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AUTOMOTIVE POWERPLANT EVALUATION

950 0641
Ken R. Stamper
Bartlesville Energy Research Center
U.S. Energy Research & Development Administration
Bartlesville, Oklahoma

ABSTRACT

The objective of this program is to obtain automotive engine performance data for use in estimating vehicle emission and fuel economy in varied service and duty.

An experimental test procedure for generating fuel consumption and emissions data adequate to characterize an engine over its full operating range has been developed for steady-state tests. The development of a test procedure for transient testing is currently underway.

The steady-state data will be collected from approximately 23 different engines, including:

- 16 current production spark-ignition engines,
- 3 pre-production or prototype advanced design spark-ignition engines, and
- 4 light-duty diesel engines which are, or could be, used in passenger car applications.

To date, steady-state "engine maps" have been completed on 10 engines. A simplified model used to compare steady-state data with chassis dynamometer data indicates that results thus far can be used to obtain estimates of fuel economy in automobiles.

INTRODUCTION

The objective of the automotive powerplant evaluation program is to obtain engine performance data for use in estimating emissions and fuel economy in varied service and duty. The performance data obtained from an engine will be referred to as an "engine map." This map provides basic engine characteristic data appropriate for use as input for engineering calculations in systems analysis involving vehicular transportation.

The specific program elements are:

1. Development and validation of test procedure.
2. Acquisition of engine performance data for three classes of engines.
3. Following and reporting developments toward an alternative fuel technology.

The current program involves developing engine maps for approximately 23 different engines. Of these, 16 are current-model, standard-production, spark-ignition engines; three are pre-production or prototype spark-ignition engines; and four are light-duty diesels which are, or could be used as automotive powerplants. These engines are listed in table 1. This sampling of engines represents a significant portion of the engine types marketed in current-model vehicles.

Except for variations noted below, each of the engines we have tested, or will test, are "fully equipped engines"* dressed with components as furnished in vehicles marketed in the 49 states outside California. The variations are:

1. An equivalent heat exchanger is used in place of the radiator.
2. The alternator or generator is not used unless it is required to drive accessories.
3. Exhaust system configuration varies slightly from the vehicle installation, but equivalent flow restriction is provided.

*SAE definition.

TABLE 1. - ENGINE DESCRIPTIONS

Manufacturer	Displacement, cu in	Carburetor, (barrels/fuel inj.)	No. of cylinders
STANDARD-PRODUCTION, SPARK-IGNITION ENGINES			
* AMC	258	1	6
Buick	455	4	8
* Chevrolet	350	4	8
* Chevrolet	350	2	8
Chevrolet	250	1	6
* Chevrolet	140	2	4
Chrysler	318	2	8
Chrsyler	225	1	6
* Datsun	119	2	4
Ford	400	2	8
Ford	351	2	8
Ford	250	1	6
Ford	140	2	4
Mazda	70	4	2 rotors
Saab	121	FI	4
Volvo	121	FI	4
PRE-PRODUCTION OR PROTOTYPE ENGINES			
Chevrolet	350	Dresserator	8
Chevrolet	350	4 bbl, turbocharged	8
* Honda	91	3-CVCC	4
DIESEL ENGINES			
* Chrysler-Nissan	198	FI	6
* Mercedes-Benz	183	FI	5
* Mitsubishi	331	FI	6
* Perkins	247	FI	6

*Steady-state testing completed as of November 1, 1975.

4. No fan is used.

5. Engine and emission control components are typically those supplied on engines with automatic transmissions.

Any other specific deviations are noted in the respective engine report.

STEADY-STATE ENGINE TEST PROCEDURE

The first task in the engine characterization program was to develop a test procedure through which repeatable, representative steady-state engine data could be obtained. For this purpose an engine equipped as noted above was installed on a test stand and run through a break-in schedule designed to simulate approximately 1,500 vehicle miles.

After engine break-in, experimental work was begun taking data at each one of an array of points, selected to represent nine distributed loads at each of seven engine speeds. Engine loads are computed as a percentage of maximum power at the respective engine speed.

The original set of data points to be run on an engine then consists of 60 to 70 speed/load points representing the engine's entire operating range from idle, no load, to maximum or rated power. About half of these points are re-run to show that the test results are repeatable and that general trends in the data are representative.

A variety of parameters and conditions are measured; those of primary interest are fuel consumption, rpm, torque, and exhaust emissions.

Emission measurement is as follows:

--Carbon monoxide (CO) and carbon dioxide (CO_2) by non-dispersive infrared analysis

--Unburned hydrocarbon by heated flame ionization detector

--Oxides of nitrogen (NO_x) by chemiluminescence detector

--Oxygen by polarographic technique

--Smoke by in-line opacity measurement

--Sulphate by barium chloranilate procedure

Other measurements of interest are listed in tables 2 and 3 for gasoline and diesel engines, respectively.

TRANSIENT ENGINE TEST PROCEDURE

Experimental work in development of the transient test procedure was begun in late summer. The procedure thus far involves an engine test setup as described above with the addition of an inertial loading system and a constant volume sampler (CVS) system for acquisition of exhaust sample.

The inertial system is designed to provide the engine loading effects of a specific weight vehicle as these effects are manifested through discrete ramp accelerations or decelerations of a short duration. Mass emission rates and fuel consumption will be determined from CVS samples. These data will be used in predicting emissions and fuel rates over engine transients as would be encountered in whichever cycle is to be estimated.

Using the results of the transient tests and the data from steady-state engine maps a third test procedure will be designed. This will in effect describe the amount of testing which is necessary to define an engine's operating characteristics in detail that is adequate to enable acceptable close estimation of engine performance in actual service over any reasonable duty cycle.

SIMPLIFIED MODEL FOR FUEL ECONOMY ESTIMATES

A specified driving cycle for vehicle testing can be thought of as being comprised of two engine modes--"powered" and "non-powered." Knowledge of the particular cycle reveals the duration of each mode. The powered mode for a given vehicle weight implies both an average and peak horsepower requirement. Using the idle fuel consumption rate for "non-powered" operation, and the fact that the "powered" fuel consumption rate may approximate a linear function of speed and

TABLE 2. - SPARK-IGNITION ENGINE TEST MEASUREMENTS

Barometric pressure	Oil temperature
Humidity	Coolant temperature
Inlet air temperature	Exhaust temperature*
Engine speed, rpm	Exhaust pressure*
Torque, ft/lb	Oil pressure
Fuel rate	CO concentration*
Throttle position	CO_2 concentration*
Ignition timing	O_2 concentration*
Manifold vacuum	Unburned HC concentration*
	NO_x concentration*

* When a catalytic converter is used in the exhaust systems these parameters are monitored before and after catalyst.
SO_3 concentration is measured on certain engines in select modes.

TABLE 3. - DIESEL ENGINE TEST MEASUREMENTS

Barometric pressure	Oil temperatue
Humidity	Coolant temperature
Inlet air temperature	Exhaust temperature
Engine speed	Oil pressure
Torque	Exhaust pressure
Fuel rate	Exhaust opacity
Control lever position	CO concentration
Combustion air flow rate	CO_2 concentration
Inlet air restriction	NO_x concentration
	Unburned HC concentration

SO_3 concentration is measured on certain engines in select modes.

torque for low to moderate engine speeds, an estimate of the cycle fuel economy can be obtained from steadv-state engine test data.

A comparison of fuel economy estimates for engines (those with completed steady-state engine maps) at various vehicle weights with published vehicle fuel economy data is given in table 4. The agreement is considered to be quite good, in all cases except for the AMC. However, the results from chassis dynamometer tests performed at the Bartlesville Energy Research Center on this vehicle support the estimated fuel economy.

CYCLE SIMULATION FROM ENGINE MAPS

The engine map data can be used as input to computer simulations of vehicle test cycles. In doing this, we understand that the Transportation Systems Center people have found fuel economy and acceleration performance are predictable to within 5 to 10 pct. Predicted NO_x emissions are accurate to within about 25 pct. Predicted carbon monoxide and unburned hydrocarbon emissions are consistently overpredicted and underpredicted, respectively. The actual data used in the comparison came from Environmental Protection Agency chassis dynamometer tests.

ALTERNATIVE FUEL TECHNOLOGY

The final program element deals with developments toward an alternative fuel technology. This does not include any experimental work within this specific program, but is directed toward surveillance of developments in the use of alternative fuels in transport applications. Information on engine performance with alternative fuels will be summarized and updated periodically. The source of this information is to be both from industry and from results of experimental work done at the Bartlesville Energy Research Center, in its in-house research and in cooperation with other governmental agencies.

SUMMATION

Steady-state engine tests have been completed on 10 engines including at least one engine from each category. A transient test procedure is being developed. Results from these tests do allow reasonable accuracy in predicting fuel economy.

Engine procurement is virtually complete. Four engines have yet to be delivered but are expected soon.

Future work plans include continuing steady-state engine mapping, developing transient engine test procedure, and mapping transient engine test modes.

TABLE 4.- COMPARISON OF ESTIMATED FUEL ECONOMY

Engine	Fuel economy, mpg								
	Estimated fuel economy						Published EPA fuel economy data		
	Urban	Highway	Urban	Highway	Urban	Highway			
I.W., lb.	2,000		3,000		4,000		Urban	Highway	I.W., lb
Honda 91-CID	27	39	24	35	21	32	27	39	2,000
Chevrolet 140-CID	32	32	20	30	18	28	21	29	2,750
Datsun 119-CID	24	35	21	32	19	30	22	33	3,000
AMC 258-CID	15	24	14	21	13	20	21	30	3,000
Chevrolet 350-CID, 2V	13	19	12	18	11	17	14	19	4,000
Chevrolet 350-CID, 4V	12	18	11	17	11	17	13	20	4,000
Nissan 198-CID	22	31	19	29	17	27	-	-	-
Mitsubishi 331-CID	17	25	16	24	14	22	-	-	-