since the equipment was completely portable. Although the technique showed great promise, the subsequent arrival of engine air pumps and carburetor air bleeds rendered intake air-flow measurement overly cumbersome. Consequently, the proportional sampler was abandoned in favor of CVS techniques.

More recently, gas flow metering technology has reached the threshold of engine exhaust gas measurement. Among the possible candidate flow meters, the ultrasonic vortex meter has been one most highly recommended for engine exhaust measurement (3). For this reason, a proportional sampler for automobile emissions research was developed around an ultrasonic vortex flow meter.

This paper describes an evaluation performed on a prototype proportional sampler developed under contract for EPA by Aeronutronic-Ford. A complete description of the sampler and its development is contained in the contract final report (4).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

An evaluation of a proportional sampler was completed to assess its value as a tool for use in automobile emissions research applications. The evaluation concerned itself with the sampler's ability to obtain representative exhaust gas samples from four different automobiles. No attempt was made to comprehensively assess the effect of sample degradation. Results from continuous sample monitoring versus bag sample analysis implied that the raw exhaust sample's integrity did not significantly deteriorate during the time period between sampling and analysis.

The test results indicate that measurements obtained for hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), and carbon dioxide (CO_2) using the proportional sampler are within 19, 46, 20 and 14 percent, respectively, of measurements obtained using the constant volume sampler. The magnitude of these differences renders the proportional sampler unacceptable as a quantitative research tool in its present configuration. It should be useful, however, for qualitative emissions testing.

The vortex flow meter was found to be the primary source of error within the proportional sampler. Although the flow meter performed adequately when metering non-pulsating type airflows, rather significant metering errors were observed when operating under actual automobile exhaust flow conditions. No detailed tests were carried out to determine what specific aspect of engine exhaust flow was adversely affecting the measurement capabilities of the vortex meter, but it is related to gas pulsations.

Future work involving integration of vortex flow meters into automobile emissions measurement systems should attempt to resolve this engine exhaust flow metering problem. Other types of flow meters being considered for use in either proportional samplers or continuous mass measurement systems should be qualified in tests using actual engine exhaust. A test procedure similar to that used in this study employing a Roots or turbine meter to measure and record integrated flow volumes is a simple and effective method for evaluating candidate flow meters.

SECTION 3

PROPORTIONAL SAMPLER

GENERAL DESCRIPTION

A schematic of the proportional sampler fluid system is shown in Figure 1. The ultrasonic vortex flow meter, the sample valve, and the signal processor (not pictured) are the three main components of the system. Exhaust gas from the vehicle enters the sampler and is immediately sampled. The sample valve is controlled through processor signals to sample at a mass flow rate proportional to the mass flow rate of total exhaust as measured by the vortex flow meter. Both sample and total exhaust flow rates are corrected to standard conditions via signal processor with the aid of temperature and pressure sensors. This insures that proportional mass flow is being maintained even though actual exhaust to sample flow ratios may vary considerably.

Figure 2 shows a front view of the proportional sampler. On the front panel are displays for cumulative exhaust volumes measured during the test and analog outputs for actual and standard exhaust gas flow rates, sample temperature, flow meter temperature, and sample valve frequency. Information obtained through proper use of these outputs can be used effectively when troubleshooting the device.

Sample Line

The sample line between the sample valve and the condenser coil in the refrigerated water bath is temperature-controlled to 93° C. This precaution is taken to avoid condensation of heavy hydrocarbons and water vapor in the sample line. The condenser coil is also temperature-controlled to +2° and the condensation is controlled at this cool temperature. After passing through the condensate trap, the sample is pumped into a tedlar sample bag for post-test analysis.

Exhaust Gas Heat Exchanger

One rather obvious feature of the proportional sampler is the heat exchanger tank. The tank occupies a volume of 0.24 m^3 and is designed to cool the exhaust gases before their entry into the ultrasonic flow meter. Since flow velocity is propagated downstream from the engine at sonic speed, the location of the vortex flow meter after the heat exchanger does not introduce any problems associated with sample lag time. The sample valve has been observed to respond almost instantaneously to changes in engine speed. A test conducted using a dual channel oscilloscope to simultaneously monitor airflow entering the carburetor and exhaust flow at the vortex flow meter indicated a 125 millisecond response time. This test was run with the standard 12-foot section located between the vehicle and the proportional sampler.

SECTION 4
EXPERIMENTAL PROCEDURES

GENERAL PROCEDURES

The experimental evaluation of the proportional sampler was carried out in an automobile emissions laboratory equipped with a chassis dynamometer. Routine gas (HC, CO, CO_2, AND NO_x) analyses were carried out in accordance with specifications given in the Federal Register (1). Chassis dynamometer operation was also conducted in accordance with these specifications, one exception being that a 24,000 CFM cooling fan was used during all tests.

Both the proportional sampler and the conventional constant volume sampler were used to sample gaseous emissions from the test vehicles. The samples were analyzed and emission measurements were obtained for each case. Measurements obtained using the proportional sampler were compared to those obtained using the CVS. These comparisons formed the basis for the proportional sampler evaluation.

Test Vehicles

Tests were conducted on four different vehicles. Each of the vehicles is described in Table 1. In order to study the effect of engine size on proportional sampler operation, the vehicles were selected to purposely represent a fairly broad range of engine displacement sizes. The vehicles were tested in the following order: 1) Ford Mustang II, 2) Chevrolet Nova (Gould catalyst car), 3) Ford Pinto, and 4) Honda CVCC.

Test Cycle

Each cycle consisted of the hot transient phase of the 1975 Federal Test Procedure (75 FTP), specifically, the 505 second portion associated with bag 3 of the 75 FTP. The test cycle included a 10-minute hot soak period between each test. Because the Honda developed an overheating problem, the soak periods between its tests were increased to 20 minutes.

The hot 505s were selected in order to rule out variabilities associated with the cold transient phase. The cold transient phase has been identified as the major source of variability for the 75 FTP because parameters that affect engine and catalyst warm-up characteristics and carburetor choke activity all come into play (5).

At least ten test cycles were completed for each vehicle on the CVS as well as on the proportional sampler. Each vehicle was tested using the proportional sampler and CVS techniques alternately over groups of five test cycles. This procedure was followed in order to compensate for possible drifts in vehicle emission rates as the testing progressed. A review of the data at the completion of the test period, however, revealed that such drifts did not occur to any significance.

Troubleshooting

A number of checks were run at the conclusion of the basis evaluation program to identify the sources of error involved in the tests.

Sample Lead Time Investigation--

The discovery of rapid response times with regard to sample valve operation prompted a closer examination of the exhaust system between the engine and the proportional sampler. Because a 12-foot section of 3-inch flexible line had been used during the tests, gases from the engine had been lagging behind the sample valve about $(50/_{x})-.125$ seconds, where x equals the actual flow rate through the exhaust line in cubic feet per minute. This effectively created a sample lead time error. For the larger displacement engines the sample lead time was less because of the higher flow rates involved. But for a vehicle having a small engine, such as the 1500cc Honda, the flow rates observed over the test cycle were always below 100 ACFM, and therefore sample lead time errors were probably significant.

Additional tests were conducted on the Honda using a short flexible connecting line between the vehicle and the proportional sampler. By reducing exhaust residence time before the sample port, it was hypothesized that sample lead times would likewise be reduced and a more representative sample would be obtained.

Sample Degradation Test--

A rather quick and simple test was performed to qualitatively determine the extent of sample degradation occurring within the proportional sampler. The Mustang II was operated in a steady state mode and gas samples were drawn off using the proportional sampler. These samples were analyzed using two different procedures. In the one procedure the sample was delivered directly for analysis, while in the other procedure the sample was stored in a tedlar bag for analysis following completion of the test. The analysis results from these two separate sampling procedures were compared as a way of assessing the extent of sample degradation in the tedlar bag sample.

Dilution Ratio Tests--

Dilution ratio tests were conducted to isolate and hopefully quantitate the error contribution of the gas analyzers. The Ford Mustang II was operated at a steady state condition and gas samples were collected simultaneously by the CVS and proportional sampler. Following analysis, the dilution ratio of the CVS sample was calculated by dividing each proportional sampler specie gas concentration (raw exhaust) by its corresponding CVS concentration. In this manner four dilution ratio values were calculated. Comments regarding the performance of the analyzers could be made by simply comparing the different values obtained for the dilution ratio.

Vortex Flow Meter--

An examination of the ultrasonic vortex flow meter was conducted to determine its accuracy in metering automobile exhaust gas flow. A Roots meter with a cumulative volume indicator was chosen as the reference meter for evaluating the vortex meter. The Roots meter had been checked out using a recently calibrated laminar flow element and excellent agreement was obtained for both devices over the range of flows to be examined. The Roots meter was connected to the carburetor intake through a 0.2 cubic meter buffer used to effectively dampen out flow pulsations to the Roots meter. An engine without an air pump or carburetor air bleeds was chosen because the mass of fuel and air entering the carburetor was equal to that of the exhaust gas leaving the tailpipe. With the vehicle's exhaust pipe connected to the proportional sampler, a series of steady and non-steady state tests were conducted and volume flows at both the Roots meter and proportional sampler were recorded.

Before the results could be directly compared, the flow volumes were adjusted to account for fuel addition at the engine and water vapor removal in the heat exchanger. Flow compensation at the Roots meter for downstream addition of fuel at the engine was calculated by assuming an air-fuel ratio of 14:1. Flow compensation at the vortex meter to account for water vapor removal upstream was calculated using a hot, raw exhaust water vapor content of 16.7 percent by volume. Since the exhaust gas exited the heat exchanger at 80°F, the water vapor content was reduced to 5.8 percent by volume, an overall reduction of almost 11 percent.

SECTION 5

RESULTS AND DISCUSSION

BASIC EVALUATION

Emissions of hydrocarbons, carbon monoxide, nitrogen oxides, carbon dioxide, and methane were measured from each of the test vehicles over numerous test cycles. The measurement data was broken down by vehicle and grouped according to the sampling method used when testing. Thus there were two distinct sets of data for each vehicle tested - one associated with the CVS sampling technique and a second associated with the proportional sampling. Each set of data was summarized by statistically calculating the arithmetic means ($\bar{x}$), coefficients of variation (CV), and 95 percent confidence intervals (CI). The emissions measurement summaries for each vehicle are contained in Tables 2 - 5.

To provide a good visual illustration depicting the extent of agreement between the two sampling methods, the 95 percent confidence intervals are graphically featured in Figures 3 - 7 for each gas specie measured. Where confidence intervals fail to overlap, a difference between the two sampling methods statistically exists. This difference varies for the different specie gases examined. The only consistent trend observed was that hydrocarbon measurements were high by the proportional sampler for each vehicle tested. Carbon monoxide results showed the best agreement in that only one of four displayed any significant difference. Both CO_2 and NO_x measurements were low by the proportional sampler in three out of four cases, while methane was high by the same majority. The "odd-ball" cases for CO_2 and NO_x both occurred when testing the Honda, which led to the speculation that some aspect associated with testing this vehicle was possibly affecting the results.

<u>Results of Sample Lead Time Investigation</u>

Because the most obvious feature of the Honda was its small engine size, sampling irregularities derived from this physical aspect were suspected. A hypothesis was formed that sample lead times, a phenomenon discussed in the previous section, were responsible for the proportional sampler's failure in obtaining a representative sample. To investigate this hypothesis, additional tests were run using a 2-foot flexible exhaust line between the vehicle and sampler in lieu of the regular 12-foot line. Because the 2-foot line substantially reduced the exhaust gas residence time in the line between the vehicle and the sample port, it was hypothesized that sample lead times would be minimized. Test results shown in Table 6, indicated that the measurement results were not as sensitive to changes in exhaust line length as hypothesized. Although this test did not rule out the existence of sample lead time errors altogether, it did lower the suspicions that this problem was the sole cause of the measurement differences noted in Figures 3 - 7.

Sample Degradation Test Results

The two sets of analyses carried out separately on the directly sampled exhaust gas and on the bag sample yielded the same concentration levels. These results indicated that storage of the sample over the 505 second test interval was not having any significant effect on sample integrity. The raw exhaust hydrocarbon and nitrogen oxide concentrations for the vehicles tested averaged 750 ppmc and 800 ppm, respectively. These levels are considerably lower than those observed in reference 2 where tests showed the disappearance with time of hydrocarbons and nitrogen oxides in raw exhaust bag samples. For the levels observed in this study, the reaction rates would be significantly lowered and thus it was not expected that sample integrity would be jeopardized.

Dilution Ratio Test Results

The dilution ratio test results indicate that the analyzers performed extremely well (Table 7). The average dilution ratio calculated over the steady state test was 9.37 with a coefficient of variation equal to 4 percent. During testing the raw exhaust volumes through the proportional sampler and diluted volumes through the CVS were also measured. The calculated dilution ratio based on these measurements was 8.85, a value about 6 percent lower than the dilution ratio calculated using specie gas concentrations. This suggested that the raw exhaust volumes being measured by the proportional sampler were somewhat high, assuming, of course, that the CVS was not in error.

Vortex Flow Meter Examination Results

The examination of the vortex flow meter was conducted by first using a test vehicle, and then later using a variable speed blower for exhaust gas generation through the meter. A statistical summary of the examination results, which consists of a linear regression analysis, is shown in Table 8. The values listed in the R^2 column are the squares of the multiple correlation coefficient R^2, which is defined as

$$R^2 = \frac{\text{Sum of squares due to regression}}{\text{Total (corrected) sum of squares.}}$$

The closer R^2 comes to equaling one, the better the fitted equation explains the variation in the data (6).

Use of Engine Exhaust--

Flow measurements were made with the engine operating over steady state and non-steady state modes of operation. The steady state speeds were adjusted to obtain flow measurement data over a range extending from 20 to 80 SCFM. The regression analysis data indicate that the truly strong correlation required between the two flow meters is lacking. Values for R^2 below 0.980 and slope values below 0.90 reflect less than adequate agreement between the two flow metering devices. Extremely poor values are apparent when the engine was tested over various non-steady states but these were a result more of bunched data than gross differences between the measurements. On the average, the non-steady state measurements differed by about 12 percent with a coefficient of variation equal to 56 percent. These results are still less than desirable.

In an effort to reduce flow pulsations upstream of the vortex meter, a 0.2 cubic meter buffer was added between the car and the proportional sampler. Again some steady state tests were run and, although some improvements were noted in the data, agreement between flow meters was less than desirable.

Use of Blower Exhaust--

Agreement between vortex and Roots meter readings was greatly improved when the blower was used for exhaust gas generation. As shown in Table 8, the steady state data produced results having an R^2 value and slope of 0.998 and 0.96, respectively. For each of the five tests conducted over the 20 to 80 SCFM range of flow rates examined, agreement between flow meters was always within 1.5 percent. The non-steady state results showed equal agreement. Values of R^2 and slope values were 0.999 and 0.97, respectively, and agreement over each of five tests was within 1 percent.

These results verify that the vortex flow meter in the proportional sampler experiences some difficulty in metering actual automobile exhaust. The rather significant errors observed are likely the major contributor to the differences obtained with the CVS and proportional sampler. Also of interest was the observation that the vortex meter measurements were neither consistently higher nor lower than those of the Roots meter. Both positive and negative differences were noted over the steady state tests using the engine.

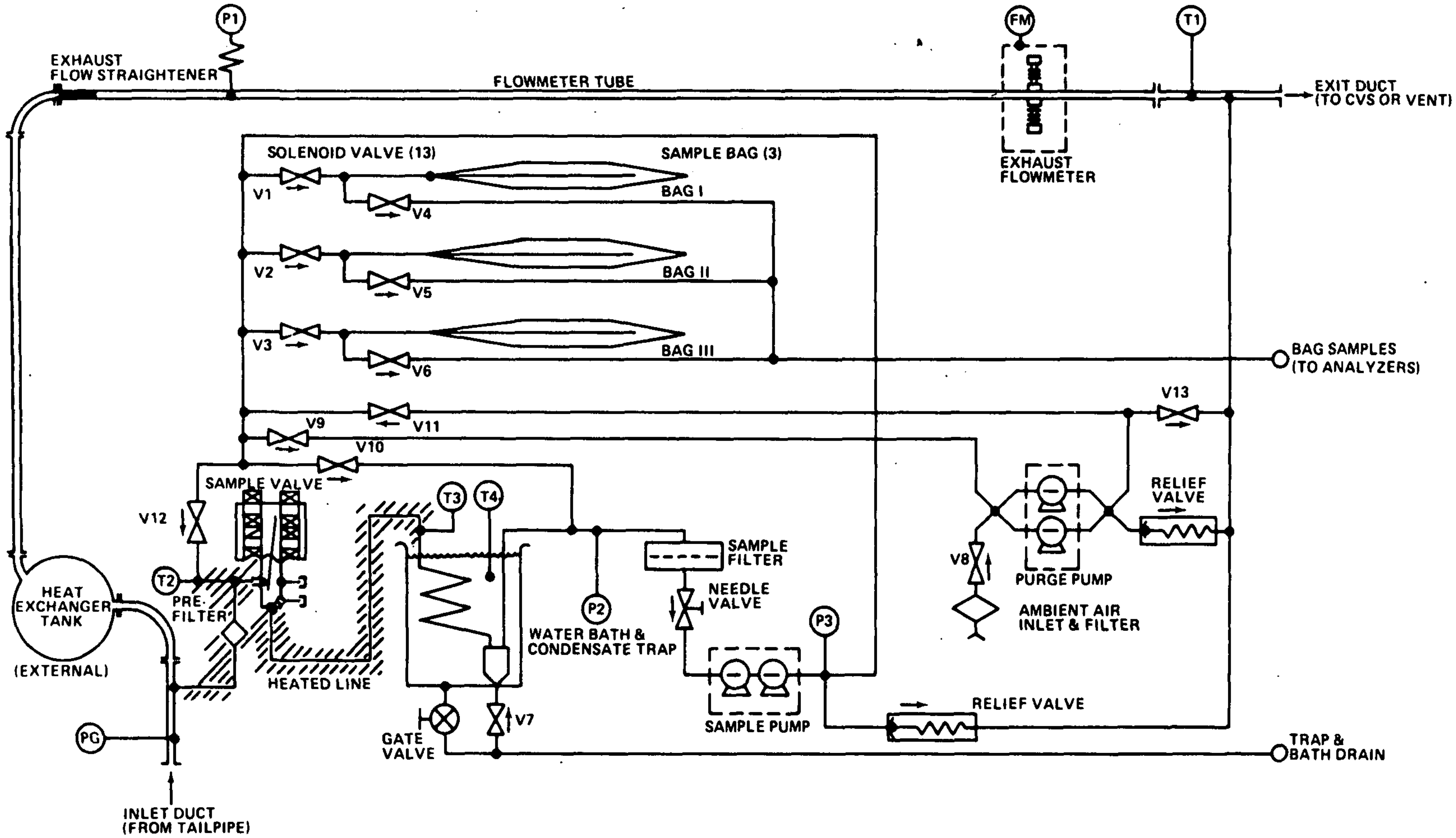

Figure 1. Proportional sampler fluid system schematic.

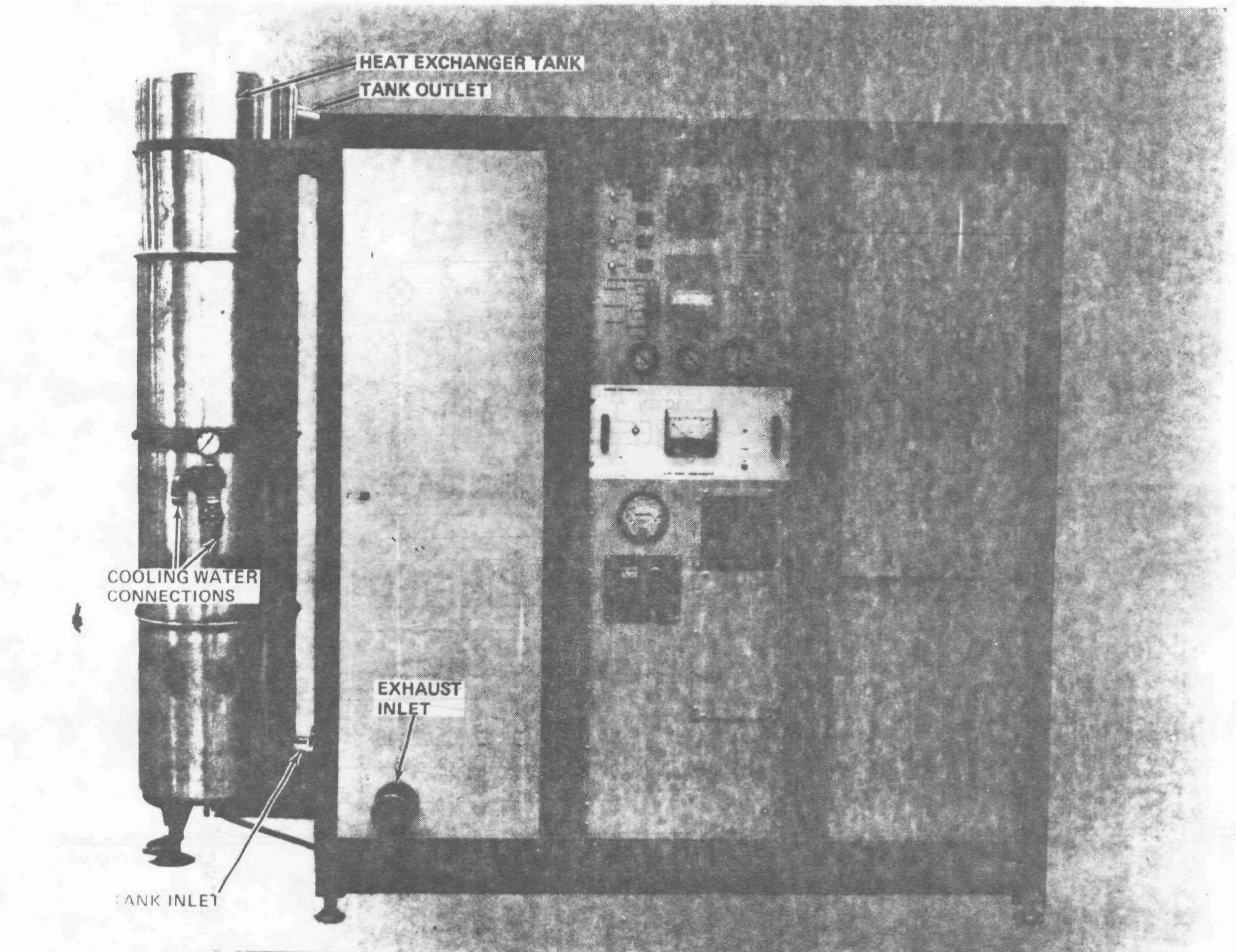

Figure 2. Proportional sampler console (front view).

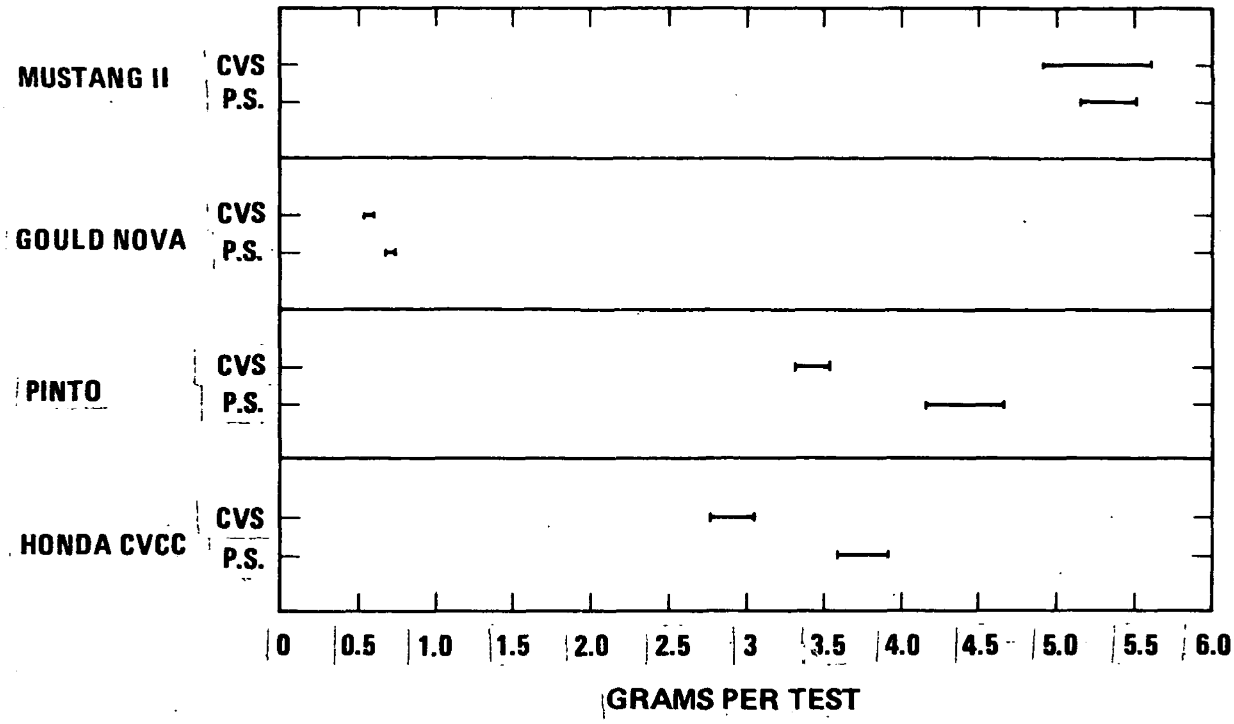

Figure 3. Hydrocarbon emission measurement comparisons - CVS vs proportional sampler.

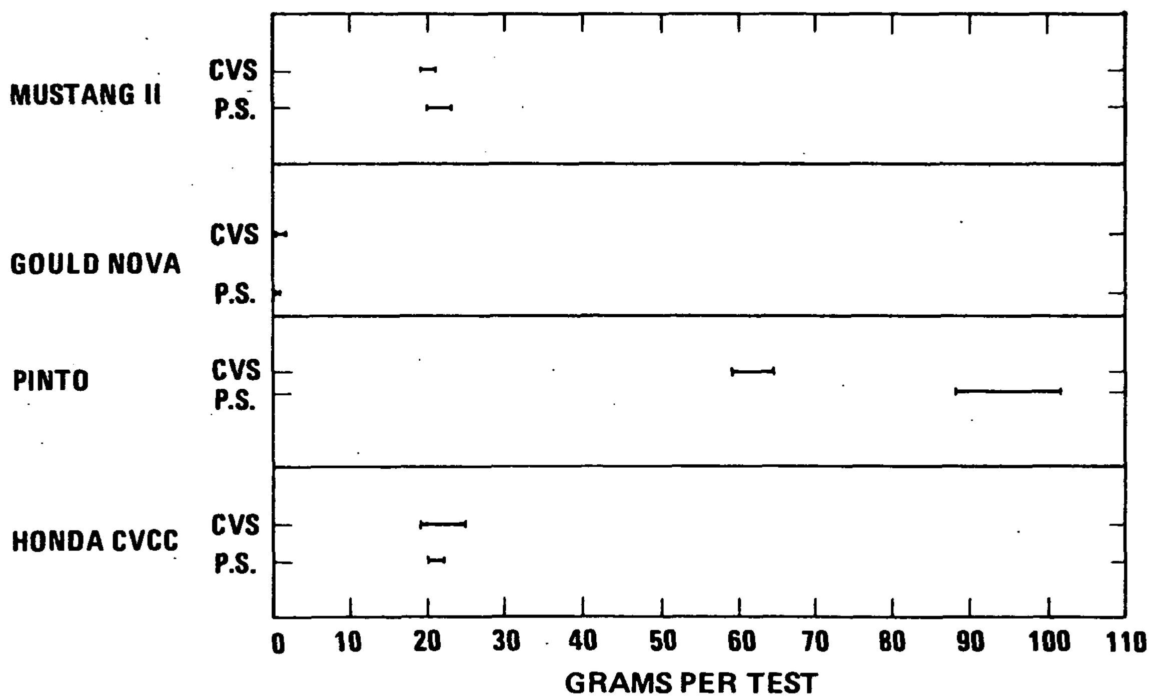

Figure 4. Carbon monoxide emission measurement comparisons - CVS vs proportional sampler.

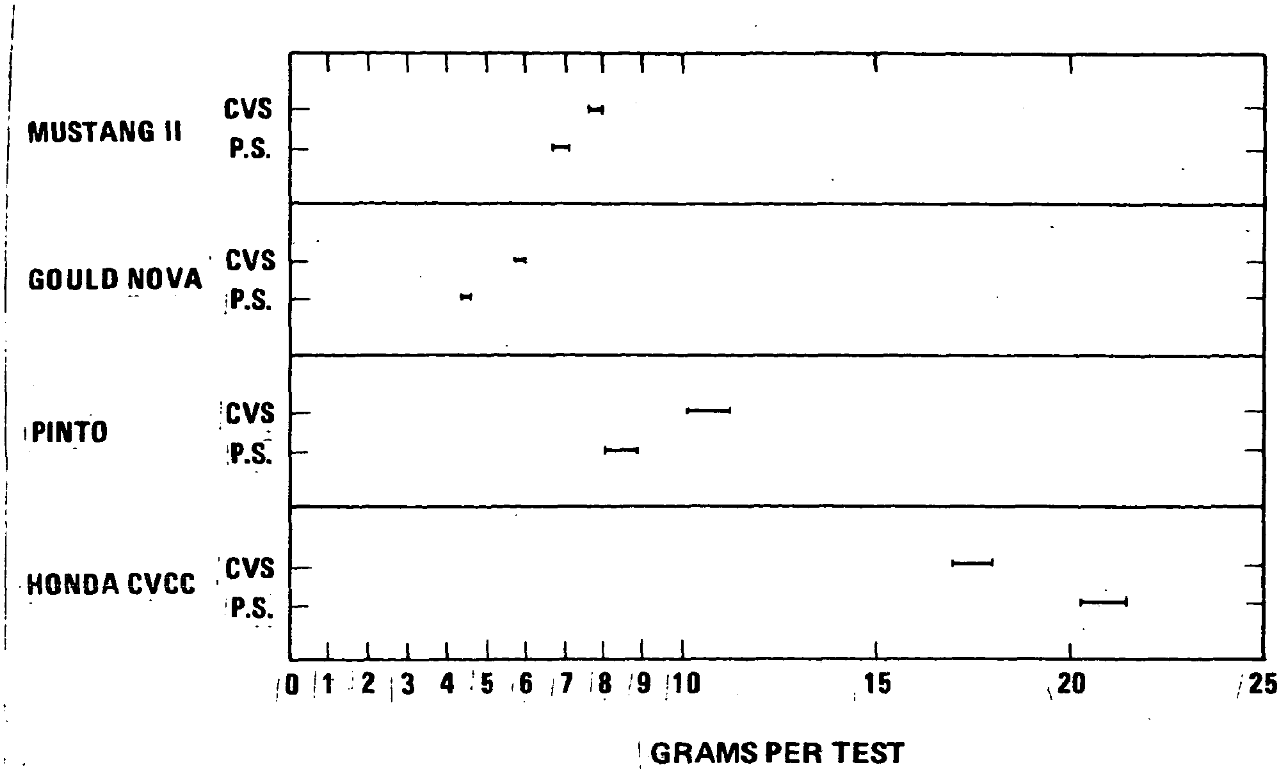

Figure 5. NO_X emission measurement comparisons - CVS vs proportional sampler.

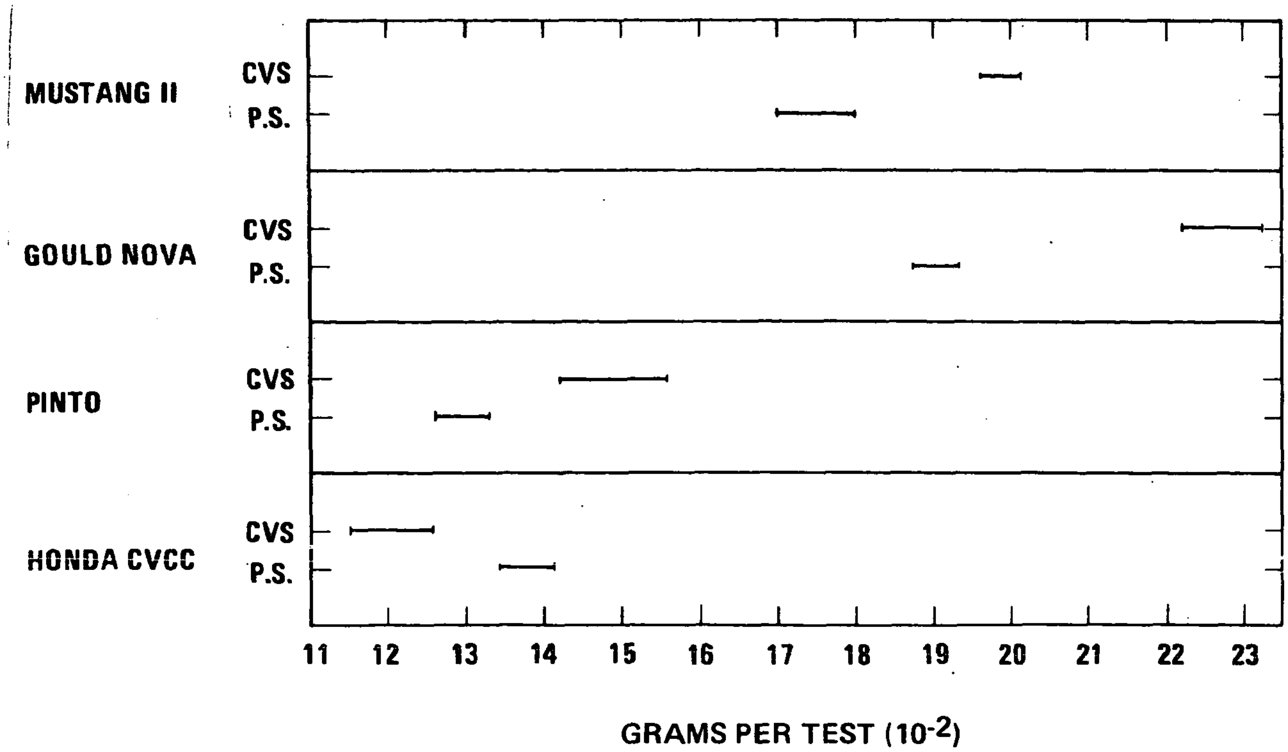

Figure 6. Carbon dioxide emission measurement comparisons - CVS vs proportional sampler.

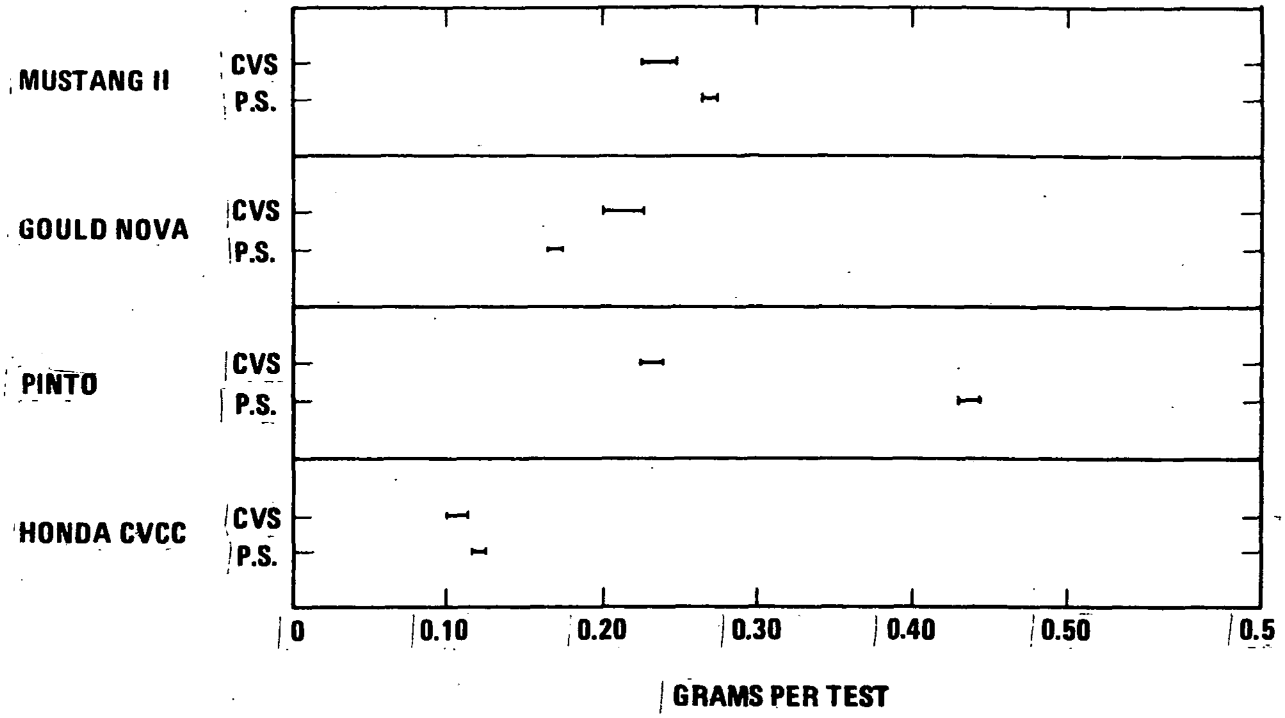

Figure 7. Methane emission measurement comparisons - CVS vs proportional sampler.

Table 1. TEST VEHICLE DESCRIPTIONS

Vehicle	Engine Size & Configuration	Primary Emission Control System
1977 Ford Mustang II	4.9 Liter Conventional V-8 2 bbl	Oxidation catalyst, Air Pump
1976 Chev. Nova (Prototype)	5.7 Liter 4 bbl Conventional V-8	Experimental Gould Oxidation Catalyst, Air Pump
1977 Ford Pinto	2.3 Liter 4 cylinder 2 bbl	Oxidation Catalyst
1976 Honda CVCC	1.5 Liter 4 cylinder 3 bbl	Stratified Charge

Table 2. FORD MUSTANG II
DATA SUMMARY

Specie Gas	Statistic	Constant Volume Sampler	Proportional Sampler
HC	$\bar{x}$	5.27 gm/test	5.33 gm/test
	CV	10%	6%
	95% CI	4.91-5.63 gm/test	5.14-5.52 gm/test
CO	$\bar{x}$	20.51 gm/test	21.97 gm/test
	CV	8%	13%
	95% CI	19.41-21.61 gm/test	20.24-23.70 gm/test
NO_x	$\bar{x}$	7.80 gm/test	6.92 gm/test
	CV	3%	5%
	95% CI	7.65-7.95 gm/test	6.71-7.13 gm/test
CO_2	$\bar{x}$	1986 gm/test	1750 gm/test
	CV	2%	5%
	95% CI	1959-2013 gm/test	1698-1802 gm/test
CH_4	$\bar{x}$	.241 gm/test	.270 gm/test
	CV	8%	4%
	95% CI	.227-.253 gm/test	.264-.276 gm/test

Table 3. CHEVROLET NOVA (GOULD CAR)
DATA SUMMARY

Specie Gas	Statistic	Constant Volume Sampler	Proportional Sampler
HC	$\bar{x}$	0.58 gm/test	0.71 gm/test
	CV	9%	7%
	95% CI	0.55-0.61 gm/test	0.68-0.74 gm/test
CO	$\bar{x}$	1.44 gm/test	0.66 gm/test
	CV	38%	35%
	95% CI	0.87-2.01 gm/test	0.53-0.79 gm/test
NO_x	$\bar{x}$	5.89 gm/test	4.50 gm/test
	CV	5%	4%
	95% CI	5.71-6.07 gm/test	4.40-4.60 gm/test
CO_2	$\bar{x}$	2272 gm/test	1905 gm/test
	CV	4%	3%
	95% CI	2217-2327 gm/test	1873-1937 gm/test
CH_4	$\bar{x}$	0.219 gm/test	0.170 gm/test
	CV	9%	6%
	95% CI	0.207-.231 gm/test	0.164-0.176 gm/test

Table 4. FORD PINTO
DATA SUMMARY

Specie Gas	Statistic	Constant Volume Sampler	Proportional Sampler
HC	$\bar{x}$	3.43 gm/test	4.41 gm/test
	CV	5%	8%
	95% CI	3.32-3.54 gm/test	4.16-4.66 gm/test
CO	$\bar{x}$	61.78 gm/test	95.03 gm/test
	CV	6%	10%
	95% CI	59.3-64.3 gm/test	88.2-101.7 gm/test
NO_x	$\bar{x}$	10.76 gm/test	8.45 gm/test
	CV	8%	7%
	95% CI	10.18-11.34 gm/test	8.03-8.87 gm/test
CO_2	$\bar{x}$	1491 gm/test	1294 gm/test
	CV	7%	4%
	95% CI	1421-1561 gm/test	1257-1331 gm/test
CH_4	$\bar{x}$	0.230 gm/test	0.460 gm/test
	CV	9%	11%
	95% CI	0.217-0.243 gm/test	0.424-0.496 gm/test

Table 5. HONDA CVCC
DATA SUMMARY

Specie Gas	Statistic	Constant Volume Sampler	Proportional Sampler
HC	$\bar{x}$	2.91 gm/test	3.75 gm/test
	CV	8%	8%
	95% CI	2.76-3.06 gm/test	3.58-3.92 gm/test
CO	$\bar{x}$	22.15 gm/test	21.29 gm/test
	CV	5%	5%
	95% CI	19.20-25.10 gm/test	20.19-22.39 gm/test
NO_x	$\bar{x}$	17.45 gm/test	20.80 gm/test
	CV	21%	9%
	95% CI	16.90-18.00 gm/test	20.17-21.43 gm/test
CO_2	$\bar{x}$	1204 gm/test	1377 gm/test
	CV	7%	5%
	95% CI	1151-1257 gm/test	1339 - 1415 gm/test
CH_4	$\bar{x}$	0.110 gm/test	0.120 gm/test
	CV	7%	5%
	95% CI	0.104-0.116 gm/test	0.114-0.126 gm/test

Table 6. COMPARISON OF EMISSION MEASUREMENT RESULTS FOR SHORT VERSUS LONG EXHAUST LINE

Specie Gas	Statistic	Short Line	Long Line
HC	$\bar{x}$	3.79 gm/test	3.71 gm/test
	CV	6%	10%
	95% CI	3.60-3.98 gm/test	3.40-4.02 gm/test
CO	$\bar{x}$	21.13 gm/test	21.43 gm/test
	CV	10%	9%
	95% CI	19.28-22.98 gm/test	19.81-23.05 gm/test
NO_x	$\bar{x}$	20.25 gm/test	21.29 gm/test
	CV	4%	6%
	95% CI	19.64-20.86 gm/test	20.26-22.32 gm/test
CO_2	$\bar{x}$	1380 gm/test	1348 gm/test
	CV	2%	7%
	95% CI	1357-1403 gm/test	1290-1406 gm/test

Table 7. CALCULATED DILUTION RATIOS

Gas Specie	Dilution Ratio
HC	8.95
NO_x	9.83
CO	9.58
CO_2	9.12
$\bar{x}$	9.37
CV	4%

CVS Volume	Raw Exhaust Volume from Proportional Sampler	8.85

Table 8. ULTRASONIC VORTEX METER
VERSUS BOOTS METER LINEAR REGRESSION ANALYSIS

VORTEX (CFM) = a + b [ROOTS(CFM)]

a = INTERCEPT

b = SLOPE

GAS GENERATOR	MODE	a	b	R^2
ENGINE	STEADY STATE	5.58	0.86	0.9333
ENGINE	STEADY STATE W/BUFFER	12.63	0.75	0.986
ENGINE	NON-STEADY	17.17	0.59	0.410
BLOWER	NON-STEADY	1.40	0.97	0.999
BLOWER	STEADY-STATE	1.34	0.96	0.998

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-600/2-77-236	2.	3. RECIPIENT'S ACCESSION NO.
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16. ABSTRACT

A test program was conducted to evaluate a proportional sampler for use in automotive exhaust gas emissions research. Automobile emissions test results obtained using the proportional sampler were compared with results obtained using the conventional constant volume sampler.

Measurements obtained using the proportional sampler for hydrocarbons, carbon monoxide, nitrogen oxides, and carbon dioxide are within 19, 46, 20, and 14 percent, respectively, of measurements obtained using the constant volume sampler. Such differences render the proportional sampler unacceptable as a quantitative research tool.

Inability of the exhaust gas flow meter to accurately measure pulsating exhaust flow is cited as the principal cause of error in the proportional sampler.

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