Report 8: Cost-Effective Reciprocating Engine Emissions Control and Monitoring for E&P Field and Gathering Engines

Technical Progress Report

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Abstract

For the period of the 8th reporting period high-impact control technologies were identified during the meeting at Cooper in Oklahoma City. The technologies that were identified will be tested on the Ajax DP-115 engine and are capable of being widely utilized by the E&P industry. Two major areas where engine controls and ignition systems, but still included were other alternatives to reduce emissions. The most exhilarating item for this quarter was when Ajax engine was delivered to the test bed at the NGML

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Introduction

The objective of this project is to identify, develop, test, and commercialize emissions control and monitoring technologies that can be implemented by exploration and production (E&P) operators to significantly lower their cost of environmental compliance and expedite project permitting. The project team will take considerable advantage of the emissions control research and development efforts and practices that have been underway in the gas pipeline industry for the last 12 years. These efforts and practices are expected to closely interface with the E&P industry to develop cost-effective options that apply to widely-used field and gathering engines, and which can be readily commercialized.

The project is separated into two phases. Phase 1 work establishes an E&P industry liaison group, develops a frequency distribution of installed E&P field engines, and identifies and assesses commercially available and emerging engine emissions control and monitoring technologies. Current and expected E&P engine emissions and monitoring requirements will be reviewed, and priority technologies will be identified for further development. The identified promising technologies will be tested on a laboratory engine to confirm their generic viability. In addition, during Phase 2 a full-scale field test of prototype emissions controls will be conducted on at least ten representative field engine models with challenging emissions profiles. Emissions monitoring systems that are integrated with existing controls packages will be developed. Technology transfer/commercialization is expected to be implemented through compressor fleet leasing operators, engine component suppliers, the industry liaison group, and the Petroleum Technology Transfer Council.

Research Progress

The work this reporting period focused on Task 4. As part of Task 4, an Ajax engine will be tested in a laboratory to determine the impact that potential emission reduction technologies will have on the Ajax engine. As such, work on the engine base was completed in early November. As shown in Figure 1 the rails are embedded in the base and are used to secure the engine and dynamometer.

Figure 1. Completion of engine base.

While the concrete was curing an initial operability test was performed at Cooper Compression in Oklahoma City. Before the test, Ajax personnel provided instruction on how to start and control the engine, including leveling the engine correctly. In addition to the test, a meeting with Cooper Ajax engineers was held to discuss the high-impact control technologies and several ideas on different applications to reduce emissions. The meeting provided ample suggestions for possible reduction in emissions as part of Task 4.

Ajax Test Objectives:

Baseline Test

A battery of baseline tests, which include varying engine torque, RPM, ignition timing, and air/fuel ratio will be conduced on the Ajax DP-115 with its original intake, air filter, ignition, ignition timing at 11°BTDC, and a mechanical fuel valve. At the conclusion of this test, a complete engine emissions map will be produced to determine the best air/fuel ratio to achieve the minimum amount of NO_X and CO emissions from the engine in its original equipment configuration. This baseline test should benchmark the existing condition for the thousands of Ajax engines that are installed in the E&P industry. The expected emissions are: NO_X 4.4 g/bhp-hr, CO 2.4 g/bhp-hr, THC 12.7 g/bhp-hr. These emissions are expected at an engine speed of 360 RPM and an ambient temperature of 100ºF according to Cooper Ajax.

Also during these tests the ignition timing will be retarded to investigate the impact on emissions. Retarded ignition timing has been shown to drastically reduce NO_X emissions in almost every case through the reduction of peak combustion pressures and temperatures.[1]

Exhaust Gas Recycle (EGR)

One technique that can be applied to the Ajax is recycling a portion of the exhaust gas back into the intake manifold. According to statements in the literature, "Substantial reductions in NO concentrations are achieved with 10 to 15 percent EGR."[2] By introducing exhaust gas into the air intake, expectations are that the residual exhaust fraction will increase that then increases the heat capacity of the mixture. The end result is a reduction in the combustion rate. Hence, the ignition timing will have to be advanced to ensure a complete burn prior to uncovering the exhaust ports. This change in timing will affect the thermodynamic performance of the engine. Nevertheless, this could be a relatively simple and inexpensive solution to reduce NOx.

New intake manifold and air filter

The second set of tests will investigate the impact of the newer style intake manifold. Currently the engine has the older mixer manifold which is similar to a carburetor. The gas is injected into the manifold and mixed with the air. This air-fuel mixture is then drawn into the crankcase though a reed valve. The air filter on the older style intake manifold consists of an oil bath that increases the pressure drop across the filter, which then reduces the amount of air drawn into the

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[1] Michael Crane and Steven King "Emission Reductions Thought Pre-combustion Chamber Design in a Natural Gas Lean Burn Engine" ICE vol-15 Fuels, Controls, and Aftertreatment for Low emissions Engines AMSE 1991.

[2] John Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill 1988. pg 583

crankcase. The newer manifold consists of just a reed valve as shown in Figure 2. The newer style paper air filter will allow the engine to take in air with less resistance as it directs less energy to pulling and pushing air thought the cylinder. From the literature, "Increased air into the cylinder cools the combustion process and decreases the NO_x more significantly." [3]
In addition to changing the intake, the research team will investigate methods to easily retrofit a better mechanism to increase the air flow across the reed valves.

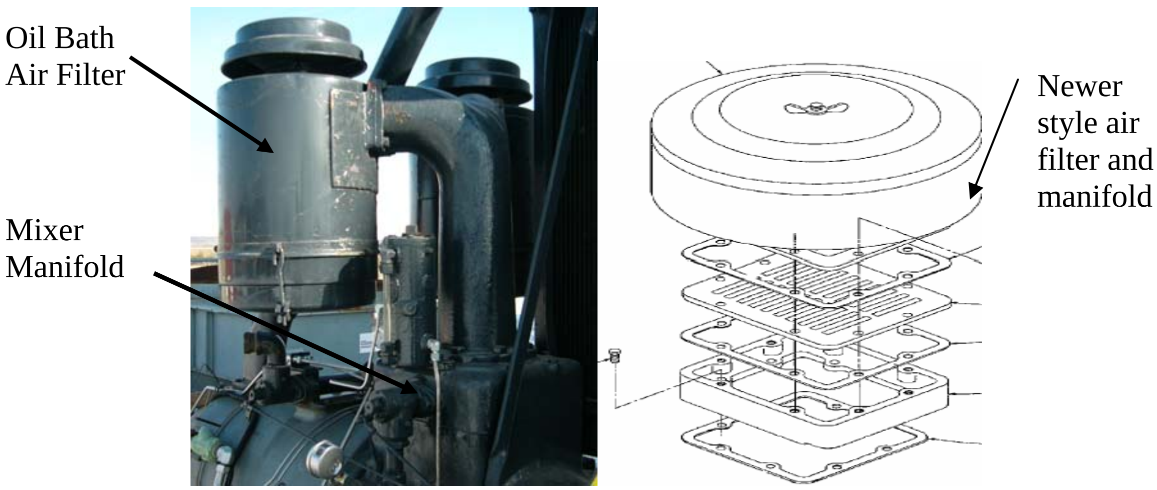

Figure 2

Pre-combustion chambers
"One advantage of natural gas is its wide flammability limits, especially on the fuel lean side where ignition natural gas can occur in the presence of more than 200 percent theoretical air."[4] Therefore, screw in pre-combustion chambers (PCCs) will be the focus of the third test to be performed. By using a pre-combustion chamber, the mixture in the main combustion chamber can be leaner. The drawback is that the spark plug no longer provides sufficient ignition energy to consistently ignite the flame. The solution is to use the pre-combustion chamber to ignite the mixture. The screw in PCC simply screws into the existing spark plug hole, and therefore minimizes the cost of this retrofit application.

There are several different manufacturers making this option readily available. Ajax has agreed to allow K-State to test the screw in PCCs developed for Cooper's GMV. Each cylinder on the GMV is 110 hp, which is similar to the Ajax DP-115. The research team plans to test other aftermarket PCCs that are readily available. Additionally, this is a relative low-cost retrofit for the engine.

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3 . Lane Sharrah. Cecil Bomar "Engine Control to meet emissions requirements on Natural Gas Fired 2-cycle engines. ICE-Vol 26-1 1996.
[4] Kanury. A.M. " Introduction to Combustion Phenomena. Combustion Science and Technology –Volume 2. Gordon and Breach.. Science Publishers. INC. 1975

Fuel valve

Currently, the OEM engine contains a spill port gas injection system that uses a hydraulic fluid system to open and close the fuel valve. The fuel regulating valve is a rotary throttle valve. This rotary valve is upstream of the fuel valve, and controls the amount of fuel that can enter the cylinder when the fuel valve opens. The fuel regulating rotary valve is controlled by the use of a mechanical governor and exhibits a slow response time that causes a delayed opening of the valve. More to the point, during the meeting at Cooper it was mentioned that the hydraulic pressure can not bleed fast enough off the valve allowing excess gas to spill into the combustion chamber.

One promising upgrade is to change the mechanical governor to an electronic governor. In addition to the governor, one additional option is to replace the mechanical fuel valve with a fast-acting electronic valve. The electronic valves are available through two aftermarket suppliers, one of which has agreed to donate a system for this project. The electronic valve will not only allow high precision fuel control, but has been shown to enhance fuel and air mixing in larger engines. Overall these options may reduce fuel consumption and allow for better control of the engine. These technologies have been chosen for tests since they can be easily retrofitted onto existing engines.

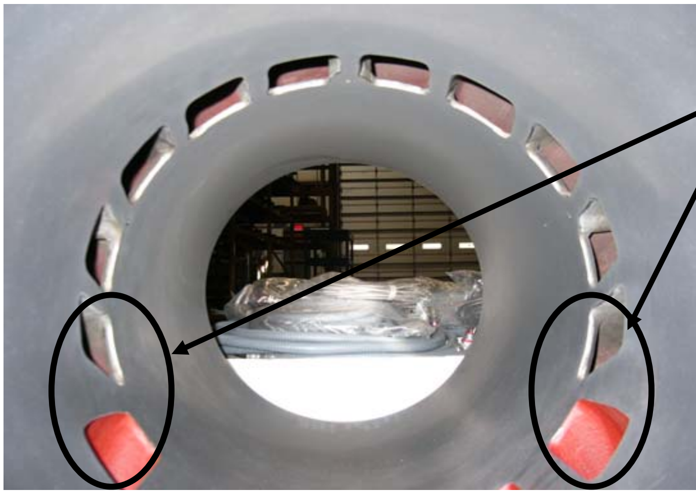
Inductive Ignition System

Another test will investigate the differences between an inductive ignition system and a the capacitor discharge system that is currently used. Inductive ignition systems use approximately the same amount of power as a capacitor discharge system. The potential advantage of an inductive system is that it can provide an adjustable arc time. The company that produces the inductive system claims that “the high energy and long, programmable arc duration are an advantage since they provide better lighting of lean of non-homogenous air/fuel mixtures.”[5]

Intake and Exhaust Ports

One observation made during the visit to Ajax is that it is possible there is short circuiting between the intake and the exhaust ports. Short circuiting causes low trapping efficiency. A low trapping efficiency can lead to higher NO_X emissions. By blocking two intake ports, shown in Figure 2, the inflow of air into the cylinder may be directed into the cylinder instead of short-circuiting to the adjacent exhaust ports. The end result will be an increase in the trapping efficiency, and in increased scavenging efficiency. Figure 3 shows how closely the intake, top, and exhaust, bottom are. If by blocking the porting in the cylinder proves effective, it can also be applied to the newer style engines to reduce emissions.

[5] Inductive Ignitions Yield Reliable Firing, Dynalco News,



The intake ports are on the top of the cylinder and the exhaust ports are on the bottom.

Figure 3

Figure 4 Ajax Engine and Dynamometer.

Future Work

In the next quarter, the Ajax engine installation and the fuel supply will be completed. The data acquisition system including the instrumentation will be installed and tested for any problems. The projected first test at the NGML will be conducted in the beginning of March.

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Conclusions

With the Ajax engine on the NGML's site, the engine test cell will come together with much more ease. This completion of the test cell and first tests should begin at the beginning of March. The battery of strategic tests has been developed and organized from most cost effective to least cost effective. With these tests it may be plausible to apply these technologies to new engines to further reduce emissions.