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A Report on the Emission Performance of the Army Sponsored Ford Stratified Charge Engine

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Vehicle Tested

The vehicle tested during this evaluation was an Army M-151 1/4 ton truck. This was the same vehicle tested in May 1970 with only minor modifications to the emission control system. The M-151 is a general purpose vehicle used throughout the world by the U. S. Army. It is equipped with a four wheel drive system with the front wheel drive portion controlled by the driver. It is also equipped with a four speed transmission. This transmission has a very low first gear and for normal driving it is not used. For all of the emission tests, the transmission was used only in second, third and fourth. A modified shift pattern was suggested by Ford due to the unusual weight to horsepower ratio of this vehicle. The Army M-151 is tested with an inertia weight of 3000 pounds calculated from the actual weight of the vehicle. This vehicle is supplied with a seventy horsepower engine, and when the friction losses of the drive train are taken into account, can only meet the required accelerations with difficulty. In addition, the independent rear suspension system will not tolerate the vibration from the four cylinder engine at low speed, necessitating more gear changes than normally required. As a result, it is difficult to achieve the best possible emission results from this engine as installed in the Army vehicle.

The engine used in these tests, a 141 CID four cylinder with 3" bore and 3 7/8" stroke, was developed by the Ford Motor Company through joint U. S. Army - APCO contracts. This

engine is the "low emission" version of their stratified charge combustion system and is called the Proco conversion.

The basic stratified charge system used by Ford uses an unthrottled air intake with fuel injected directly into the cylinder. This engine uses a low pressure (600 p.s.i.) mechanical fuel injection pump that is integrated with the ignition distributor. The injected fuel mixes with a portion of the air in the vicinity of the spark plug, where it is ignited. The combustion system is shown in Figure 1. The extended tip spark plug places the spark near the center of the cup combustion chamber.

In order to provide low emissions from this engine, several modifications were made in the control systems. Extensive dynamometer tests indicated that a very close control over fuel air ratio was required in order to achieve the emission values needed to meet 1976 standards. For this reason an air throttle system was developed to provide a 17:1 air-fuel ratio. In addition exhaust gas recirculation was added to reduce the amount of oxides of nitrogen. Due to the direct cylinder injection this exhaust gas recirculation seems to have no effect on driveability, even at 11% recycle used during the first three minutes of test. During the remainder of the test, about 9-10% recycle was used.

This engine was provided with a thermal reactor. However, the contribution of the reactor to emission reduction was minimal according to Ford data. In addition, an Engelhard

off-the-shelf catalytic reactor was used to reduce the peak on hydrocarbons and to encourage a reaction between the CO and NO in the exhaust. A lead sterile fuel was used to be compatible with this reactor.

The air-fuel ratio control was an experimental unit and did not contain an ambient pressure compensator. The lack of pressure compensation made the system dependent on atmospheric pressure and explains some of the variation in test data.

As this vehicle does not need enrichment during start or warm-up, there is little change between cold and hot start data other than that found due to the cold catalyst. For this reason repetitive hot starts were not attempted.

Data on two new standard M-151's is also enclosed for information. A single number has been obtained by averaging 3 tests on each vehicle.

Data from this vehicle was reported in report number 70-4 "Exhaust Emissions from a Stratified Charge Ford Combustion Process (FCP) Engine". In addition, data on another standard M-151 is in report number 70-2 "Emissions from a Standard M-151 Jeep".

Tests Used

In order to evaluate the emission performance of the vehicles tested the 1972 LA4-S4 test cycle was used for all tests. This is the test cycle that will be used for certifying all

new light duty motor vehicles beginning in 1972. The emission standards for various years are shown below, with the 1975 standards also shown with the emissions data.

	HC	CO	NO_2
1972	3.4	39	---
1973	3.4	39	3
1975	.46	4.7	3
1976	.46	4.7	*

*The number for 1976 NO_x has not been determined although present thinking is that it will be in the range of 0.3 to 0.7. Throughout the report, HC will be used to abreviate unburned hydrocarbons, CO will be used for carbon monoxide and NO_x for oxides of nitrogen.

For these tests results are reported with HC measured using a flame ionization detector, CO and CO_2 using a non dispersive infrared analyzer and oxides of nitrogen using a modified Saltzman technique and the chemiluminescent technique.

Emission Results

The results of our tests are reported in Tables 1 and 2. In Table 1 a comparison is made between the projected standards, the vehicle as tested and the standard M-151. From this table it appears that the vehicle may meet the standards for 1976. The emission reduction over the standard vehicle is very significant.

Conclusions

The Ford stratified charge system has the potential of meeting the 1976 emission standards and still maintain the driveability and fuel economy of the uncontrolled vehicle.

HYBRID COMBUSTION SYSTEM

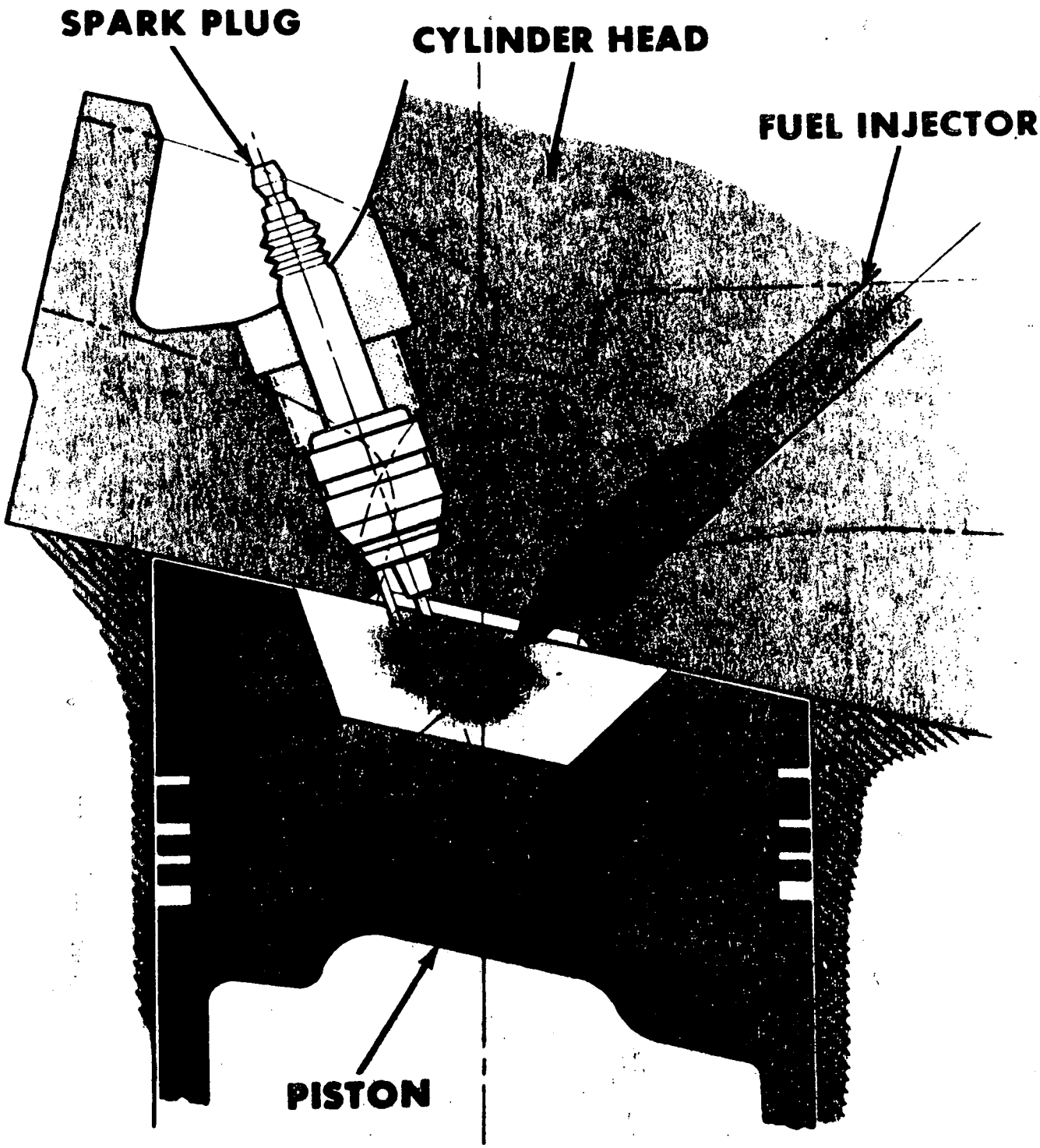

FIG 1

Table 1

1972 LA4-S4 Emission Test Comparison

All Results in Grams Per Mile

	HC FID	CO IR	CO_2 IR	NO_x Saltz	NO_x CI
PROCO (FCP)	0.3	3.2	439	0.6	0.6
Federal Standards (1976)	0.46	4.7	---	---	.3-.7 (est.)
Standard M-151 (1 of 2 Vehicles, 6 tests)	5.4	122	428	1.8	2.0

Table 2

1972 LA4 Emission Test Results

All Results in Grams Per Mile

All Tests on Ford Proco System

Notes	HC FID	CO IR	CO_2 IR	NO_x Saltz	NO_x CI
No EGR	0.2	0.9	376	1.9	1.9
EGR Special Shift	0.3	3.2	439	0.6	0.6
EGR Special Shift	0.3	1.7	412	0.9	0.9
EGR Special Shift	0.6	1.5	386	1.0	1.2
EGR Standard Shift	0.4	1.7	435	0.5	0.7