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13. ABSTRACT (*Maximum 200 words*)

A brief description is given of the facilities of the ERC, indicating the equipment purchased under the grant and discussing some of the unique features and uses.

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Final Report for Equipment Grant DAAL03-86-G-0199

FINAL REPORT

G. L. Borman

August 15, 1991

U. S. Army Research Office

DAAL03-86-G-0199

U.W.-Madison

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Grant Purpose and Needs

The subject grant, DAAL03-86-G-0199, provided funds for purchase of equipment to be used for projects funded by contract DAAL03-86-K-0174. These projects were to accomplish two major objectives of the Engine Research Center; (1) to produce research results which would help the army in its quest for more efficient, higher power density engines, (2) train students who could use the most advanced research technologies in their future work. The major categories of equipment needed for such research are; engines, data acquisition systems, emissions analysis instruments, shop facilities, computers, lasers, and a variety of special purpose instruments and special purpose rigs.

Results

At the start of the grant the lab was equipped with engines, electric dynamometers, emissions analysis instruments and working but inadequate data acquisition systems. Shop facilities, computers and lasers were totally inadequate. Only a few modern special purpose instruments were available. The most modern diagnostic instrument was a two component LDV purchased from a previous ARO instrumentation grant. The engine dynamometer control system was very old and in need of replacement. This status of the laboratory was remarkably changed during the grant period from September 1986 to June 30, 1991. The facilities as they exist as of June 30, 1991 are listed in Table 1. The equipment obtained from the subject grant have outlined roman numerals.

Looking at the engines listed in Table 1 it is quite clear that only one of 12 engines was purchased under the grant. All of the engines except I, which was obtained from a TACOM contract, and VII were obtained as gifts from a company. The purchased oil test engine (VII) was obtained because it had appropriate features for modification as part of a special engine-fed-bomb to be used for diesel spray investigations. The modifications were performed at the ERC.

The old control system for the dynamometers was replaced by a modern system purchased through a grant from the university. However, many of the test stands were improved by using equipment purchased under the grant.

The general purpose equipment was greatly improved by purchase of items XIII to XVI. The item XIII acquisition equipment was obtained because it is specially designed for engine data analysis.

The computer facilities, items XXIII to XXVI were purchased for two purposes. The microvax and PC-type workstations are used to process experimental data. The Silicon Graphics Workstations and the Titan are used for modeling work. The computation intensive calculations required by the CFC codes (KIVA) are primarily done on Cray computers at the San Diego Center and Cray Research. However code development, some trial calculations and output processing are done on the S.G. workstations and the Titan. Specially air conditioning for the room which houses the Titan was provided by a gift from G.M.C..

Each of the special purpose items (XXVII to LIII of Table 1) is either an off-the-shelf item incorporated in a special system, a device specially modified by the manufacturer or a device specially designed and constructed at the ERC.

Examples of much used commercial devices are the lasers (XXVIII, XXX, XXXII, XXXIII, and XXXV of Table 1). The copper vapor laser XXVIII can be used as a synchronized light source for the high-speed camera and used to image diesel spray plumes in the high pressure bomb (L) or the engine-fed-bomb (VII).

Examples of modified devices are the PDPA (XXXVII) and the special deformation machine (XL). In each case the modifications have made possible taking of data specially suited to engine environments.

Examples of instruments created in the ERC are given by items XXXI, XXXIV, XXXVIII, XLI, XLIII, XLVI, and XLVIII. The coherent fiber system and the radiation instrument are examples of special systems created to make in-cylinder measurements. The Lodge stressmeter and the shock tube are examples of special devices incorporating unique design features which allow measurements duplicating engine-like conditions. It should be noted that items XLIVI and LI are gifts from industry.

The items listed here along with the faculty, staff and students that utilize them form a powerful facility for up-to-date research. This facility in turn helps to attract additional facilities. For example, the fiber optic, laser induced fluorescent method of oil film measurement developed at the ERC caused Cummins to contribute the L-10 engine so that a modern engine could be used to exercise the method. Similarly, the development of unique heat transfer instrumentation at the ERC attracted Isuzu to offer an all ceramic LHR engine for research at the ERC. It must be commented however that although the equipment is now quite modern, it will take a continuing investment of several hundred thousand dollars per year to keep the system current and a similar amount to keep the items in good repair. Maintenance of the laser and computer system is particularly expensive.

<u>Productivity</u>

By the end of the research contract associated with this equipment grant it is estimated the 20 visiting researchers, 36 PhD's and 32 MS students will have benefitted from the equipment. Thus far, 70 reviewed technical papers have been generated. Because these degrees and publications are to be reported in the final report for contract DAAL03-86-K-0174, that information is not repeated here.

TABLE 1
ERC FACILITIES

The ERC is housed in the first three floors of the Engineering Research Building. The basement engine cells currently contain nine engine test stands. Each engine is connected to an electric dynamometer with speed control, and all setups include conventional oil and water temperature controls, air and fuel flow measurements, and a shaft encoder. The engines currently in use follow.

I	TACOM/LABECO; single-cylinder diesel with special head for instrumentation, simulated turbocharging, and mini-dilution tunnel.
II	CAT-OIL TEST I; with special head and injector, simulated turbocharging.
III	Triptane See-Through; small engine with optical ports through piston into clearance volume, annular sapphire ring for observation into the clearance volume, and a special head with a large instrumentation port for mounting surface thermocouples or further optical access.
IV	DDA 53; single-cylinder two-cycle diesel with simulated turbocharging and EFI, spark plug in head, auxiliary port injection, and pilot injection.
V	Cummins NH single cylinder with simulated turbocharging, special instrumentation ports in head, special load control system, and minidilution tunnel.
VI	CFR; single-cylinder with variable compression ratio optical ports and heated homogeneous charge for autoigniting combustion.
VII	CAT-OIL TEST II; single-cylinder open chamber modified for optical access spray chamber.
VIII	Ford Ceramic Diesel; single-cylinder direct-injected with a number of different configurations, each with a different number of ceramic and low-cooled parts.
IX	Cummins L-10; one active cylinder, direct-injected with electronic fuel injection, simulated turbo-charging, and instrumentation for liner oil-film measurements.

In addition, there are three small engines, one of which is connected to a variable speed drive and the other two to water brake dynamometers. These engines are:

X	Mercury Glass Two-Stroke; single-cylinder ported two-stroke with almost complete optical access to the combustion chamber.
XI	Briggs and Stratton: single-cylinder with specially-modified head and piston for piston surface temperature measurements using infrared imaging and evaluation of candidate ceramic materials.
XII	Kubota; single-cylinder with instrumentation for determining emissions and performance characteristics.

Table 1 (Continued)

General purpose equipment include those below.

XIII	Twelve channels of high-speed data acquisition (externally clocked 80286 and 80386 machines)
XIV	Low-speed data acquisition systems.
XV	Tektronix 11401, 2430, 2210 digital oscilloscopes.
XVI	Tektronix FG 504 function generator, other scopes, DMM, etc.
XVII	Gas chromatography instruments, and exhaust emissions analysis instruments for CO, CO_2, NO, NO_x UHC, H_2O gas analysis and soot mass.
XVIII	Borescope
XIX	Pyrometer and high-temperature black body for optical calibration.
XX	Cameras and darkroom facilities.
XXI	PCs dedicated for experiment control.
XXII	Complete full-size and range machine shop, including vertical milling machine and engine lathe, band saw, welding equipment, and complete tooling.

Computer facilities dedicated to Center use are listed below.

XXIII	A Micro Vax II minicomputer with Telnet access to Cray supercomputers at the San Diego Supercomputer Center and at Cray Research in Mendota Heights, Minnesota.
XIV	Several PC-type workstations with CAD, graphics, wordprocessors, etc.
XXV	Two Silicon Graphics Workstations for interactive sessions with the Cray computers that include extensive graphics animation.
XXVI	An Ardent Titan Supercomputer/Workstation capable of very high speed computations, typical of those necessary for multidimensional simulations such as KIVA, and advanced display features.

Table 1 (continued)

Special equipment usually dedicated to a single experiment or setup include the following.

XXVII	High-speed movie camera.
XXVIIII	Ten Watt copper-vapor laser for use in high-speed photography and PIV.
XXIV	Three laser Doppler velocimeter two-component systems with traversing systems.
XXX	Excimer laser for laser-induced fluorescence.
XXXI	Three video camera/frame grabber systems for digital image analysis.
XXXII	Two Nd: YAG lasers, dye laser for Raman spectroscopy.
XXXIII	Two HeCad lasers for fluorescence studies of engine oil film thickness.
XXXIV	Coherent fiberoptic bundle for visualization and spatially-resolved measurements in ordinary diesel engines.
XXXV	Many smaller lasers for scattering and extinction measurements, particle image velocimetry, speckle interferometry.
XXXVI	0.5 and 1 m spectrometers.
XXXVII	Phase/Doppler Particle Analyzer.
XXXVIIII	Radiant heat transfer instrument.
XXXIX	Surface thermocouples for dynamic heat transfer.
XL	High temperature, controlled atmosphere deformation machine.
XLI	High shear rate Lodge stressmeter.
XLII	Flow bench for measuring valve and port flow characteristics.
XLIII	A shock tube and special radiation source to simulate conditions in the engine cylinder at the time of injection.
XLIVI	Pump test stand for testing high flow rate injection systems.
XLV	Gated image-intensified CID camera for in-cylinder imaging.
XLVI	Hybrid optical-numerical and all-optical PIV processors.
XLVII	Berglund-Liu type monodisperse droplet generators.
XLVIII	Zuech and Bosch-type rate-of-injection meters.
IL	Jet-stirred reactor for soot oxidation studies.
L	High-pressure bomb for spray studies.
LI	Elevated pressure flow tube for soot formation/oxidation studies.
LII	High-pressure continuous flow spray facility.
LIII	Long-distance microscope photographic lens.