Advanced Radiation Techniques for Inspection of Diesel Engine Combustion Chamber Materials and Components

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LLNL -- 97003435
Final Report

CRADA No. TC-069-91-1-C

Date: October 9, 1995

TACT:

Revision:

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Caterpillar, Inc.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550

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Caterpillar Inc.
Technical Center
P. O. Box 1875
Peoria, IL 616561875

B. Project Scope

Heavy duty truck engines must meet stringent life cycle cost and regulatory requirements. Meeting these requirements has resulted in convergence on 4-stroke 6-in-line, turbocharged, and after-cooled engines with direct-injection combustion systems. These engines provide much higher efficiencies (42%, fuel consumption 200 g/kW-hr) than automotive engines (31%, fuel consumption 270 g/kW-hr), but at higher initial cost. Significant near-term diesel engine improvements are necessary and are spurred by continuing competitive, Middle - East oil problems and Congressional legislation. As a result of these trends and pressures, Caterpillar has been actively pursuing a low-fuel consumption engine research program with emphasis on product quality through process control and product inspection. The goal of this project is to combine the nondestructive evaluation and computational resources and expertise available at LLNL with the diesel engine and manufacturing expertise of the Caterpillar Corporation to develop in-process monitoring and inspection techniques for diesel engine combustion chamber components and materials. Early development of these techniques will assure the optimization of the manufacturing process by design/inspection interface. The transition from the development stage to the manufacturing stage requires a both a thorough understanding of the processes and a way of verifying conformance to

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process standards. NDE is one of the essential tools in accomplishing both elements and in this project will be integrated with Caterpillar's technological and manufacturing expertise to accomplish the project goals.

C. Technical

Deviations: The project schedule was extended because of a labor strike at Caterpillar. Technical Center personnel were unavailable for a number of months and work was therefore delayed. Work was completed by the end of CY1994. No unresolved issues remain but future work is being planned via the WFO mechanism.

D. Partner Contribution

Caterpillar supplied components and assemblies necessary for the technique evaluations. Caterpillar personnel came to LLNL to learn to use reconstruction and signal/image processing codes required for the analysis of data supplied by LLNL. They have installed the appropriate codes on their systems. Results of the work has been supplied to Caterpillar production units and formal presentations made to encourage those units to adopt the technologies on the factory floor. Caterpillar has adopted some of the codes provided for their own use.

E. Financial (\$K)

Federal	\$1100
Non-Federal	<u>1266</u>
Total Funding	\$2366

F. Documents/Reference List**Reports**

Letter	October 29, 1992	portliner
Letter	April 26, 1992	thermistors
Letter	August 1996	glow plugs and engine sensors
Letter	November 3, 1993	fuel injector assembly
Letter	January 13, 1992	ports
Letter	September 24, 1993	powdered metals
Report	August 4, 1993	Research on the Inspection of Diesel Engine Components with Penetrating Radiation
		Report I: Small Diesel Engine Components
Letter	February 9, 1993	Ultrasonic Velocities of Zirconium Oxide Composite
Report	End of project	Fuel injector analysis Tools
Report	End of Project	Radius of Curvature Measurements

Presentations at Caterpillar

December 1992

March 1993

August 1994

Inspection Results - Data Supplied on Digital Tape

Subject

fuel injector tips

pistons

fuel injector assemblies

engine sensors

glow plugs

lead sleeves

hotplates

portliner

engine block

track

G. Property and Proprietary Information:

Laboratory Items at Caterpillar

- SGI Indigo workstation and disks
- Dell computer 433/L PC-AT
  - MATROX IMAGER-AT card
  - Ethernet card and PC-NFS card
  - C-Compiler
- 10 mm x 2" x 2" scintillating glass
- Artecon 150mB tape drive

Caterpillar Items at LLNL

Miscellaneous components used as test objects in project.

All property will be returned to its owner.

H. Acknowledgment

Participant's signature of the final report indicates the following:

- 1) The Participant has reviewed the final report and concurs with the statements made therein.
- 2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
- 3) The Participant certifies that all reports, inventions disclosures and patent applications attributable to the project are completed or are in process and a list is attached to this report.

<u>Charles Anderson</u>	<u>Jerry Haskins</u>
<u>12/13/96</u>	<u>1/2/97</u>
Date	Date

Attachment I – Accomplishments Summary

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Project Accomplishments Summary (Attachment I) CRADA No. TC-069-91-1-C

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A. Parties

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B. Background

Heavy duty truck engines must meet stringent life cycle cost and regulatory requirements. Meeting these requirements has resulted in convergence on 4-stroke 6-in-line, turbocharged, and after-cooled engines with direct-injection combustion systems. These engines provide much higher efficiencies (42%, fuel consumption 200 g/kW-hr) than automotive engines (31%, fuel consumption 270 g/kW-hr), but at higher initial cost. Significant near-term diesel engine improvements are necessary and are spurred by continuing competitive, Middle - East oil problems and by Congressional legislation. As a result of these trends and pressures, Caterpillar has been actively pursuing a low-fuel consumption engine research program with emphasis on product quality through process control and product inspection.. The transition from the development stage to the manufacturing stage requires a both a thorough understanding of the processes and a way of verifying conformance to process standards. NDE is one of the essential tools in accomplishing both elements and in this project will be integrated with Caterpillar's technological and manufacturing expertise to accomplish the project goals.

The successful application of NDE to process control requires that NDE be used to characterize materials and components during the development phase in order that the effect of manufacturing variables on results can be determined. We have refined

our ability to make these determinations through years of weapons program activity.

C. Description

The goals of this project were to improve the efficiency of diesel engines while meeting or exceeding new environmental regulations, develop in-process monitoring and inspection techniques for diesel engine combustion chamber components and materials. We accomplished this by combining the nondestructive evaluation and computational resources and expertise available at LLNL with the diesel engine and manufacturing expertise of the Caterpillar Corporation.

During the course of the project we evaluated the effectiveness of different NDE techniques for the inspection of pistons, exhaust manifolds, fuel injector tips, fuel injector assemblies, engine sensors, and engine blocks. When a technique was selected for a specific component we determined the optimum inspection variables, developed signal processing tools as required, and determined the accuracy and sensitivity of the data. This information was supplied to Caterpillar for their application to the production environment.

D. Expected Economic Impact

Actual economic impact of this work is not yet available. The impact will occur in Caterpillar's efforts to improve fuel efficiency, reduce emissions, and extend product life. Caterpillar has implemented our signal and image processing code (VIEW) and our suite of computed tomography reconstruction codes and have installed a radiographic film digitizer based on our design. They have used our input in their application of thermal imaging and ultrasonics and will install a CT system this calendar year.

E. Benefits to DOE

NDE systems being developed for manufacturing applications apply equally well to surveillance, inspection after assembly, and inspection prior to disassembly. Data analysis techniques and software developed for these programs apply directly to weapons program needs and the knowledge of industrial manufacturing/casting processes will help us apply process monitoring to the weapons program. Computed tomography provides three dimensional data about the properties of the internal volume elements of a component which is essential to stockpile surveillance. Equipment and hardware purchased for tech transfer programs is already being used for weapons related activities and we gain valuable experience by installing prototype systems on real production lines

F. Industry Area

Heavy equipment, trucking, diesel engines

G. LLNL Point of Contact for Project Information

Daniel J. Schneberk (510) 423-3531 (510 422-3834

Jerry J. Haskins (510) 423-4267 (510 422-3834

H. Company Size and Point(s) of Contact

Caterpillar Inc.

30,000 employees

Annual Sales of \$2b

Charles Anderson (309) 578-6163 contact for information

Gregg Happoldt (309) 578-8875

FAX (309) 578 2953

RELEASE OF INFORMATION

I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

Charles Anderson
Caterpillar Inc

12 DEC 96

Date