Technical Support Report for Regulatory Action

The Effect of Dynamometer Inertia Weight Simulation on Fuel Economy Measurements

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Standards Development and Support Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air and Waste Management
U.S. Environmental Protection Agency

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1. Introduction

1.1 Background

Exhaust emissions and fuel economy measurements made by EPA are done by sampling the vehicle's exhaust while it is operated on a Direct Drive Variable Inertia Flywheel (DDVIF) dynamometer. The vehicle is placed on the rolls of the dynamometer, and the inertia weight and horsepower specified in the Federal Register (1) for that weight vehicle are set. The inertia weight is set by engaging the proper set of flywheels to the dynamometer rolls. Since the simulation of inertia weight is done by the use of flywheels, the actual test weight of the vehicle (curb weight + 300 pounds) cannot be simulated. Instead, the nearest inertia weight setting to the vehicle's test weight is selected.

The Federal Register currently specifies inertia weight intervals of 250 pounds for vehicles between 1000 and 3000 pounds test weight and 500 pound intervals for vehicles between 3,000 and 5,500 pounds test weight for light duty vehicles. Proposed for 1978 is the requirement to test light duty trucks at weight intervals the same as for light duty vehicles but with the weight extended up to 6500 pounds test weight (curb weight + 500 pounds). In addition, some trucks above 6500 pounds test weight may be tested as light duty trucks at the manufacturers option. Weights above 5500 pounds are in 500 pounds intervals. The inertia weight-horsepower table for light duty vehicles from the Federal Register (1) and the proposed table for light duty trucks are given in Table 1-1.

1.2 Current Facilities

The equipment currently used at the EPA certification testing facility includes six light duty DDVIF dynamometers with a maximum inertia weight simulation capability of 5500 pounds. These dynamometers have the capability of simulating inertia weight in 250 pound intervals from 1750 pounds to 3000 pounds and in 500 pound intervals from 3000 pounds to 5500 pounds. Each of the dynamometers is enclosed in a test cell. In addition to these dynamometers there is a medium duty DDVIF dynamometer which is capable of testing in the weight range 4500 to 10,000 pounds in 500 pound intervals. This dynamometer is in the light duty certification soak area and is currently not enclosed in a test cell. Similar equipment to that used by EPA is found in the test facilities used by the manufacturers of light duty vehicles and light duty trucks.

Table 1-1

Inertia Weight-Road Load Table for Light Duty Vehicles and Light Duty Trucks

Loaded vehicle weight, pounds	Equivalent inertia weight pounds	Road load power at 50 m.p.h. Horsepower	
		Light Duty Vehicles (1)	Light Duty Trucks (2)
up to 1,225	1,000	5.9	9.5
1,226 to 1,375	1,250	6.5	10.3
1,376 to 1,625	1,500	7.1	11.2
1,626 to 1,875	1,750	7.7	12.0
1,876 to 2,125	2,000	8.3	12.8
2,126 to 2,375	2,250	8.8	13.6
2,376 to 2,625	2,500	9.4	14.5
2,626 to 2,875	2,750	9.9	15.3
2,876 to 3,250	3,000	10.3	16.1
3,251 to 3,750	3,500	11.2	17.7
3,751 to 4,250	4,000	12.0	19.4
4,251 to 4,750	4,500	12.7	21.0
4,751 to 5,250	5,000	13.4	22.7
5,251 to 5,750	5,500	13.9	24.3
5,751 to 6,250	6,000	14.4	25.9
6,251 to 6,750	6,500		27.6
6,751 to 7,250	7,000		29.2
7,251 to 7,750	7,500		30.9
7,751 to 8,250	8,000		32.5
8,251 to 8,750	8,500		34.2
8,751 to 9,250	9,000		35.8
9,251 to 9,750	9,500		37.4
9,751 to 10,000	10,000		39.1

(1) Light duty vehicles over 5,750 pounds loaded vehicle weight shall be tested with a 5,500 pound equivalent inertia and a 14.4 horsepower road load.

(2) Light Duty Truck Regulations are proposed for model year 1978.

1.3 Problem Statement

There are two problems with the current dynamometer equipment used for testing. First, there is inherent inaccuracy in testing due to the simulation of the vehicle's weight and road load power in intervals. Secondly, the Clayton DDVIF dynamometer in use by EPA and the light duty vehicle and truck manufacturers does not have the capability to test vehicles above 5500 pounds equivalent inertia weight.

The problem of the inherent inaccuracy due to testing in intervals can best be visualized by means of an example. Under the current requirements a vehicle whose test weight is 3250 pounds is tested at 3000 pounds inertia with a horsepower setting of 10.3 horsepower. Likewise, a vehicle whose test weight is 3251 is tested at 3500 pounds at a horsepower setting of 11.2 horsepower. These two vehicles are essentially the same weight, but the vehicle tested at 3500 pounds is required to move a weight 500 pounds greater than the vehicle tested at 3000 pounds and operate against a road load power 0.9 horsepower greater. Thus, the vehicle tested at 3500 pounds must work harder to operate during the driving cycle and higher exhaust emissions and lower fuel economy values would be expected.

The inertia weight and road load power absorbtion simulation are dependent on the weight of the vehicle and table values based on the test weight are used. Data presented in this report indicate the effects on fuel economy of varying both inertia weight and road load power absorbtion simultaneously according to the requirements of the Federal Register (1). Thus, for the duration of this report only improvements in inertia weight simulation will be considered with the assumption that this would also include similar improvements in road load power simulation. In the future, road load power simulation could be made more accurate independent of inertia weight simulation, and thus improvements could be made beyond those discussed. This report will primarily deal with improvements in inertia weight simulation and its effect on the accuracy of fuel economy measurements. It is assumed that any improvement in the accuracy of measuring fuel economy levels will also improve the accuracy of exhaust emission measurements. Fuel economy measurements are considered more critical because these values are used to rank vehicles according to their fuel economy capabilities. This, in turn, can affect vehicle marketability. Improving the accuracy of exhaust emission measurements is also important and this would occur with any improvement in inertia simulation. However, this report will limit its discussion to fuel economy accuracy.

The ideal situation would be to test a vehicle at its actual test weight. However, this level of accuracy in simulation is difficult to justify due to its relatively high cost and the fact that other sources of inaccuracy influencing the test results may be improved more cost effectively. The fundamental sources of test variability are discussed later in this report. There is also variability in the weight of the same vehicle model from one vehicle to another. Thus, the optimum situation may be described as simulating the test weight of the vehicle closely enough such that the inaccuracy in fuel economy measurements due to weight simulation is small compared to overall test variability, and of a similar magnitude as other sources of error. Since the cost of simulating a vehicle's test weight increases as greater accuracy is achieved, practical considerations need to be kept in mind.

In order to decide what degree of simulation is required, the magnitude of other errors and the magnitude of overall test variability must be examined. With this knowledge, a reasonable level of accuracy may be chosen. Coupling the desired levels of accuracy with information relating the effect of inertia weight on actual fuel economy values will provide the means to select an appropriate inertia weight simulation interval. This is the primary objective of the investigation.

The secondary objective is to examine alternative dynamometer configurations which can be used to achieve improved inertia weight simulation as well as to provide the expanded range of weights necessitated by the proposed regulations on light duty trucks.

2. Technical Discussion

2.1 Variability

Variability continues to be an important factor when considering fuel economy and exhaust emission testing. In a general sense, variability may be interpreted as the inability to duplicate previous results. Variability in vehicle testing may be described as the inability to obtain exactly the same fuel economy or emissions results while striving to recreate the original testing conditions. There are several fundamental sources of variability: (1) the vehicle being measured, (2) the measuring process, (3) the personnel, and (4) the environmental conditions.

1) The Vehicle Being Measured. When considering chassis dynamometer testing, there are many potential sources of variation in the vehicle itself. There are limited data available to establish the respective contributions to overall test variability.

a) Vehicle preparation. Vehicle preparation prior to testing involves physical handling of several components that could affect subsequent test results. Differences in handling the fuel induction system, for instance, could result in different evaporative canister loading. Soak time and soak temperature could affect the condition of the intake manifold, choke system, and exhaust treatment devices which, in turn, could affect the test results.

b) Sensitivity inherent in the design of the vehicle. Carburetor calibration, EGR calibration, evaporative system and fuel system design are different for various vehicles. Under given test conditions each system may respond in a different manner. Even in vehicles with identical components, there exists variability due to slight differences in each component and their interactive effects on the entire system.

2) The Measuring Process. When reviewing total test variability, the measuring process has a significant impact. Each piece of equipment contributes to the test variability depending on its precision and repeatability.

Fundamentally, accuracy can be viewed as the level of observation one chooses to accept. The smallest unit of measurement (also called "least count") should be selected to adequately reflect the desired level of observation. A level of observation should be chosen based on technical needs, but also with an awareness of the equipment available to meet those needs. A device or system whose accuracy exceeds the immediate need, however, may prove cumbersome, overly complicated, and invariably more expensive. Accuracy, as applied to the field of chassis dynamometer testing, might be explained through the example of inertia flywheel weight selection. It will be shown later that the existing limitation in flywheel selection systematically biases the fuel economy results. The magnitude of this bias is directly related to the accuracy in simulating the vehicle inertia.

Repeatability is the ability to produce consistent results when subjected to the same conditions. When the repeatability faulters, the intended accuracy becomes less meaningful. In other words, even though a device or system has the capability of extremely accurate measurements, this benefit is reduced if the device or system is unable to satisfactorily repeat the values. One source estimates the maximum variability of the measuring process to be ±5% for replicate testing (2). Restated, this estimates the maximum repeatability error to be ±5%. Several fundamental sources of equipment-related variability should be considered:

a) Dynamometer. The data presented in Table 2-1 establishes the estimated error in fuel economy values associated with the current inertia increment schemes. This systematic bias may be minimized through better inertia weight simulation. The repeatability of the current dynamometer system, however, is yet another factor contributing to test variability. It has been estimated that the present direct drive variable inertia flywheel (DDVIF) system has a repeatability error of ±2.5% (2).

b) Constant volume sampler. Factors affecting the variability of this piece of equipment could be any of the following: temperature and pressure fluctuations, non-proportionate sampling, varying blower flow characteristics, leaks or condensation. The repeatability error estimated for this part of the measuring process is ±1.0% (2).

c) Analyzer system. Instrument technology has kept pace reasonably well with the demand to measure very low concentrations of pollutants. However, variability still exists and must be considered when performing fuel economy tests. Common sources of variability include stability (drift), interference from water vapor or other gases and flow rate stability. A prime source of variability in this area is the calibration gas. The variation attributed to this portion of the measuring process could be expected to be on the order of ±0.5% (2).

3) The Personnel. The inability of one person to consistently duplicate a specific technique is a prime source of variability in test results. The variability increases with the number of persons utilized in the testing.

4) The Environmental Conditions. Barometric pressure, humidity, temperature, and air circulation in the test site may influence the test results from the vehicle, and thus any variation in these parameters introduces variability. These factors combined could be expected to influence the repeatability by ±1% (2).

2.2 Criteria for Selecting an Acceptable Inertia Weight Interval Scheme

The weight of a vehicle affects both the exhaust emissions and fuel economy capabilities. A decrease in vehicle weight will generally result in lower exhaust emissions and greater fuel economy. Thus, there is a real advantage in reducing the weight of a vehicle and the auto manufacturers should be encouraged to do so. There is currently an incentive to the auto manufacturers to take enough weight out of their vehicles such that they will be tested at the next lower weight class. Because of the size of the current weight intervals, it is very difficult to take enough weight (as much as 500 pounds) out of some vehicles. The manufacturers are expected to concentrate primarily on reducing the weight of vehicles which are just above the cut-off weight between inertia weight classes so that the goal of having the vehicles tested at the lower weight can be achieved for a minimum of effort. Therefore, one criterion for establishing the proper weight intervals is to have them small enough so that there is an incentive to reduce weight in all vehicles. Any reduction in the current interval size will help to increase the incentive to reduce weight.

If the manufacturer does take a small amount of weight out of a vehicle and thereby qualifies to be tested at a lower weight, the resulting test will show a much larger apparent increase in the fuel economy of that vehicle than was actually achieved by the small weight reduction. For example, consider the case of a 2,376 pound vehicle which is required to be tested at an inertia weight setting of 2500 pounds. Data indicate that a test on the same vehicle at an inertia weight setting of 2250 pounds would result in a 1.0 mpg higher fuel economy value. Thus, as the vehicle is currently tested, the result is 0.5 mpg lower than the actual fuel economy of that vehicle. By reducing the vehicle's weight one pound to 2375 pounds, the vehicle is then required to be tested at 2250 pounds. The small reduction in weight of one pound would have a very small effect on the actual fuel economy of the vehicle, but the apparent fuel economy benefit is 1.0 mpg better than the result when it was tested at 2500 pounds, and it is roughly 0.5 mpg better than the vehicle's actual fuel econony. Thus, there currently exists the problem that when a vehicle's weight is near the cut-off weight between two inertia weight classes, the measured or apparent fuel economy can be lower or higher than the vehicle's actual fuel economy. This problem is inherent when inertia weight intervals are used. It is desirable to reduce these inherent errors as much as practicable and this can be accomplished by reducing the weight interval size. Therefore, reducing the interval size can provide weight reduction incentives for more vehicles, and more accurate test results. Achieving smaller and smaller inertia weight increments is progressively more expensive and progressively complicates the test. Therefore, the largest acceptable interval must be determined.

The selection of the most desirable interval is somewhat subjective and depends on which criterion seems to be the most important (i.e., incentive for weight reduction, test accuracy, lowest equipment cost, test simplicity). The accuracy of the fuel economy test is such that the final values are currently rounded to the nearest whole mile per gallon. The fuel economy value that is reported is, therefore, within ±0.5 mpg of the value measured. One could select an inertia weight interval scheme such that the error associated with testing the vehicle at the weight class immediately above or below the proper weight class would result in an error no larger than 1.0 mpg. An inertia weight interval scheme which allowed anything greater than a 1.0 mpg error would have an inherent

Vehicle Weight	% change in weight to get to next class	% change in Fuel Economy		Change in Fuel Economy (mpg)	
		Ref. 1	Ref. 2	Ref. 3	Ref. 2
2000	12.5	5.0	4.1	1.5	1.2
2250	11.1	4.1	4.1	1.1	1.1
2500	10.0	2.7	4.2	.6	.9
2750	9.1	2.4	4.0	.6	1.0
3000	16.7	5.9	7.8	1.1	1.4
3500	14.3	6.9	6.4	1.1	1.0
4000	12.5	7.0	5.4	1.1	.8
4500	11.1	5.0	3.9	.8	.6
5000	10.0	4.9	2.8	.6	.4
5500	9.1	5.1	2.2	.6	.4

Table 2-1 Changes in Fuel Economy Due to Testing Vehicle at Next Highest Inertia Weight Class.

possible error of 2.0 mpg due to the fact the fuel economy values are rounded to the nearest whole mile per gallon. Unless the vehicle could be tested at its actual weight there would always exist the possibility that a 1.0 mpg error could occur when the measured fuel economy value is rounded. Therefore, limiting the fuel economy error to 1.0 mpg due to errors in inertia weight simulation is desirable and further limiting this error would merely serve to reduce the probability that a test at the next lowest weight class would result in a 1.0 mpg higher reported fuel economy value. The incentive to reduce weight could, in fact, be reduced if an interval scheme were used that would result in low probabilities that the reported value would increase by 1.0 mpg if the vehicle could be tested at the next lowest weight class.

2.3 Effect of Inertia Weight on Fuel Economy

The data in Table 2-1 indicate the actual and percent errors which result when a vehicle of the weight shown is tested at the next highest inertia weight. The data shown from Reference (3) is based on 127 data entries. Data from this source will be the one primarily used in any further evaluation. Similar data from Reference (4) indicates that, while the values are not identical with those from Reference (3), they are very similar. Comparing these data also serves to illustrate another important fact concerning fuel economy errors as they relate to inertia weight changes. There is a wide scatter of such data between vehicles.

Summarizing and extrapolating these data show that, with the current inertia weight increments, actual errors as large as 1.6 mpg can occur when testing is done at an inertia weight above or below the proper one for the vehicle's test weight and these errors occur at the lowest inertia weight class that is currently used for testing (1750 pounds). In addition, a maximum percent error as large as 7% can occur at the 4000 pound inertia weight class. An error as large as 1.6 mpg is unacceptable with respect to the previous discussion in that it could allow a change in the measured fuel economy of 2 mpg when a vehicle is tested at the next lowest weight class. Such errors could create situations in which the relative ranking of vehicles is incorrect. Therefore, an inertia weight class scheme which reduces these errors should be proposed.

2.4 Alternative Solutions

1) Take No Action. As was stated earlier, the current situation is one in which there exists a possibility of errors as large as 2.0 mpg resulting from small reductions in vehicle weight. The marketability of vehicles is becoming increasingly dependent on the fuel economy of the vehicle relative to other vehicles, and thus taking no action to improve the current inertia weight simulation is undesirable. Also, the fuel economy values generated by the test should be reasonably accurate so that the consumer can predict his expected operating costs prior to

purchasing a vehicle. The percent errors associated with the current weight interval scheme are such that substantial errors as large as 3.5% in this estimate can be made. For these reasons, some improvement in simulation should be pursued.

2) Establish Correction Factors. If accurate correction factors could be established, the errors due to systematic inertia weight errors could be greatly reduced. This alternative would not require modification of the current dynamometers used by EPA or by the industry, and thus projected equipment costs would be zero. The cost to establish good correction factors could, however, be substantial. Studies done by Murrell (5) indicate that the error varies with weight and thus the correction factor would have to vary depending on the weight of the vehicle. In addition the correction factor could also be a function of other vehicle parameters such as engine size and possibly axle ratio. It would be very costly to establish tables of correction factors based on all of these factors, and the values would have to be verified in the future should substantial vehicle modifications be made. If great pains were not taken to assure that the correction factors were accurate, manufacturers could contend that the correction factors applied to their vehicles were unfair. Further, manufacturers could be expected to optimize vehicle design to take advantage of the parameters employed in a correction factor which could negate the validity of the basis upon which they were generated. Such contentions could grow more serious due to new legislation which requires certain fuel economy levels to be met. For these reasons it is not recommended that improving the current inertia weight simulation be accomplished by the use of correction factors.

3) Use Smaller Inertia Weight Increments. In order to simulate inertia weight closer to the actual test weight of a vehicle, additional inertia weight flywheels will be required on existing dynamometers. Electric dynamometers would also provide this feature. The cost of adding flywheels to the dynamometers currently used both at EPA and throughout the vehicle industry would be much lower than purchasing new electric dynamometers and thus the addition of flywheels is the only alternative which will be considered further. The addition of a 125 pound flywheel to the current dynamometers would approximately halve the current errors. The addition of both a 62.5 pound flywheel plus a 125 pound flywheel would cut errors roughly by one-fourth. The addition of yet smaller flywheels would progressively reduce errors. Similarly, however, the addition of one flywheel would roughly double the number of inertia weight classes and the number of dynamometer settings. Likewise, two flywheels would roughly quadruple the number of classes. Also, the equipment cost would increase with an increasing number of additional flywheels. Thus, adding flywheels can reduce the errors associated with inertia weight simulation, but it is desirable to only add enough flywheels to obtain an acceptable level of accuracy.

Figure 2-1 shows the required intervals needed to meet various accuracy criteria. The errors discussed are errors resulting from testing at the next highest or next lowest weight interval. This figure was constructed based on the data in Table 2-1. This figure shows that a 5% maximum error is achievable by merely extending the 250 pound intervals to the 4500 pound weight class. However, this still allows for up to a 1.6 mpg error for the lightest weight vehicles. The addition of a 125 pound flywheel will limit errors to a maximum of 1.0 mpg and 5%. With the addition of a 125 pound flywheel, the maximum error occurs at roughly the 3000 pound weight class. If the use of 125 pound intervals is extended to 4000 pounds, the maximum error occurs at both the lowest weight class and the 4000 pound weight class. This maximum error is 3% or 0.8 mpg when the vehicle is tested at the next lower or higher weight class. Thus, a 125 pound flywheel can reduce errors substantially and can meet the requirement of an error no greater than 1.0 mpg even at the lowest weights.

The addition of a 62.5 pound flywheel will insure errors less than 0.5 mpg and 2.5%. But, since errors no greater than 1.0 mpg can be achieved by using only a 125 pound flywheel, the use of a 62.5 pound flywheel would primarily add cost and complexity. Thus, the recommended course of action is to add a 125 pound flywheel to the dynamometer and use the 125 pound intervals from 1500 to 4000 pounds, the 250 pound intervals from 4000 to 5500 pounds, and the 500 pound intervals above 5500 pounds. This would require the addition of a 125 pound inertia weight wheel to current light duty DDVIF dynamometers. This inertia weight scheme insures that errors in the actual fuel economy values due to the inertia weight simulation are no greater than 0.4 mpg at any test weight.

Currently, there are few vehicles which are required to be tested below the 1750 pound weight class. However, in the future, vehicles are expected to become increasingly lighter and, therefore, it is recommended that the capability to test vehicles at weights down to 1500 pounds be obtained.

2.5 Lead Time

If smaller inertia weight increments are required for testing vehicles in the future, it will take time to produce, deliver, and install the needed equipment for dynamometers at EPA and throughout the industry. Some manufacturers may require slight modifications while others may require modifications as extensive as those needed at the EPA test facility.

Currently, there are approximately 300 dynamometers in the field of the type used at EPA. It would take at least 120 days to produce and deliver the equipment to modify 20-30 dynamometers. In 180 days

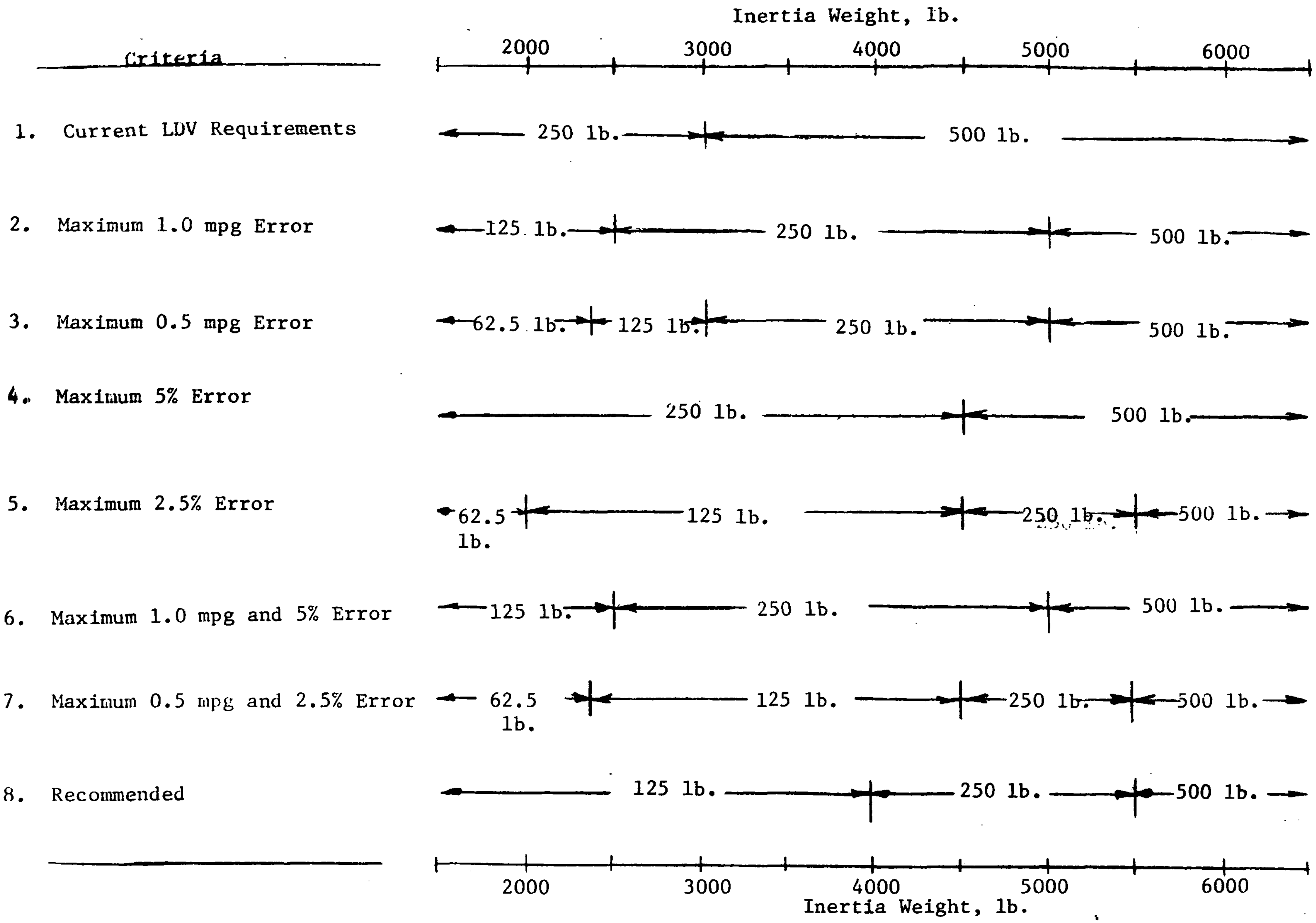

Figure 2-1 Inertia Weight Increment Ranges Required to meet various criteria.

equipment could be supplied for 75 dynamometers, and it would take roughly 360 days to equip 175 dynamometers. Thus, based on these estimates by Clayton Manufacturing Co., it would take approximately one year to equip half of the dynamometers in the field.

In addition to these production and delivery times, time will be required for equipment installation. This time will depend on the extent of the modification. If no modification to the dynamometer pit is required, it would take about one week to install the needed equipment. Depending on the extent of pit modifications required, this time changes.

3. Dynamometers

The following dynamometer layouts are intended to familiarize the reader with the existing light duty vehicle (LDV) certification dynamometer configuration and the dynamometer configurations which might be employed to satisfy the following requirements:

1) Inertia weight simulation up to 6,500 pounds.

2) Finer increments in the inertia weight simulation (to improve fuel economy error).

Each configuration has associated with it certain advantages and disadvantages. These considerations have been addressed where possible. It is understood, however, that each dynamometer user has a specific set of requirements. What may be an advantage to one user, may be a disadvantage to another user. These dynamometer configurations have been evaluated with respect to the requirements previously mentioned and apply specifically to the facilities at the Motor Vehicle Emission Laboratory, Ann Arbor, Michigan.

3.1 Current Dynamometer Configuration.

Light duty vehicle certification work is performed exclusively on the Clayton Direct Drive Variable Inertia Flywheel (DDVIF) dynamometer equipment. Figure 2-2 displays the general equipment design.

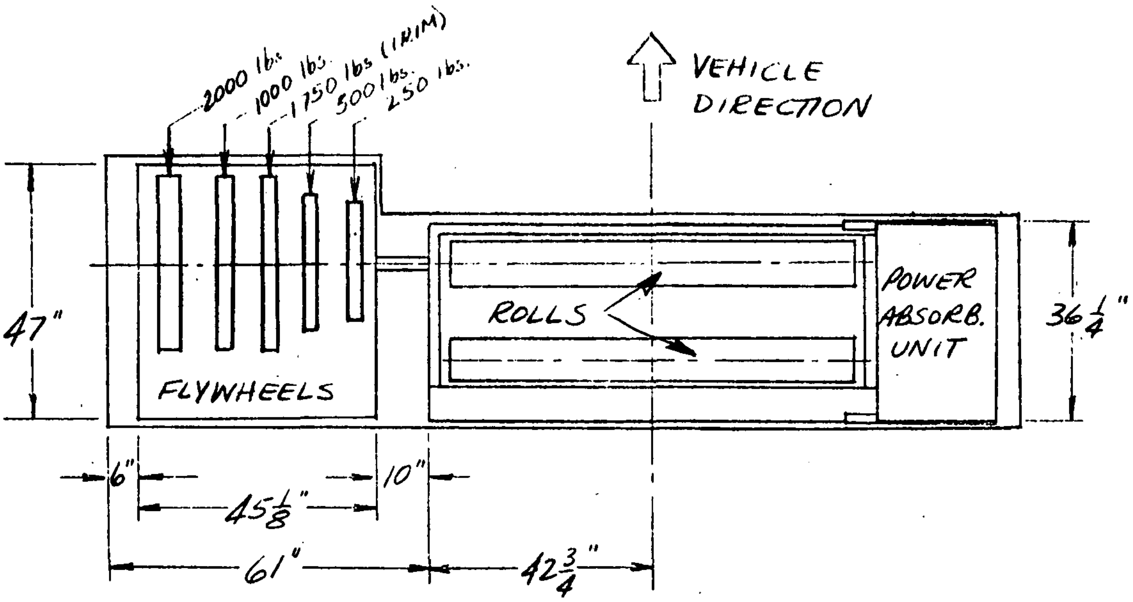

Figure 2-2 Current Equipment Design

This design consists of several fundamental systems:

1) Rolls. Two rolls are used to provide the interface between the vehicle drive wheels and dynamometer.

2) Power Absorption Unit. This component provides the capability of simulating actual road load at the vehicle drive wheels. Basically, it is comprised of a water brake which is capable of absorbing a maximum of 50 horsepower.

3) Inertia Weight Flywheels. The inclusion of these weights provides for the simulation of actual vehicle inertia. The current system of weights is capable of simulating from 1,750 pounds to 5,500 pounds. These weights can be easily switched in or out to provide the test weights shown in Table 2-2.

	FLYWHEEL WEIGHTS				
TEST WEIGHT	1750	250	500	1000	2000
1750	X				
2000	X	X			
2250	X		X		
2500	X	X	X		
2750	X			X	
3000	X	X		X	
3500	X	X	X	X	
4000	X	X			X
4500	X	X	X		X
5000	X	X		X	X
5500	X	X	X	X	X

Table 2-2 Engagement Chart for Current Equipment

The dynamometer configurations to follow are similar to the current equipment in basic design. All configurations shown are of the Clayton type. Let it be restated that the relative merits of these configurations are based specifically on the comparison with the equipment currently used in the Motor Vehicle Emission Laboratory.

3.2 Configuration A.

Shown in the diagram below (Figure 2-3), is a configuration which would satisfy both requirements set forth earlier.

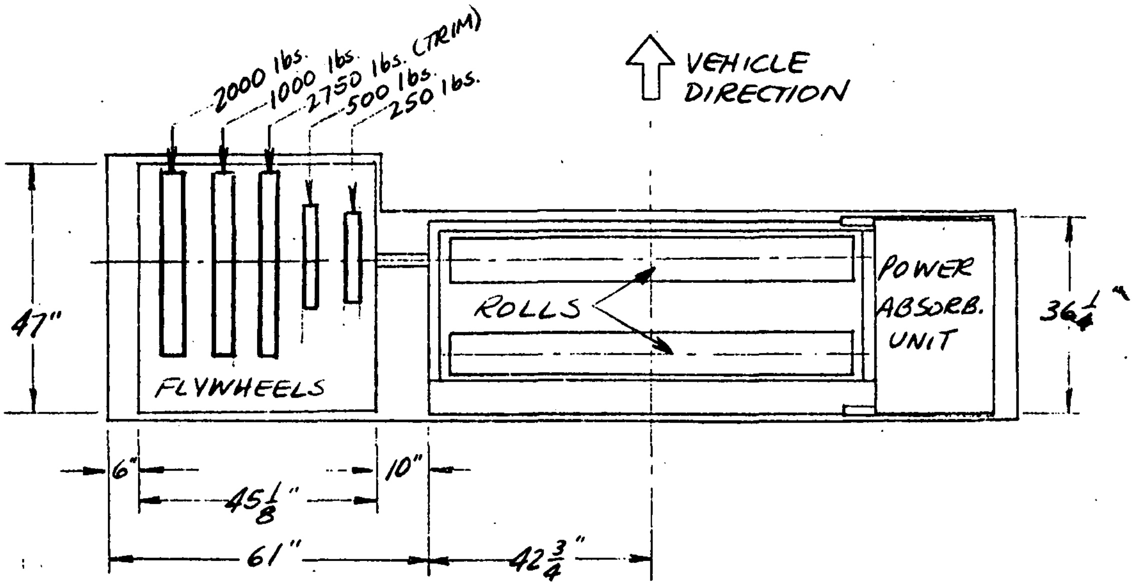

Figure 2-3 Equipment Design for Configuration A

The system could be placed in the existing dynamometer enclosure without alterations. The system would be capable of testing up to 6,500 pounds inertia and would provide a 250 pound increment up to 5,000 pounds, and a 500 pound increment up to 6,500 pounds. However, one serious drawback to this system is that it is incapable of simulating inertia weights less than 3,000 pounds. Table 2-3 displays the inertia weight combination available with this system.

	FLYWHEEL WEIGHTS				
Test Weight	2750	250	500	1000	2000
3000	x	x			
3250	x		x		
3500	x	x	x		
3750	x			x	
4000	x	x		x	
4250	x		x	x	
4500	x	x	x	x	
4750	x				x
5000	x	x			x
5500	x	x	x		x
6000	x	x		x	x
6500	x	x	x	x	x

Table 2-3 Engagement Chart for Configuration A

The equipment cost to modify an existing dynamometer in this manner would be approximately $1,650. Installation would be estimated to be $1,200, bringing the total package cost to $2,850.

3.3 Configuration B.

Shown in Figure 2-4 is a dynamometer system which would complement configuration A.

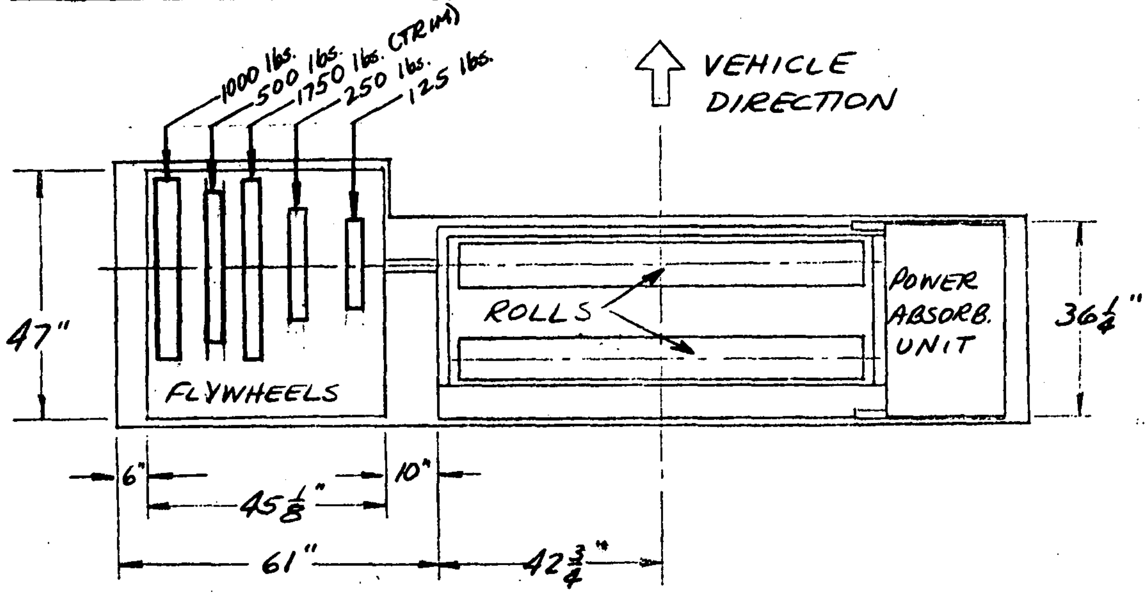

Figure 2-4 Equipment Design for Configuration B

The modification could be done without altering the dynamometer enclosure. The system would be capable of simulating inertia weights from 1,750 to 3,500 pounds. Inertia weight increments would be 125 pounds up to 3,000 pounds inertia, and 250 pounds up to 3,500 pounds inertia. The corresponding drawback to this configuration is that inertia weight simulation is limited to 3,500 pounds.

	FLYWHEEL WEIGHTS				
Test Weight	1750	125	250	500	1000
1750	x				
1875	x	x			
2000	x		x		
2125	x	x	x		
2250	x			x	
2375	x	x		x	
2500	x		x	x	
2625	x	x	x	x	
2750	x				x
2875	x	x			x
3000	x		x		x
3250	x			x	x
3500	x		x	x	x

Table 2-4 Engagement Chart for Configuration B

The equipment cost would be approximately $600 to modify an existing dynamometer. The installation cost would be approximately $1200, bringing the estimated cost of the package to $1,800.

3.4 Configuration C.

Figure 2-5 displays a dynamometer system which could be obtained with slight modification to the dynamometer enclosure.

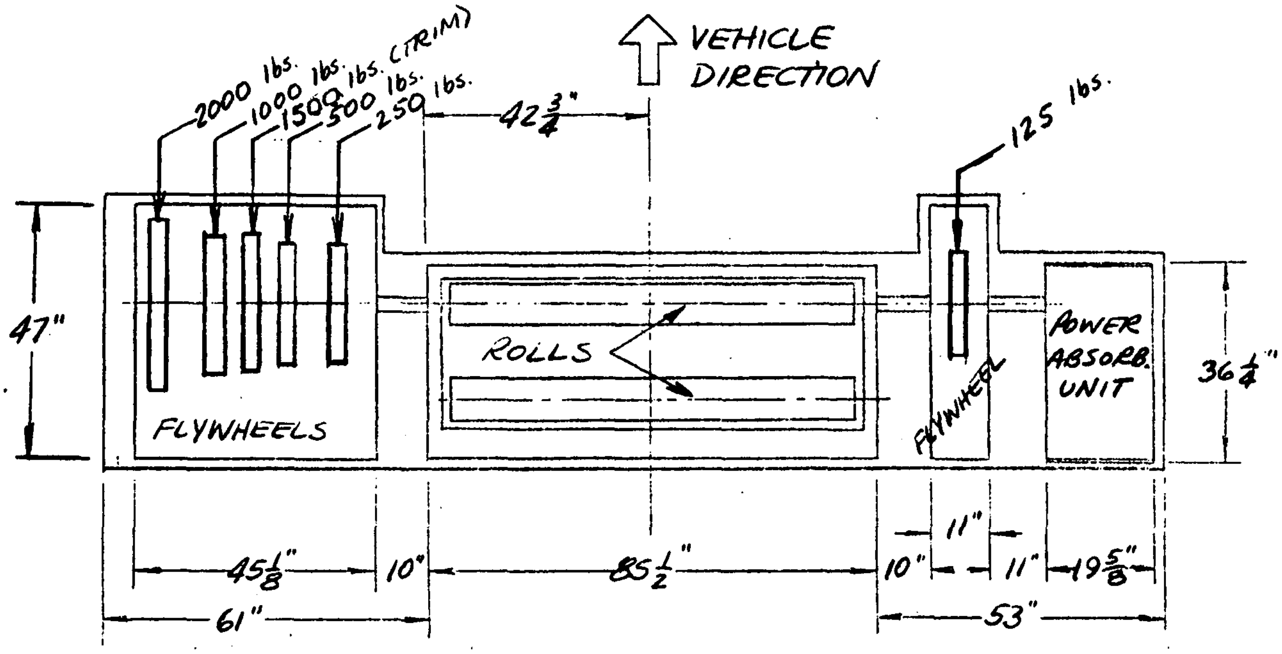

Figure 2-5 Equipment Design for Configuration C

This system would be capable of simulating inertia weights from 1,500 to 5,250 pounds. Inertia weight simulation up to 4,000 pounds would be in increments of 125 pounds. Above 4,000 pounds inertia, the increment would be 250 pounds. Table 2-5 displays the combinations available.

	FLYWHEEL WEIGHTS					
Test Weight	1500	125	250	500	1000	2000
1500	x					
1625	x	x				
1750	x		x			
1875	x	x	x			
2000	x			x		
2125	x	x		x		
2250	x		x	x		
2375	x	x	x	x		
2500	x				x	
2625	x	x			x	
2750	x		x		x	
2875	x	x	x		x	
3000	x			x	x	
3125	x	x		x	x	
3250	x		x	x	x	
3375	x	x	x	x	x	
3500	x					x
3625	x	x				x
3750	x		x			x
3875	x	x	x			x
4000	x			x		x
4250	x		x	x		x
4500	x				x	x
4750	x		x		x	x
5000	x			x	x	x
5250	x		x	x	x	x

Table 2-5 Engagement Chart for Configuration C

The estimated equipment cost to modify an existing dynamometer would be $2,000. Installation would be expected to be on the order of $2,000, bringing the total package cost to $4,000. However, since this dynamometer system does not provide testing capability up to 6,500 pounds inertia, it would have to be accompanied by one or more dynamometers capable of doing so in order to fulfill the stated objectives.

3.5 Configuration D.

This dynamometer package would also necessitate modifying the dynamometer enclosure. The inertia weight simulation capability would be from 1,500 pounds to 6,500 pounds. This capability may be achieved using either of the two following configurations shown in Figures 2-6 and 2-7.

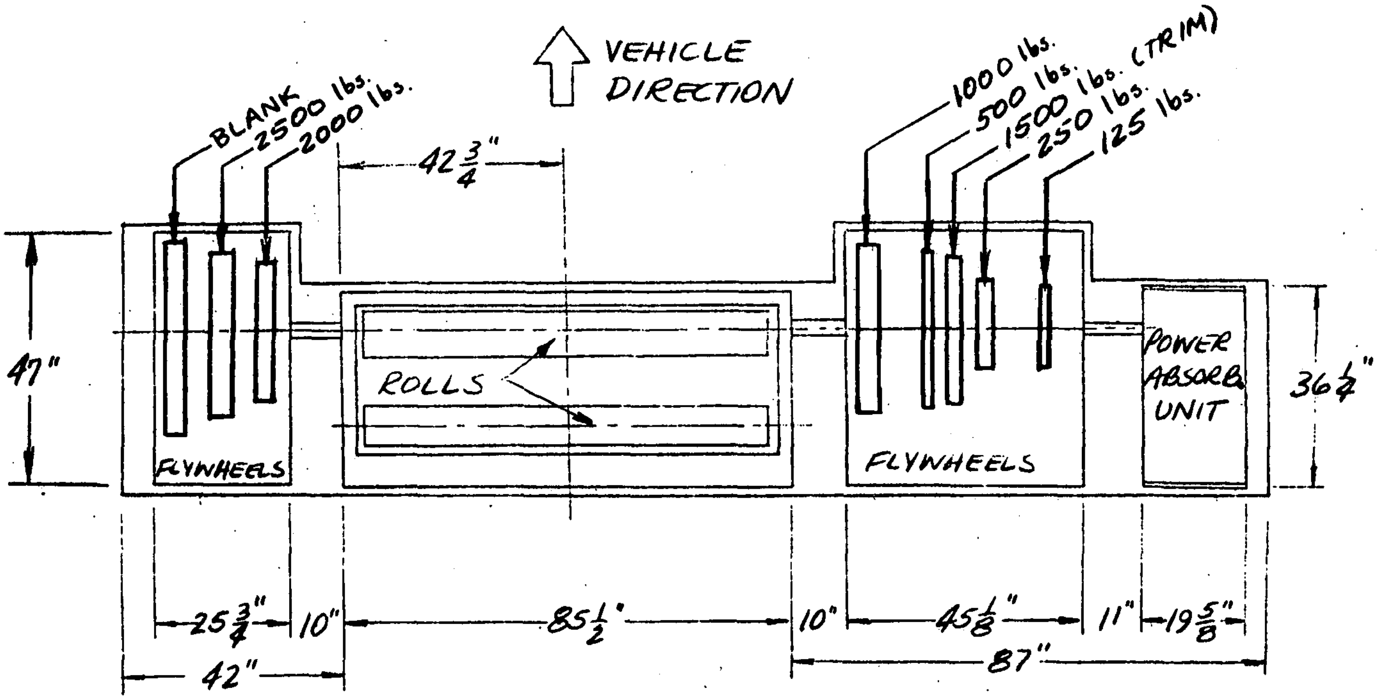

Figure 2-6 Equipment Design for Configuration D

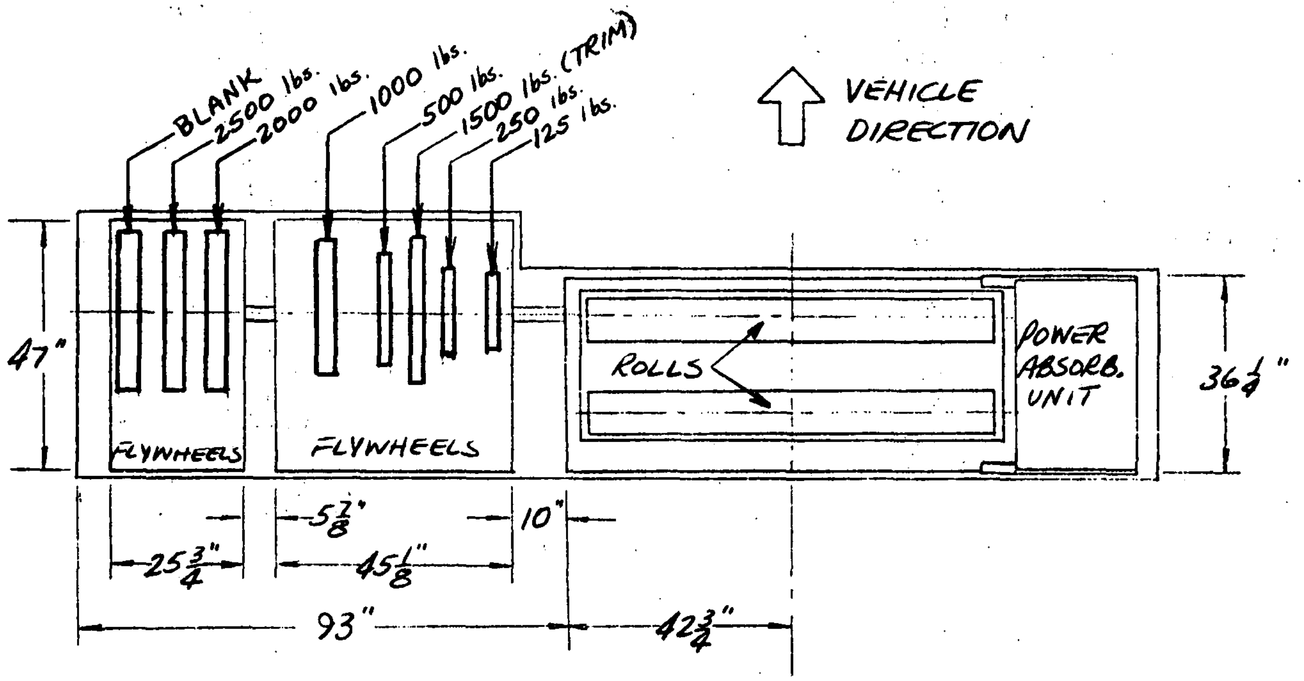

Figure 2-7 Alternative Equipment Design for Configuration D

Inertia weight could be simulated in increments of 125 pounds up to 4,000 pounds, 250 pounds up to 5,000 pounds; and 500 pounds up to 7,500 pounds. Table 2-6 displays the total inertia weight simulation capability.

	FLYWHEEL WEIGHTS							
TEST WEIGHT	1500	125	250	500	1000	2000	2500	
1500	x							
1625	x	x						
1750	x		x					
1875	x	x	x					
2000	x			x				
2125	x	x		x				
2250	x		x	x				
2375	x	x	x	x				
2500	x				x			
2625	x	x			x			
2750	x		x		x			
2875	x	x	x		x			
3000	x			x	x			
3125	x	x		x	x			
3250	x		x	x	x			
3375	x	x	x	x	x			
3500	x					x		
3625	x	x				x		
3750	x		x			x		
3875	x	x	x			x		
4000	x			x		x		
4250	x		x	x		x		
4500	x				x	x		
4750	x		x		x	x		
5000	x			x	x	x		
5500	x			x	x		x	
6000	x					x	x	
6500	x			x		x	x	
7000	x				x	x	x	
7500	x			x	x	x	x	

Table 2-6 Engagement Chart for Configuration D

The estimated equipment cost associated with this configuration is $10,000 to modify an existing dynamometer. Installation would cost approximately $3,000. Thus, the total package would cost approximately $13,000 per dynamometer.

3.6 Configuration E.

This configuration would encompass the features specified in configuration D. However, the blank hub shown in Figures 2-6 and 2-7 would be utilized with an additional 62.5 pound inertia weight flywheel. This would provide the inertia weight simulation capability shown in Table 2-7.

	FLYWHEEL WEIGHTS							
Test Weight	1500	62.5	125	250	500	1000	2000	2500
1500	x							
1562.5	x	x						
1625	x		x					
1687.5	x	x	x					
1750	x			x				
1812.5	x	x		x				
1875	x		x	x				
1937.5	x	x	x	x				
2000	x				x			
2062.5	x	x			x			
2125	x		x		x			
2287.5	x	x	x		x			
2250	x			x	x			
2312.5	x	x		x	x			
2375	x		x	x	x			
2437.5	x	x	x	x	x			
2500	x					x		
2625	x		x			x		
2750	x			x		x		
2875	x		x	x		x		
3000	x				x	x		
3125	x		x		x	x		
3250	x			x	x	x		
3375	x		x	x	x	x		
3500	x						x	
3750	x			x			x	
4000	x				x		x	
4250	x			x	x		x	
4500	x					x	x	
4750	x			x		x	x	
5000	x				x	x	x	
5500	x				x	x		x
6000	x					x		x
6500	x				x	x		x
7000	x					x	x	x
7500	x				x	x	x	x

Table 2-7 Engagement Chart for Configuration E

References

1. Federal Register, Vol. 39, No. 133, Section 85, July 10, 1974.

2. Paulsell, C. D. and R. Kruse, "Test Variability of Emission and Fuel Economy Measurements Using the 1975 Federal Test Procedure," SAE Paper No. 741035.

3. Murrell, J. D., "Factors Affecting Automotive Fuel Economy," SAE Paper 750958.

4. Marks, C., and G. Niepoth, "Car Design for Economy and Emissions," SAE Paper No. 750954.

5. U.S. Environmental Protection Agency, "Factors Affecting Automotive Fuel Economy," Office of Air and Waste Management, MSAPC, September 1975.