INVESTIGATIONS OF GASOLINE AND DIESEL ENGINES WITH MAGNETICALLY-EXCITED FUEL SYSTEMS

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ABSTRACT

Retrofit-device manufacturers have marketed many magnetic devices which are claimed to improve vehicle mileage and reduce exhaust emissions. However, the U.S. Environmental Protection Agency (EPA), has decided that the claimed benefits for most of these devices are not substantiated. Because both manufacturers and EPA made their contradictory evaluations by the same FTP and HFET procedures, the authors conducted an engine-research investigation on a single-cylinder engine and multi-cylinder engines. Magnetic fields were applied to both gasoline and diesel fuel systems. The present results show a general improvement in fuel economy (in the order of 10%) for the engines investigated. In the case of gasoline-powered engines, the unregulated NOX emissions increased approximately by 100% while CO and HC emissions dropped by as much as 20% and 16%, respectively. The results suggest that magnetic fields cause molecular reorientation of polar compounds which are added to fuels as ignition improvers or antiknock additives. The resulting increase in fuel-flow turbulence enhances both vaporization and combustion, and improves fuel economy. It has been found that while emissions of hydrocarbons and carbon monoxide decrease, NOX emissions increase.

Keywords: Engines, Magnetic fields.

INTRODUCTION

The drive towards cleaner environment and more energy conservation has been intensified by stringent federal regulations of both emissions and fuel economy. Auto manufacturers have joined efforts with part suppliers to meet federal requirements, even before deadlines. On the other hand, retrofit-device manufacturers have also swamped the market with many products that are claimed to improve vehicle mileage and to reduce exhaust emissions. Among these retrofit devices is the magnetic type, the topic of this paper. The brochures supplied by manufacturers give few details about these devices and do not satisfactorily explain how they operate or how reliable they are. However, some advertisements mention that magnetic fields generated by such "fuel economizers" are responsible for the claimed improvements.

A fuelmizer [1] was claimed to reduce emissions, to improve fuel economy, and to increase engine power. The device is a permanent magnet that is firmly mounted against the fuel line. The theory of operation, as offered by the manufacturer, is that the magnetic field of the device acts upon the electric dipole moments of the fuel molecules, and produces a polarization and general alignment of the molecules. The manufacturer reported that although the polarization effect is partially lost prior to combustion, the remaining degree of alignment would accelerate the oxidation process. The manufacturer claimed a 14% improvement of fuel economy for two diesel-powered vehicles in fleet usage. The manufacturer also claimed that the Highway Fuel Economy Test (HFET) on a gasoline-powered sedan showed a 9.8% improvement of fuel economy due to the use of the fuelmizer. The emissions of the latter vehicle were claimed to have dropped by 46.3% for hydrocarbons (HC) and by 15.4% for carbon monoxide (CO). The Environmental Protection Agency (EPA) evaluated the fuelmizer, and concluded that the information supplied by the manufacturer was insufficient to adequately substantiate either the emissions or fuel economy benefits claimed for the device.

Another manufacturer introduced a fuel polarizer [2] for treating hydrocarbon fuel by a magnetic unit that measures approximately 750 gauss at the magnet surface. The manufacturer claimed that magnetic field would promote heat transfer, vaporization, and combustion. The device was designed for carbureted spark-ignited engines only. Reduction of regulated exhaust emissions was reported as 5-10% for CO and 2-10% for HC. Improvement in gas mileage, as measured by SAE methods, was reported as 5%. The manufacturer provided no test data and made no claims regarding unregulated emissions. When the EPA tested the fuel polarizer on different car models, the data showed no significant improvement of either vehicle emissions or fuel economy [2].

Because both manufacturers and EPA made their controversial evaluations based on the Federal Test Procedure (FTP) [3] and the Highway Fuel Economy Test (HFET) [4], the authors followed a different approach by conducting an engine-research investigation. The experiments were run in two phases:

(i) Phase I: on a single-cylinder multi fueled engine, and
(ii) Phase II: on a 4-cylinder diesel engine and a 6-cylinder gasoline engine.

Magnetic fields were applied to both gasoline and diesel fuel systems. The resulting effects on the performance and emissions were evaluated.

EXPERIMENTAL PROCEDURES

The experiments were run in two phases:

(i) Phase I: on a single-cylinder, multifueled engine, and
(ii) Phase II: on a 4-cylinder diesel engine and a 6-cylinder gasoline engine.

Phase I. A single-cylinder, 4-stroke multifueled engine was used through this phase (Table 1). The engine is coupled to a DC dynamometer. Chromel-alumel thermocouples were used for measuring the temperatures of the intake air, exhaust gases, cooling water, and lubricating oil.

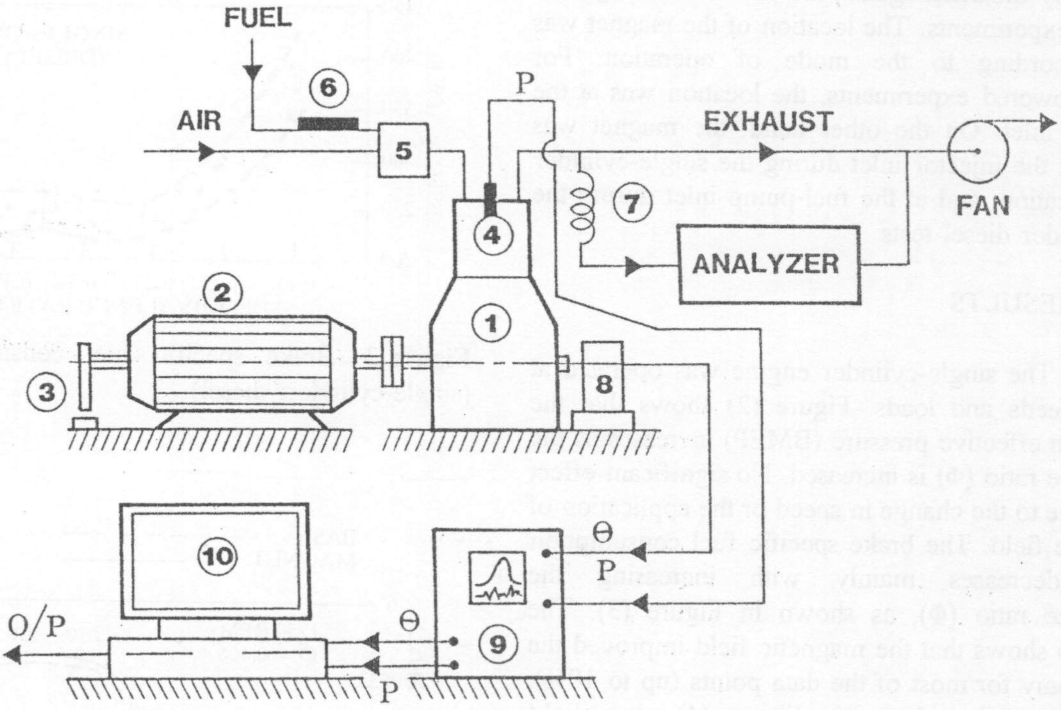
Table 1. Test Conditions (Phase I).

Engine Type	Single-cylinder, 4-stroke, Multifueled, water cooled.
Engine Dimensions	
bore * stroke (mm)	95 * 82
displacement (m^3)	0.581 * 10^{-3}
Speed	1000 - 2000 RPM
Torque	5 -25 N.m
BMEP	108 -540 kPa
Spark Advance (gasoline)	5 - 25° BTC
Injection timing (diesel)	15° BTC
Equivalence Ratio	
gasoline	0.8 - 1.3
diesel	0.14 - 0.50

The rate of flow of the intake air was measured by a laminar flowmeter located between the air filter and the intake manifold. The rate of fuel consumption was measured by the constant-volume method. The rate of coolant flow was measured by a rotameter. A compact microprocessor-controlled system (TQ E32 Mk) was used for measuring the engine speed, cylinder pressure and swept volume. The system includes an incremental shaft encoder which identifies the crank angle to a resolution of 0.5°. This information is passed to the microprocessor which computes the value of the swept volume at each crank angle. The cylinder pressure was measured by a piezo-electric pressure transducer (Kistler 6121) with a linearity factor better than ± 0.3%.

Emissions were measured (in the case of gasoline operation) by a Richard Oliver multigas exhaust analyzer under steady-state conditions of engine operation. The system consists of a forwarding oven, a sample conditioner, a chemiluminescent-analysis module, a flame ionization detector (FID), and an NDIR module connected to the system computer via an RS232 interface. Figure (1) illustrates a schematic layout of the experimental system.

Phase II. Two production engines were tested for fuel economy in this phase. A 4-cylinder diesel engine (Table 2) and a 6-cylinder, carbureted gasoline engine (Table 3) were run at various loads and speeds. A Froude-type hydraulic dynamometer was used for torque measurements. The rate of fuel consumption was measured by the constant-volume method.



1. ENGINE
2. DYNAMOMETER
3. LOAD CELL
4. PRESSURE TRANSDUCER
5. CARBURETOR
6. MAGNET
7. GAS SAMPLING TUBE
8. SHAFT ENCODER
9. DATA ANALYZER
10. COMPUTER

Figure 1. Schematic of engine and instrumentation (single-cylinder arrangement)

Table 2. Test Conditions (Phase II) - Diesel.

Engine Type	4-cylinder, in-line, 4-stroke, water-cooled.	
Engine Dimensions bore * stroke (mm) displacement (m^3)	 91.4 * 127.0 $3333 * 10^{-6}$	
Speed	1000 - 2000	RPM
BMEP	15 - 700	kPa
Torque	4 - 186	N.m
Injection Timing	15°	BTC
Equivalence Ratio	0.23 - 0.77	

Table 3. Test Conditions (Phase II) - Gasoline.

Engine Type	6-cylinder, in-line, 4-stroke, water-cooled.	
Engine Dimensions bore * stroke (mm) displacement (m^3)	 79 * 78 $2294 * 10^{-6}$	
Speed	1450 - 2500	RPM
Torque	20 - 90	N.m
BMEP	109 -491	kPa
Spark Advance	5 - 25°	BTC

A 650-gauss magnetic device of the fuelmizer type was securely mounted against the fuel line during both phases of experiments. The location of the magnet was varied according to the mode of operation. For gasoline-powered experiments, the location was at the carburetor inlet. On the other hand, the magnet was installed at the injector inlet during the single-cylinder diesel operation, and at the fuel-pump inlet during the multi-cylinder diesel tests.

DIESEL RESULTS

Phase I. The single-cylinder engine was operated at various speeds and loads. Figure (2) shows that the brake mean effective pressure (BMEP) increases as the equivalence ratio (Φ) is increased. No significant effect appears due to the change in speed or the application of a magnetic field. The brake specific fuel consumption (BSFC) decreases mainly with increasing the equivalence ratio (Φ), as shown in Figure (3). The figure also shows that the magnetic field improved the fuel economy for most of the data points (up to 10%). This effect is also shown in Figure (4) as a slight increase in the values of gas pressure, which means an increase in the indicated work for the same amount of fuel.

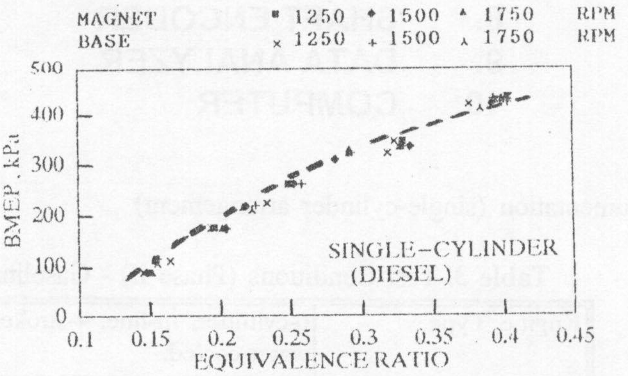


Figure 2. Brake mean effective pressure (BMEP) (single-cylinder; diesel).

Phase II. The 4-cylinder engine was operated at various speeds and loads. The fuel-economy results are shown in Figure (5). Again, the use of the magnetic field resulted in general improvement of BSFC that ranges between a maximum of 10.2% at 1500 RPM and a minimum of 3.3% at 1700 RPM.

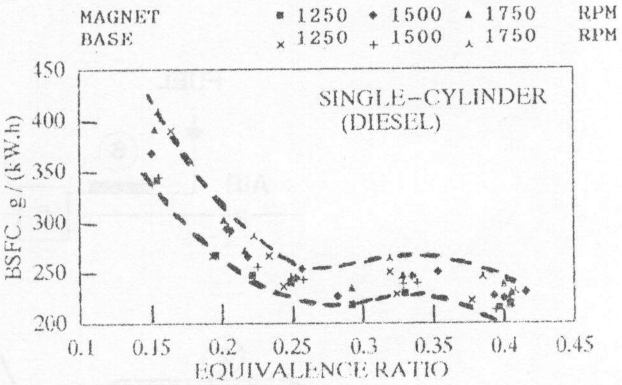


Figure 3. Brake specific fuel consmption (BSFC) (single-cylinder; diesel).

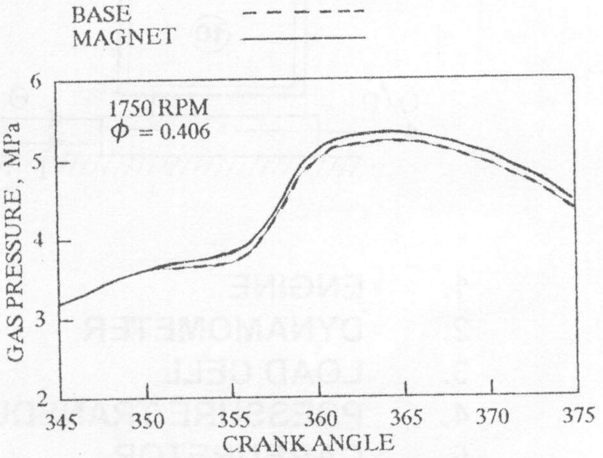


Figure 4. Effect of magnetic field on Gas pressure history (single-cylinder; diesel).

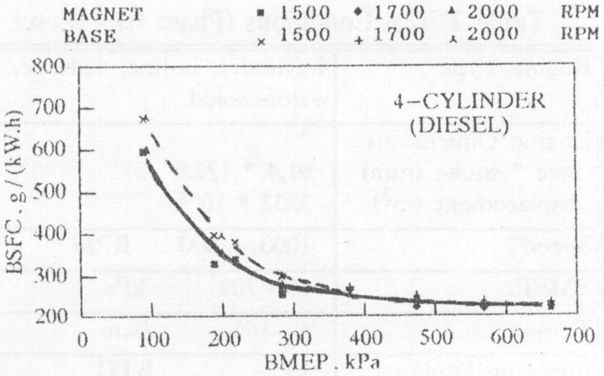
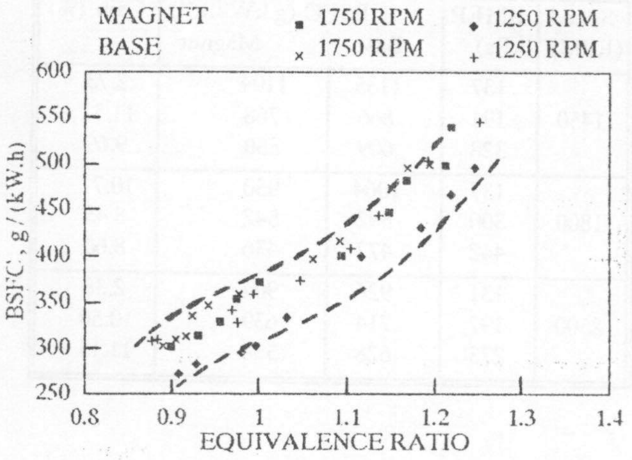
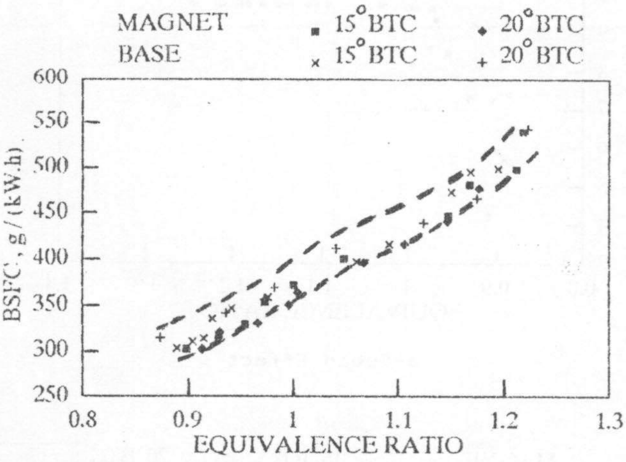


Figure 5. Brake specific fuel consumption (BSFC) (4-cylinder; diesel).



a-Speed Effect

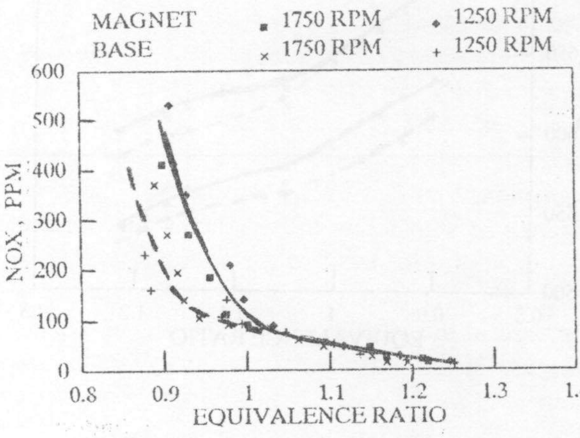


b-Spark Advance Effect

Figure 6. BSFC due to magnetic field (single-cylinder; Gasoline).

GASOLINE RESULTS

Phase I. The equivalence ratio (Φ) was varied in every set of experiments as an independent variable. The measured dependent variables were the brake specific fuel consumption (BSFC), exhaust temperature, and exhaust emissions (NOX, THC, CO, and CO_2). The parameters under investigation were the spark advance and engine speed. The experiments were conducted with the magnetic fuelmizer mounted against the fuel line at the carburetor inlet. The results were compared to the baseline performance in the absence of the magnetic device. Figure (6) shows the factors that influence the brake specific fuel consumption (BSCF) when the single-cylinder engine was run in the spark-ignition mode. The figure shows the expected result that the BSFC improves as the fuel-air mixture becomes leaner. It appears from Figure (6a) that the magnetic field improves the BSFC by an average of 9% at 1250 RPM, while this improvement is about 3.7% at 1750 RPM. Figure (6b) shows a 6.9% average improvement in BSFC at 20 degrees of spark advance, and a 3.7% improvement when the spark is 15-degree advanced.



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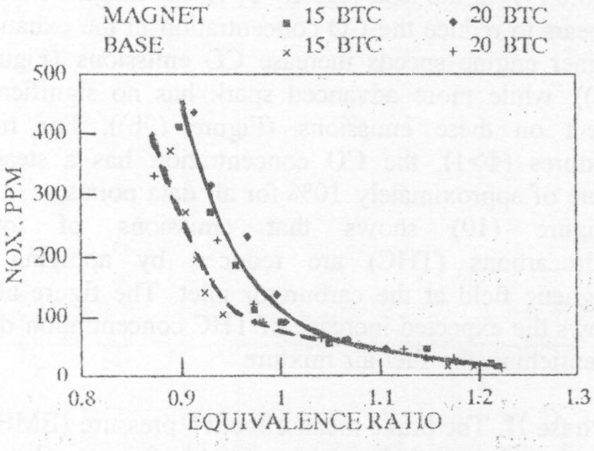


b-Spark Advance Effect

Figure 7. NOX Emissions due to magnetic field (single-cylinder; Gasoline).

Figure (7) shows that NOX emissions increase with leaner equivalence ratios. The figure shows that there is no apparent effect of magnetic field on NOX emissions for $\Phi > 1$ (rich zone). On the other hand, the effects are clearly pronounced for $\Phi < 1$ (lean zone) where the NOX emissions increase with applying a magnetic field at carburetor inlet. Exhaust temperature measurements indicated that the increase of NOX emissions as a result of the magnetic field was due to an increase in the combustion temperature (Figure 8).

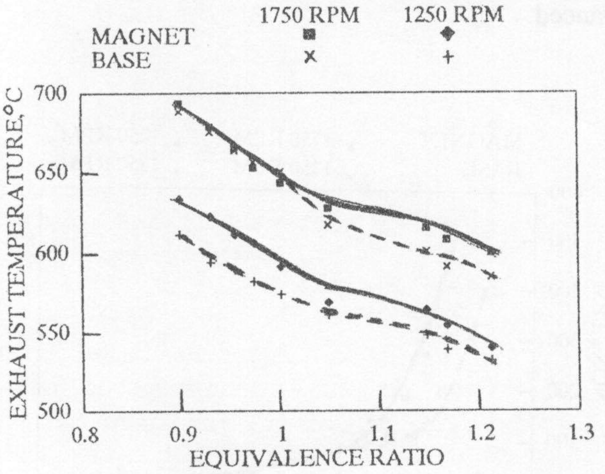


Figure 8. Exhaust temperature (single-cylinder; Gasoline).

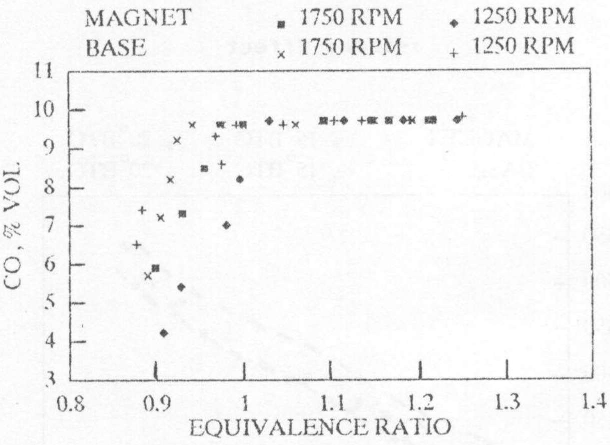
The factors influencing CO emissions are shown in Figure (9). In the lean region ($\Phi<1$), the magnetic field appears to reduce the CO concentration in the exhaust. Higher engine speeds increase CO emissions (Figure (9a)), while more advanced spark has no significant effect on these emissions (Figure (9b)). For rich mixtures ($\Phi>1$), the CO concentration has a steady value of approximately 10% for all data points.

Figure (10) shows that emissions of total hydrocarbons (THC) are reduced by applying a magnetic field at the carburetor inlet. The figure also shows the expected increase of THC concentration due to enriching the fuel-air mixture.

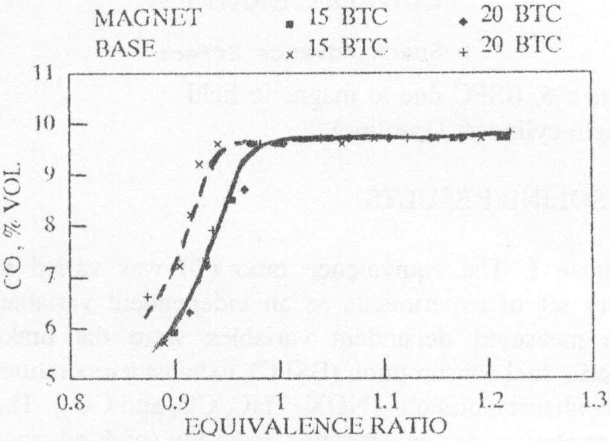
Phase II. The brake mean effective pressure (BMEP) was varied as an independent variable for a number of speeds (Table 4). Fuel economy was evaluated for each test. The results presented in Table 4 and Figure (11) show gains in fuel economy between 2.38% and 11.32%.

Table 4. Fuel Economy Results (Phase II)-Gasoline

Speed (RPM)	BMEP (kPa)	BSFC ($g.kW^{-1}.h^{-1}$) Base	Magnet	Gain (%)
1450	137	1135	1104	2.73
	191	866	768	11.32
	328	609	550	9.69
1800	137	1064	950	10.71
	300	592	542	8.45
	442	477	436	8.60
2500	131	926	904	2.38
	197	714	639	10.50
	273	628	558	11.15



a-Speed Effect



b-Spark Advance Effect

Figure 9. CO emissions due to magnetic field (single-cylinder; Gasoline).

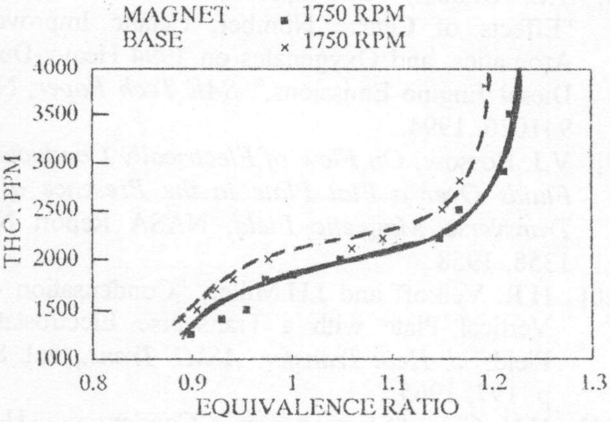


Figure 10. THC emissions due to magnetic field (single-cylinder; Gasoline).

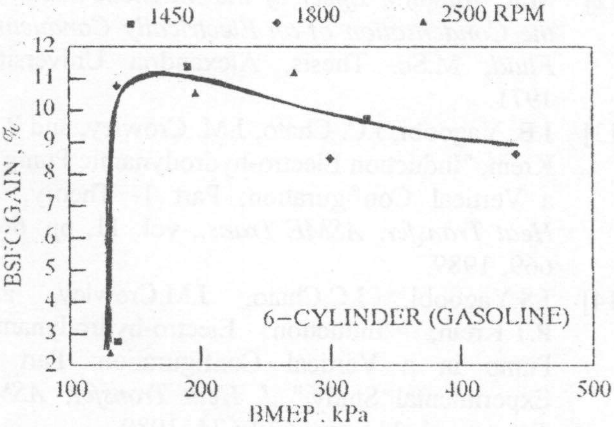


Figure 11. BSFC gain due to magnetic field (6-cylinder; Gasoline).

DISCUSSION

The influence of the magnetic field on fuels and their combustion is attributed to polar compounds that exist in modern fuels. Among these compounds added to gasolines are oxygenates and organometallic antiknock additives such as tetra-ethyl-lead (TEL), ethers, iron-penta-carbonyl, and nickel carbonyl [5]. As for diesel fuels, polar compounds are added in the form of aromatic ignition improves (e.g. hexyl benzene) up to 30%, and ignition-accelerating additives such as alkyl nitrates [6,7,8]. The present results mean that a magnetic field applied to a fuel system would cause molecular reorientation of polar compounds. The resulting increase in fuel-flow turbulence is thought to increase heat transfer coefficients, and consequently enhances both fuel vaporization and burning reactions. This outcome is supported by the established literature [9-15] that the application of magnetic or electrostatic fields to electrically conducting fluids is associated with increases in swirl, heat flux, and heat transfer coefficients.

CONCLUDING REMARKS

1. An engine-research approach was applied in this investigation in order to evaluate the effects of magnetically-excited fuel systems on the performance and emissions of internal combustion engines.
2. The experiments conducted on a single-cylinder diesel engine (Phase I) resulted in a general improvement of fuel economy (up to 10%) when a magnetic field was applied to the fuel system. On the other hand, the experiments on the 4-cylinder diesel engine (Phase II) showed an improvement in fuel economy (up to 10.2%) with the application of magnetic field.
3. The fuel-economy results for a single-cylinder gasoline engine (Phase I) show general improvement in BSFC (up to 10%) when a magnetic field is applied to the fuel system. The improvement is more pronounced at 1250 RPM than at 1750 RPM. On the other hand, the experiments on the 6-cylinder gasoline engine (Phase II) show gains in fuel economy between 2.38 and 11.32%.
4. When measurements of unregulated exhaust emissions were taken during the spark-ignition mode of operation of the single-cylinder engine, the data showed increases in NOX emissions (up to 100%) and reduction in CO and HC emissions (up to 20 and 16%, respectively) in the presence of the fuelmizer at carburetor inlet.
5. Due to the increasing use of aromatics, oxygenates, and polar ignition improves in fuels, it is obvious that magnetic fields applied to fuel systems produce favorable effects on fuel economy and some emissions. More future investigations are needed in the area of physics of fuel flow in the presence of magnetic fields, and the resulting effects on fuel vaporization, chemical kinetics, and combustion characteristics.

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