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MONTHLY TECHNICAL STATUS REPORT
FOR THE MONTH OF

May, 1977 #1

Contract #EC-77-C-03-1399

HC03-778T11439

Air Assisted Fuel Injection and Ignition
A New Concept to Improve the Automotive Diesel Engine

Submitted To:

San Francisco Operations Office
Energy Research and Development Administration
1333 Broadway
Oakland, California 94612

August 19, 1977

By

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The objective in May was to formulate guidelines for selecting a single cylinder engine to be used for the research program.

We feel that the AVCO Lycoming W-71 engine is not suitable for this study. This engine is not used commercially for automotive applications and the automotive engine community is not familiar with it. Also it is a primitive design. Therefore the impact of our new technology will not be fully appreciated by the U.S. automotive industry if we decided to modify W-71 as we proposed at the time the proposal was submitted to ERDA.

We like to select an engine that is currently being used in cars and on which sufficient technical information is available. For the proof-of-principle experiments any engine can be used but we believe the study will have more impact if a well publicized automotive engine is used for research.

Thinking along these lines will be refined next month and the pros and cons of various commercial automotive diesels will be studied.

A summary description of the contract was prepared and submitted to ERDA for the ERDA/CONRT Combustion and Fuels Technology Program Contractor Review Meeting to be held in July in San Francisco.

CONTRACT DESCRIPTION SUMMARY

1. Title: AIR ASSISTED FUEL INJECTION AND IGNITION - A
NEW CONCEPT TO IMPROVE THE AUTOMOTIVE DIESEL
ENGINE
2. Contractor: Scientific Energy Systems Corporation
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4. Contract No.: EC-77-C-03-1399

Contract Period: May 10, 1977 to September 30, 1978

Funding: \$260,466
5. Objectives and Anticipated Results:

It is anticipated that by employing high temperature, high pressure air to inject fuel into the combustion chamber of a diesel engine, the combustion process can be improved significantly. Better combustion should lead to better fuel economy, lower emissions of nitrogen oxides and unburnt hydrocarbons, less smoke, less noxious odors, reduced noise, less vibrations, increased power per unit weight of the engine, improved cold starting capability and engine operation with a wider range of fuels.

Work Statement Outline and Schedule

The program involves development, design, fabrication and breadboard testing of an air assisted fuel injector for a single cylinder diesel engine. The experiments are to be guided by an analytical combustion study based on a stochastic model of turbulent mixing with chemical reactions. The injector is to be designed by the end of 1977. Fabrication and testing of the new injector is scheduled for completion by September 1978.

Mixing: Conventional systems utilizing high pressure fuel injection cannot significantly increase the initial kinetic energy of the fuel jet without excessive increase in the injection pressures required. A tenfold increase in the initial kinetic energy of the jet will require a tenfold increase in pressure difference Δp across the injector orifice - from a Δp of 2,000 to 5,000 psi for conventional automotive diesel engine injection systems at present to a Δp of 20,000 to 50,000 psi and will present problems in jet over-penetration and excessive wall impingement due to high jet momentum.

With the air injection approach, however, the energy density of the jet can be greatly increased at relatively modest air pressure and quantity, and low fuel pressure, since the air performs the bulk of the atomization. The energy content of the air is intimately contained within the fuel jet and is dissipated within the spray, thereby effectively accelerating the small scale mixing process.

Ignition: In conventional engines, ignition must necessarily occur at the fringe of the fuel jet, where air is present and has been mixed with fuel for the required length of delay time. The mechanical energy released by combustion will not have nearly as pronounced an effect on the mixing process as if the energy had been released in the vicinity of the center of the jet.

In air assisted injector, ignition is more likely to occur in the center of the jet and the resultant energy release may have the effect of exploding the jet and greatly accelerating both large and small scale mixing. This difference from a conventional injector is due to the atomizing air which is combustible. Areas in the hot fuel-air jet which are at locally stoichiometric conditions will ignite far more rapidly than fuel at the jet fringe which has mixed with relatively cool cylinder air.

Advantages of Air Assisted Injection:

1) Higher air utilization: The improved small scale mixing reduces the number of locally overly-rich fuel elements such that smoke-limited torque can be significantly increased. Thus power per unit displacement can be improved by 13 to 19% at equal speed.

2) Lower compression ratios: High pressure ratios are required in conventional diesels for start-up and satisfactory operation at light load conditions. The use of properly controlled hot air for injection gives the engine designer another control variable which can be used to influence ignition delays and trade-offs can be made between the injection air temperature and the compression ratio. Because of the resultant lower peak pressures, lower compression ratio will increase the power to weight ratio by allowing the engine structural weight to be reduced.

Air Assisted Fuel Injection: The objective of this program is to design and demonstrate an injection system which has the potential for making the diesel engine significantly more attractive as an automotive power plant. The heart of the diesel engine is the combustion process which is controlled mainly by the microscale fuel-air mixing and the ignition delay. Improved local fuel-air mixing is the key to reducing emissions of nitrogen oxides, odor and smoke and improving air utilization to increase specific power. The novel combustion system under investigation replaces the conventional high pressure fuel injector by an air-assisted fuel injector which utilizes hot, high pressure atomizing air to inject fuel into the combustion chamber. Unlike the air atomized diesels of the early 1900's there is no external multistage compressor to add bulk, weight and excessive parasitic loss. Close integration of the air injection system is an important requirement, since the heat of compression is a necessary ingredient in the present design.

The simplest and most efficient way to obtain both the air pressure and temperature required for high jet energy and high jet temperature is by utilizing a small part of the compressed air charge at top dead center, and compressing it further in the injection plunger as nearly adiabatically as possible to the desired conditions. An embodiment of such an arrangement is disclosed in a pending patent application.

However, until the benefits of air-assisted injection can be quantified and the air requirements determined, the air and fuel injection system will be activated and powered by external means so as to provide flexibility in controlling quantity, timing, pressure and temperature of the injected air. Of course, the engine head and the injector will have to be modified.

It is estimated that atomizing air mass equal to the fuel mass at full load will be required. Air will have to be compressed to 1500 psi and 1500°F. At full load operation, the energy content of the atomizing air will be two to eight times that contained in the fuel jet from solid jet injectors. At part load operation, as much as a factor of 50 increase in jet energy can be obtained since the jet energy can remain constant while fuel quantity is reduced.

The ideal power required to generate the air is estimated as 0.02 hp per cylinder at idle and 0.1 hp per cylinder, at 4000 rpm for a typical automotive size cylinder of 500 cm³ displacement. It is thus clear that the air power requirement is quite small and should not impose an obstacle to good engine efficiency. Because of the small power drain, the mass and pressure of the atomizing air charge can be increased further if necessary, to obtain the required mixing rates and ignition delay. Some of this air power requirement is compensated by the power that was required for the fuel injection pump.

3) Higher speed operation: The problems associated with fuel delivery requirements and ignition delays at high speeds can be solved using this approach since the delivery rates can be easily controlled through air pressure (and orifice size) and the ignition delays can be reduced by using hot air for injection. Ten to fifteen percent improvement in power at equal displacement may be obtained by raising the engine speed.

4) Lower emissions of nitrogen oxides, smoke, odor, unburnt hydrocarbons and particulates should result because combustion can be made to occur at locally favorable fuel-air ratios.

5) Multi-fuel operation: The high temperature atomizing air and rapid mixing significantly reduce the ignition delay, thus making operation on a wide range of fuels feasible.

6) Reduced cost of fuel injectors: Because lower fuel pressures are required, dimensional tolerances can be relaxed.

7) Reduced noise: By virtue of rapid ignition and mixing, the amount of fuel which has mixed to explosive proportions during the delay period is reduced, eliminating much of the roughness caused by high pressure rise rates.

8) Fast starting: Cold starting can be accomplished quickly because of high temperature atomizing air which is obtained by rapid compression of a small charge of air in the cylinder.

9) High efficiency: The lack of necessity for a prechamber or swirl chamber may allow the engine efficiency to approach efficiencies of open chamber engines - about 5 to 8% improvement. Higher power/displacement and potentially lower compression ratio will also increase part load efficiency due to reduced friction loss.

Current Status: We are in the process of selecting an engine which will then be modified. An air assisted fuel injection system will then be designed for the research engine. Performance tests before and after the modifications should give quantitative data on the improvements in operating characteristics due to the air-assisted injector. Also, we are formulating an analytical model describing the mixing process of the air injection combustion system, with total emphasis toward support of the design of the research engine injection hardware. The model will provide necessary information for selecting the operating range of the critical parameters and will serve as a basis for planning the experimental program.