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Coal Diesel Combined-Cycle Project

Annual Report
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Federal Energy Technology Center
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1.0 Introduction

1.1 Clean Coal Diesel Technology Project Overview

The Clean Coal Diesel project will demonstrate a new Clean Coal Technology that has technical, economic and environmental advantages over conventional power generating methods. This innovative technology enables utilization of coal-based fuel in large-bore, medium-speed, diesel engines. Modular power generating applications in the 10 to 100 megawatt size range are the target applications.

The project is led by Arthur D. Little, Inc. (ADL), supported by a team consisting of the University of Alaska, Fairbanks (UAF), the Cooper-Bessemer Reciprocating Division of Cameron (Cooper), CQ, Inc., the Energy and Environmental Research Center of the University of North Dakota (EERC), and the Usibelli Coal Company.

The University of Alaska campus in Fairbanks, Alaska, is the project's host site. At this location, the University will construct and operate the Clean Coal Diesel System, which will serve as a 6.2 MW diesel powerplant addition. The University will also assemble and operate a 5-ton per hour coal-water fuel processing plant. The plant will utilize local coal, brought by truck from Usibelli's mine in Healey, AK.

The project involves the operation of a clean coal diesel engine on a coal-water fuel for 6,000 hours to demonstrate durability, low emissions, and other commercial performance characteristics. This demonstration is a vital step on the coal diesel commercialization path. With success, the team envisions the following key markets for the coal diesel (after gas prices rise to a level that CWF is competitive): 1) non-utility (NUG) new capacity, 2) small utility repowering, and 3) exports to developing countries of coal technology.

The estimated performance characteristics of the mature commercial embodiment of the Clean Coal Diesel, if achieved, will make this technology quite competitive:

- 48% efficiency
- $1300/kW installed cost
- Emission levels controlled to 50-70% below New Source Performance Standards

1.2 Clean Coal Diesel Development History

Since 1985, Cooper-Bessemer has conducted extensive research and development work to burn coal-based fuel in a diesel engine, under the sponsorship of Morgantown Energy Technology Center of the U.S. Department of Energy, and in cooperation with Arthur D. Little, Inc., and other leading U.S. companies. The research work on a single-cylinder research engine between 1985 and 1988 firmly established the feasibility of burning Coal Water Fuel (CWF), which is a mixture of equal parts by weight of finely powdered coal and water. This led to our undertaking a five-year project in 1988 to develop a six-cylinder production version of the diesel engine to operate on CWF. This project yielded very encouraging results:

- Cooper's 200 kW and 1800 kW research engines were operated for over 1200 hours, developing full power with good fuel consumption and without any deposits inside the engine.
- New technologies were developed to combat the wear due to constituents in the coal.
- A full scale emissions control system demonstrated our ability to reduce NO_x, SO_x, and particulate emissions to levels significantly below current and anticipated future regulatory limits.

In 1994, the Department of Energy entered into a cooperative agreement for Cooper-Bessemer and Arthur D. Little to conduct a $38.3 million Clean Coal Technology V (CCT-V) demonstration project. The objective of the demonstration is to prove that the coal diesel technology is durable and reliable by operating 6000 hours in a realistic powerplant operating setting.

As a result of developments following the withdrawal of the original host site (Easton, Maryland), Arthur D. Little has reached agreement with DOE to resite the Clean Coal Diesel Demonstration to Fairbanks, Alaska. The coal diesel will serve as an addition to the powerplant owned and operated by the University of Alaska, Fairbanks.

1.3 Project Goals and Participants

The objective of the Clean Coal Diesel project is to demonstrate a new Clean Coal Technology that has technical, economic and environmental advantages over conventional power generating methods. The Coal Diesel Technology is an innovative, modular technology that will service the generation market in increments of less than 100 megawatt (MW). The project involves the operation of a clean coal diesel engine on a coal-water fuel for 6,000 hours to demonstrate durability, low emissions, and other commercial performance characteristics.

Specific objectives are to demonstrate that the Coal Diesel Technology:

- Is durable and can operate 6,000 hours in a realistic commercial setting
- Will meet efficiency targets
- Can effectively control criteria pollutants to levels that are well below anticipated standards, as well as reduce greenhouse gas emissions
- Can accommodate substantial power demand swings

Team Member and Key Roles in the Demonstration

The project is led by Arthur D. Little, Inc., supported by a team consisting of the University of Alaska, Fairbanks, the Cooper-Bessemer Reciprocating Division of Cooper Cameron, CQ, Inc., the Energy and Environmental Research Center of the University of

North Dakota, and the Usibelli Coal Company. Also, the Ohio Coal Development Office (OCDO) provided valuable support during the initial stages of the project. The key roles for each organization are as follows:

- **University of Alaska, Fairbanks**: Host the demonstration; obtain permits; oversee design and construction of the powerplant addition (using A&E and local contractors); operate the powerplant. UAF's School of Mineral Engineering will also provide consulting on coal science and coal processing. The Mineral Industry Research Laboratory will design and oversee the construction of the coal-water fuel production plant and operate it.
- **Arthur D. Little, Inc.**: Provide technical direction; manage the CCT-V demonstration; assist Cooper with commercialization plans; assist CQ with coal cleaning.
- **Cooper**: Design, fabricate, and install 20-cylinder coal diesel engine (6.2 MW); conduct component durability testing; use the demonstration to establish foundation for commercial introduction; lead the market introduction of coal diesel.
- **CQ, Inc. and EERC**: Support design of the coal cleaning and hydrothermal treatment plant; provide technical assistance with operation of the plant, including training of operators; assist with commercialization, as requested.
- **Usibelli Coal Company**: Provide source coal; assist team with commercialization strategy; provide management expertise and marketing personnel.

1.4 Clean Coal Demonstration Plan and Schedule

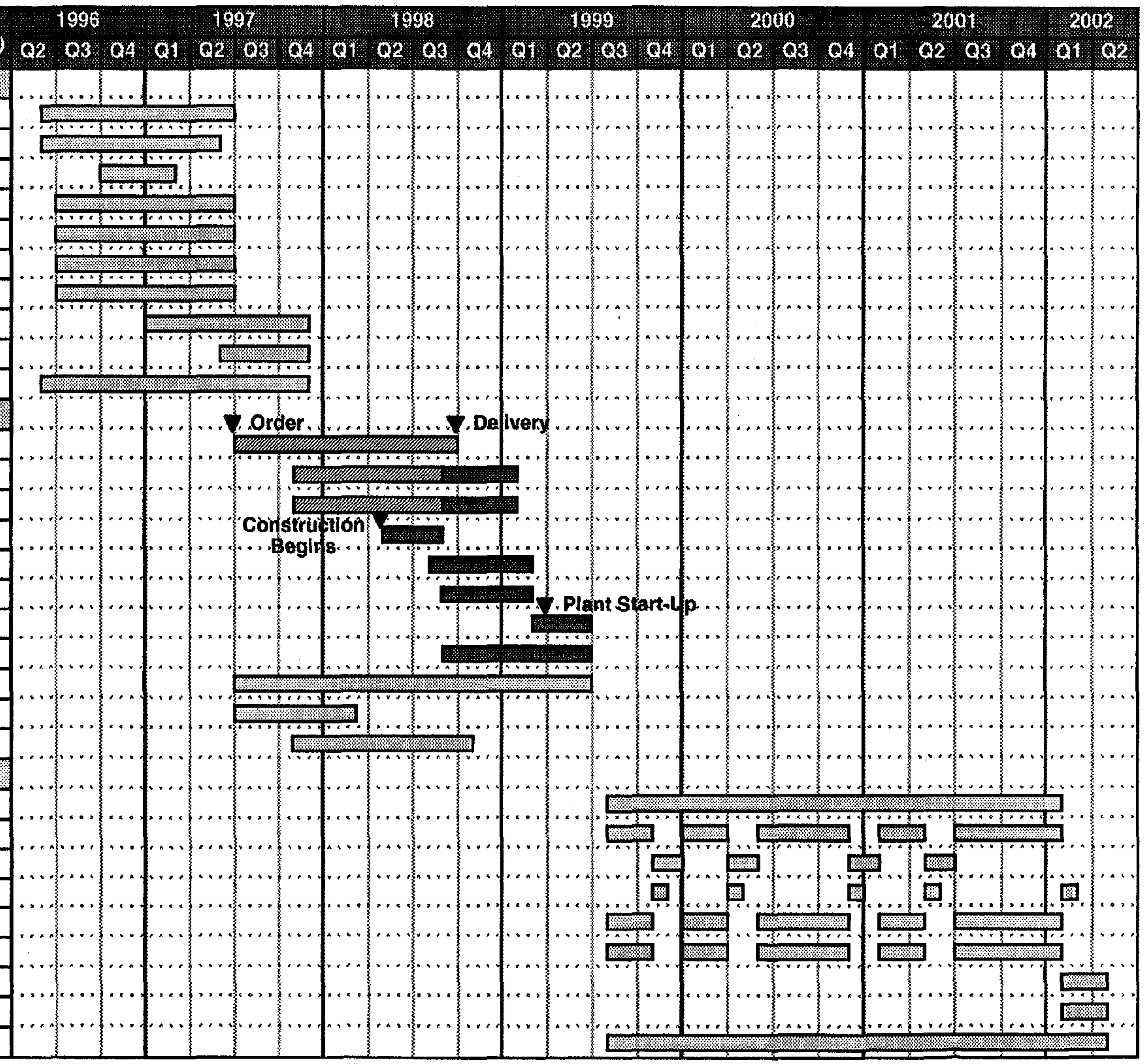
The University of Alaska campus in Fairbanks, Alaska, is the project's host site. At this location, the University will construct and operate the Coal Diesel System, which will serve as a 6.2 MW diesel powerplant addition (to the existing two oil-fired boilers and two stoker-type coal-fired boilers). The Clean Coal Diesel System includes a 20-cylinder, 400 rpm Cooper-Bessemer LSVC type engine, generator, integrated emission control system and standard auxiliary systems. Engine exhaust will be fed to a waste heat boiler to generate steam for additional power generation and for UAF heating.

The University will also assemble and operate a 5-ton per hour coal-water fuel processing plant. The plant will utilize local coal brought by truck from Usibelli's mine in Healey (approximately 80 miles from UAF).

The project is organized into three phases: Design (June 1996 to November 1997), Construction (July 1997 to July, 1999), and Demonstration Tests (August 1999 to April 2002). Each is concisely described below. Figure 1-1 shows the planned schedule for the project.

Figure 1-1. Schedule and Milestones for UAF Site

TASK	Description	Start (1st of)	Finish (End of)
PHASE I—Design Engineering		Jun 96	Nov 97
1.1	Permit/Certificate	Jun 96	Jun 97
1.2	Plant preliminary design	Jun 96	May 97
1.3	Environmental monitoring plan/test plan	Oct 96	Feb 97
1.4	Design 20 cylinder engine components	Jul 96	Jun 97
1.5	Coal slurry qualification tests	Jul 96	Jun 97
1.6	Emission system design	Jul 96	Jun 97
1.7	Lab engine tests	Jul 96	Jun 97
1.8	Coal cleaning plant design	Jan 97	Nov 97
1.9	Plant design engineering	Jun 97	Nov 97
1.10	DOE reports and project reviews	Jun 96	Nov 97
PHASE II—Construction		Jul 97	Jul 99
2.1	Engine fabrication	Jul 97	Sep 98
2.2	Emission system	Nov 97	Jan 99
2.3	Coal cleaning and slurry facilities	Nov 97	Jan 99
2.4	Building/Foundations	May 98	Aug 98
2.5	Stack/Radiators/Balance of plant	Aug 98	Feb 99
2.6	Engine installation and plant erection	Sep 98	Feb 99
2.7	Commissioning UAF plant	Mar 99	Jul 99
2.8	Instrumentation	Sep 98	Jul 99
2.9	DOE reports and project reviews—Phase II	Jul 97	Jul 99
2.10	Six-Cylinder Engine Tests—Part 2	Jul 97	Feb 98
2.11	Boiler Conversion to CWS	Nov 97	Nov 98
PHASE III—Demonstration Tests		Aug 99	Apr 02
3.1	CWS plant performance tests	Aug 99	Jan 02
3.2	CWS engine performance tests	Aug 99	Jan 02
3.3	Engine component replacements	Nov 99	Jun 01
3.4	Engine component wear monitoring	Nov 99	Feb 02
3.5	Emission control tests and data evaluation	Aug 99	Jan 02
3.6	Plant operation and maintenance records	Aug 99	Jan 02
3.7	Engine restoration	Feb 02	Apr 02
3.8	Update commercialization plan	Feb 02	Apr 02
3.9	DOE reports and project reviews—Phase III	Aug 99	Apr 02



Fabrication   Installation   Commissioning   ▼ = Proposed Milestone

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Phase I: Design, Permitting, and Coal Fuel Tests. The Coal Diesel System, complete with emission controls, will be designed using contracted A&E services so as to integrate the diesel with the existing UAF powerplant. The permit and NEPA process will be completed. During the permit application period (8-12 months), the coal cleaning and slurry process will be fine tuned for specific Alaska coals (from Usibelli) so that the engine will run optimally on these coals. The coal slurry plant will be designed to take advantage of existing LRCWF process techniques and CQ's coal cleaning steps. The 5 ton per hour coal process plant will be designed by the same A&E with inputs from UAF, CQ, and EERC. Also in Phase I, Cooper will complete an additional 100 hours of testing using their 1800 kW engine, with emphasis on validating the performance of CWF produced from Alaska coal and also on refining the design specifications for durable components.

Phase II: Construction and Start-Up. The engine, generator, exhaust gas treatment system, standard auxiliary systems, CWF storage and supply system will be manufactured and installed. The coal process plant will also be assembled within an existing UAF building adjacent to the powerplant. Piping for slurry delivery will be installed in the existing utilities corridor. Phase II ends when both the coal diesel powerplant and the coal fuel production plant are successfully started up.

Phase III: Demonstration Tests. The demonstration will take place over a three-year period following extensive shakedown tests in 1999. Several test runs totaling 6000 hours are planned. The University of Alaska will operate the powerplant on conventional fuel when the engine is not being operated on CWF. At the end of the demonstration program, the University will have the option to operate the CWF powerplant or have the engines converted back to operate on conventional fuel, depending on prevailing oil prices relative to engine-grade coal slurry fuel.

1.5 Key Phase I Accomplishments in 1996

Highlighted below are the key project accomplishments for calendar year 1996:

- The project team completed the initial series of coal-water fuel performance tests on Cooper's full-scale LSC-6 engine at their Mt. Vernon, Ohio test facility. This engine was operated with one cylinder burning Ohio CWF and the remaining five firing diesel fuel. About 34,000 pounds of CWF were consumed. In these tests, the fuel efficiency, exhaust temperature and peak cylinder pressure for CWF firing were all within desired ranges. Overall, these test results indicate that Ohio CWF meets our requirements for satisfactory engine performance.

- Cooper completed in-use durability testing of the chromium carbide exhaust valves in the CWS cylinder of the full scale LSC engine. We successfully accumulated approximately 180 hours of engine operation with these valves in use. The coated portions of the valves showed little or no wear.

- Following this initial Phase I test series, Cooper completed the LSC engine teardown and in-cylinder components inspection. ADL materials specialists visited Cooper's engine laboratory to inspect the in-cylinder components. The ADL-Cooper team concluded that cylinder liner, exhaust valve, and compression ring wear rates were low. The injection nozzle tip showed evidence of increased wear since the last detailed inspection; however, engine performance was not affected.

- Since the town of Easton, Maryland had decided to withdraw from our Clean Coal project due to changes in their powerplant needs, the team actively sought a new host for the demonstration. Much of this effort focused on potential sites in Ohio, Illinois and Alaska. The team, in consultation with DOE, decided that it is best to relocate the project to Fairbanks, Alaska with the University of Alaska Fairbanks serving as the host.

- The team submitted a resiting proposal package to DOE, based on the Fairbanks, Alaska site. The team carried out planning activities for relocation of the coal diesel demonstration project to the University of Alaska, Fairbanks. Project budgets and task schedules for all phases were refined. A detailed cost-to-complete analysis, incorporating the project relocation and testing of Alaska coal, was carried out for Phase I. Several team members from Arthur D. Little and Cooper performed a site inspection at UAF Alaska with DOE staff.

- ADL staff met with UAF to discuss contractual issues and to prepare a draft agreement for UAF's participation in the project. The draft project agreement for UAF participation is being reviewed by UAF and will be finalized early in 1997.

- The team completed the Environmental Impact Volume for the University of Alaska, Fairbanks demonstration. As part of this effort, staff from DOE, Mangi Environmental, and ADL visited the University of Alaska, Fairbanks to address environmental issues. Meetings were held with key university staff and State of Alaska environmental officials.

- The UAF's Planning and Project Services Department coordinated selection of the project's A&E firm. The University of Alaska prepared and issued a request for proposals. Three responsive proposals for the project's A&E activities were received by UAF. Interviews with these teams were held in mid-December. A team led by R. W. Beck was selected and contract negotiations were initiated.

- EERC completed the preparation of CWF from samples of Alaska coal. Six drums having coal with ash contents of 6.2 - 9.6 % were produced. This fuel, starting with the lowest ash content, will be tested in the Model JS-1 Cooper engine to validate combustion performance and to evaluate initial wear characteristics. Engine tests for the initial batch of Alaska CWF have been scheduled for January.

- We held discussions with CANMET's Western Research Center regarding their ability to clean 5 - 10 tons of Usibelli coal for Phase I testing at Cooper. This facility has a heavy media cyclone cleaning circuit that is capable of processing this quantity of coal.

2.0 Permits and EIV/NEPA Documents

An Environmental Information Volume (EIV) was prepared as a basis for assessing the environmental impacts of the Clean Coal Diesel Project and the project's environmental features while meeting the intent of DOE's CCT-V program. The sections below provide highlights from this document.

2.1 Facility Modifications

The following table summarizes the proposed modifications to the existing power plant equipment and its operation:

Table 2-1. Current and Proposed Configuration and Operation of Existing Powerplant Equipment

Boiler No.	Current Configuration and Operation	Proposed Configuration and Operation
1 and 2	Both coal fired stokers. Alternating operation with one boiler on hot standby and the other covering base load as required.	Both boilers will remain as coal fired stoking. One of these boilers to be put on cold standby, the other to be used to cover base load requirements.
3	Fuel oil operated. Only used during peak load conditions.	Retrofit to burn coal-water fuel and/or oil to cover base load. New baghouse to be provided to capture particulate emissions.
4	Fuel oil operated.	Hot standby. This boiler will remain fuel oil operated.

2.2 Air Quality Impacts

The air quality staff of the Alaska Department of Environmental Conservation (ADEC) have reviewed the proposed modifications to the power plant and the coal processing area in the MIRL building. These changes have been approved by ADEC in an October 8, 1996 modification to the existing powerplant air permit equipment list, assuming that the modifications do not cause a net increase in current or permitted emissions. Table 2-2 compares estimated maximum annual emissions for the demonstration runs of the coal diesel engine on CWF (in 2001, the year of maximum test operations) to both the UAF powerplant permit limits and the 1995 reported actual emissions for the powerplant.

Table 2-2. Comparison of Estimated Coal Diesel Engine Demonstration Emissions *

Pollutant	Estimated Annual Emissions (TPY)		
	Coal Diesel Engine on CWF (2001)	UAF Powerplant 1995	UAF Powerplant Permit Limit
SO_2	**12.2** [(a)]	275.3	1429
NOx	**16**	400.7 [(c)]	710
Particulates	**0.3** [(b)]	4.3	63
CO	**36.1**	139.1	504

* Engine at full load; 52.7 MMBtu/hr input, 4000 hrs of operation on CWF
(a) SO_2 emissions based on 0.24% sulfur content and 70% reduction by APC equipment.
(b) Assumes 99.99% collection efficiency by cyclone-baghouse combination.
(c) Based on AP-42 emission factors

During the course of the test program, the new engine will also be fired on fuel oil (i.e., No. 4 & No. 1 oil mixture). This portion of the test plan has been represented based on an actual firing rate of 500 hours per year. In addition, the emissions from these operations have been presented in Table 2-3 based on a by-pass of the air pollution control train. The by-pass would be necessary during the testing phases so that inspections and troubleshooting operations could take place. The 500 hours are a conservative assumption, based on the needs of the test plan. In other words, the by-pass operations would likely be less than those presented in Table 2-3, but a conservative approach has been taken for purposes of providing emissions estimates relative to the proposed test plan.

In reviewing the emissions rates in Table 2-3, it can be seen that the proposed operation of the CCD project is expected to result in lower overall actual annual emissions as compared to the non-CCD (no-build) case. Although reducing the plant's overall NOx emissions, by itself the new emissions unit (i.e., the CWF/oil diesel) would represent greater than a 40 ton per year source of potential NOx emissions. Without the demonstration project and without federally enforceable emissions offsets, this would indicate that Prevention of Significant Deterioration (PSD) permitting requirements might be applicable. In this situation, the Clean Coal Technology projects are exempted from Part C of the Clean Air Act/PSD under the 1990 amendments, specifically under Title IV. This project, as currently conceived, is projected not to exceed the applicable Significant Impact Levels for ambient impacts and would comply with the applicable PSD increments.

Table 2-3. Estimated Annual Air Emissions for UAF Demonstration Project

Year of Maximum Coal Diesel Engine Operation

	Unit	Operating Hours	Fuel Type	Coal Use	Oil Use	Energy In	SO_2		NOx		Particulates		CO		Power Out	Steam Out
				Tons/Yr	Gal/Yr	BBtu/Yr	lb/MMBtu	TPY	lb/MMBtu	TPY	lb/MMBtu	TPY	lb/MMBtu	TPY	MM kWh	MM lb
Without CCD Project	Stoker Boiler	7000	Coal	30000		490	0.380	93.1	0.835	204.6	0.007	1.7	0.305	74.7	21	154
	Stoker Boiler	7000	Coal	30000		490	0.380	93.1	0.835	204.6	0.007	1.7	0.305	74.7	21	154
	Oil Boiler	1000	No 4/No 1 Blend		190000	27	0.750	10.1	0.143	1.9	0.014	0.2	0.036	0.5	2	0
	Oil Boiler	1000	No 4/No 1 Blend		190000	27	0.750	10.1	0.143	1.9	0.014	0.2	0.036	0.5	2	0
	Diesel Engine	650	No 4/No 1 Blend		126000	18	0.707	6.4	3.100	27.9	0.070	0.6	0.810	7.3	2	0
Totals:						1052		212.8		440.9		4.4		157.7	48	308
With CCD Project	Stoker Boiler	7000	Coal	11000		180	0.380	34.2	0.835	75.2	0.007	0.6	0.305	27.5	10	31
	CWF Boiler	5000	CWF	16200		416	0.380	79.0	0.400	83.2	0.003	0.6	0.040	8.3	10	230
	Coal Diesel	4000	CWF w/DF pilot	8100	78000	220	0.111	12.2	0.146	16.0	0.003	0.3	0.328	36.1	25	42
	Coal Diesel	500 (Oil Mode)	No 4/No 1 Blend		196000	28	0.707	9.9	3.100	43.4	0.070	1.0	0.810	11.3	3	5
	Thermal Oxidizer	7200	Propane			2	1.066	1.3	0.153	0.18	0.004	0.005	0.021	0.025	0	0
Totals:						844		136.6		217.9		2.6		83.2	48	308
				Change in annual emissions due to Clean Coal Diesel project				**-36%**		**-51%**		**-42%**		**-47%**		

Notes: 1. Estimates are for the project year having the highest Coal-diesel utilization
2. All emission estimates are based on AP-42 emission factors, except for the coal-diesel (emissions based on demonstration test data) and the CWF boiler (ADL estimates)
3. Coal mass for stoker boilers is "as-fired"; coal mass for CWF boiler is "dry"
4. Thermal oxidizer treats emissions from hot water drying coal processing plant
5. See text for discussion of ammonia and fugitive emissions

Assumptions: Coal HHV = 16.4 MMBtu/ton
Engine input = 52.7 MMBtu/hr (LHV)
Without CCD project, diesel engine is installed and utilized for black start and peak power production

ADEC's preliminary review of the coal processing proposal indicated that they expect to consider this process insignificant and not requiring a construction permit based on 18 AAC 50.300.(b)(1)(A). This regulation indicates that an industrial process with a total rated capacity or design throughput of greater than five tons per hour has the potential for violating ambient air quality standards and therefore is required to obtain an operating permit. The coal cleaning and hot water drying (HWD) process is designed for a throughput not to exceed 5 tph, and will therefore, not require a separate permit.

The coal processing will result in some emissions of volatile organic compounds (VOC) from the HWD process. The primary concern with these emissions is odor due to the potential presence of hydrogen sulfide (H_2S) and mercaptans. To minimize the potential for odors and VOC, the HWD emissions will be treated in a thermal oxidizer to a destruction efficiency of 99.99%. In addition, it is anticipated that the coal crushing and grinding operations conducted in this building will generate particulate fugitive emissions. However, these operations are to be conducted inside a building in enclosed processes that are conducted in a wet phase, such that fugitive particulate emissions will comply with OSHA requirements. No direct venting of these operations is anticipated.

Table 2-3 provides a more detailed comparison of estimated annual air emissions from the UAF power plant, with and without the Clean Coal Demonstration (CCD) project. The table shows that with the CCD project, emissions of four criteria pollutants (SO_2, NOx, particulates and CO) are estimated to be less than without the project. Table 2-3 also includes the fuel burning and SO_2 emissions from the thermal oxidizer used to treat the offgases from the HWD process.

As shown in Tables 2-2 and 2-3, CO emissions from the powerplant are estimated to decline by about 47% with the CCD project. Should further reductions of CO emissions from the project become necessary, the use of additional control technology (e.g. catalytic reduction) can be considered as a likely effective mitigation measure.

2.3 Waste Management

The total solid residuals production requiring offsite placement during the 3-year test period is expected to be less than 1,000 tons. These materials, largely comprised of coal ash, are expected to be handled in the same manner as the existing coal ash from the UAF powerplant, provided that the profile of leachable trace metals is similar, which is expected. Prior to placement in a permitted landfill as fill or disposal, representative samples of waste will be analyzed using the Toxicity Characteristic Leaching Procedure (TCLP) to ensure that the material is nonhazardous and meets the requirements of the Alaska Department of Environmental Conservation for the intended disposition. In the event any hazardous wastes are generated by the project, they will be managed by a licensed, commercial company under the UAF Risk Management Department program.

Liquid waste will be produced from boiler blowdown and the flushing of the HWD system. The blowdown is expected to contain concentrated minerals similar to that already produced by the existing UAF plant. Blowdown will be combined with that from the other UAF boilers and discharged in accordance with the University's existing requirements. The flush water will be generated each time the HWD system is shut down. It will contain suspended solids and some trace condensable organic compounds. Approximately 2,000 to 3,000 gallons of waste water will be generated per flush and will be stored in a holding tank for analysis. If the material is suitable for discharge to the sanitary sewer, it will be discharged. If the material is not suitable for discharge, it will be managed as all other similar liquid wastes on campus are managed, via a licensed hauler/contractor for off-site disposal.

2.4 Impact on Water Resources

2.4.1 Groundwater

The UAF Utilities Department has a series of wells that supply potable and process water needs for the University; these are the only water supply wells identified within at least 1,500 feet of the proposed site.

Beginning in the late 1980's, some wells on campus exhibited elevated levels of benzene and other organic contaminants. There has been no indication in the data reviewed thus far of contamination by trace metals. The University has developed an extensive monitoring well network, by the use of which they have characterized the extent of groundwater contamination and the sources believed responsible. Remedial action plans are in various stages of development. The more recent data indicate a decline and/or lack of contamination at the locations of the proposed project facilities. Neither the power plant nor the MIRL building are currently identified by the University as continuing sources of contamination.

2.4.2 Surface Water

The proposed site is located within the drainage area of the Deadman Slough and thereafter the Chena River. Deadman Slough is located about 1000 feet to the south of the site, with intervening forest, rail bed and roadways.

The existing stormwater runoff from the site drains through a series of open ditches and culverts to swales and vegetated off-site wetlands enroute ultimately to a ditch along the North side of the embankment of the adjacent Alaska Railroad tracks. There is no surface connection of surface water runoff through this embankment to an off-site location.

2.5 Noise Impact

Project construction and operations would occur in areas of existing round-the-clock industrial-type activity, where existing noise levels are already high. The UAF staff indicated that there was no history of noise complaints related to these existing operations.

The addition of the diesel engine and the ancillary air pollution control equipment is not anticipated to increase the noise level above that measured in the existing power plant.

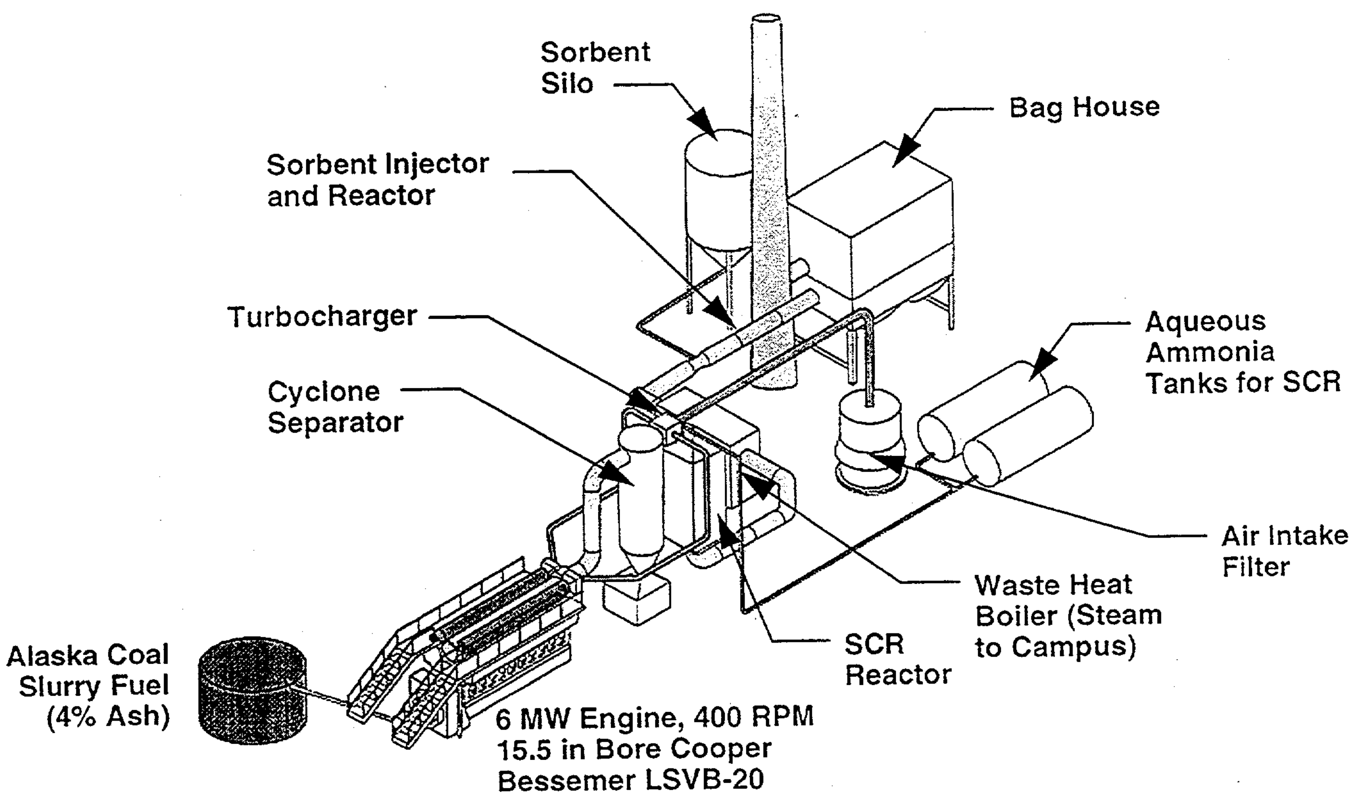
The addition of the coal processing plant in the MIRL building will include a ball mill and other grinding equipment with the potential for generating significant noise inside the building. According to a manufacturer of this type of equipment, the noise level can be as high as 92 dbA within 6 feet of the equipment. Since this equipment will be located inside the building, the employees working with the equipment will be required to wear proper hearing protection. The noise level outside the building may be slightly elevated in the immediate surrounding areas, but is not expected to be elevated at any of the nearby receptors (500 to 1500 feet away).

Any sustained noise level experienced by the employees above 85 dbA will require the implementation of an OSHA noise conservation program. The requirement for such a program will be assessed once the vendor selection is made for the grinding equipment. A noise conservation program will be implemented through the Risk Management Department at UAF, if necessary. Past experience with similar equipment indicates that some vendors are able to reduce the noise level of the equipment to below 85 dbA.

3.0 University of Alaska Powerplant Design

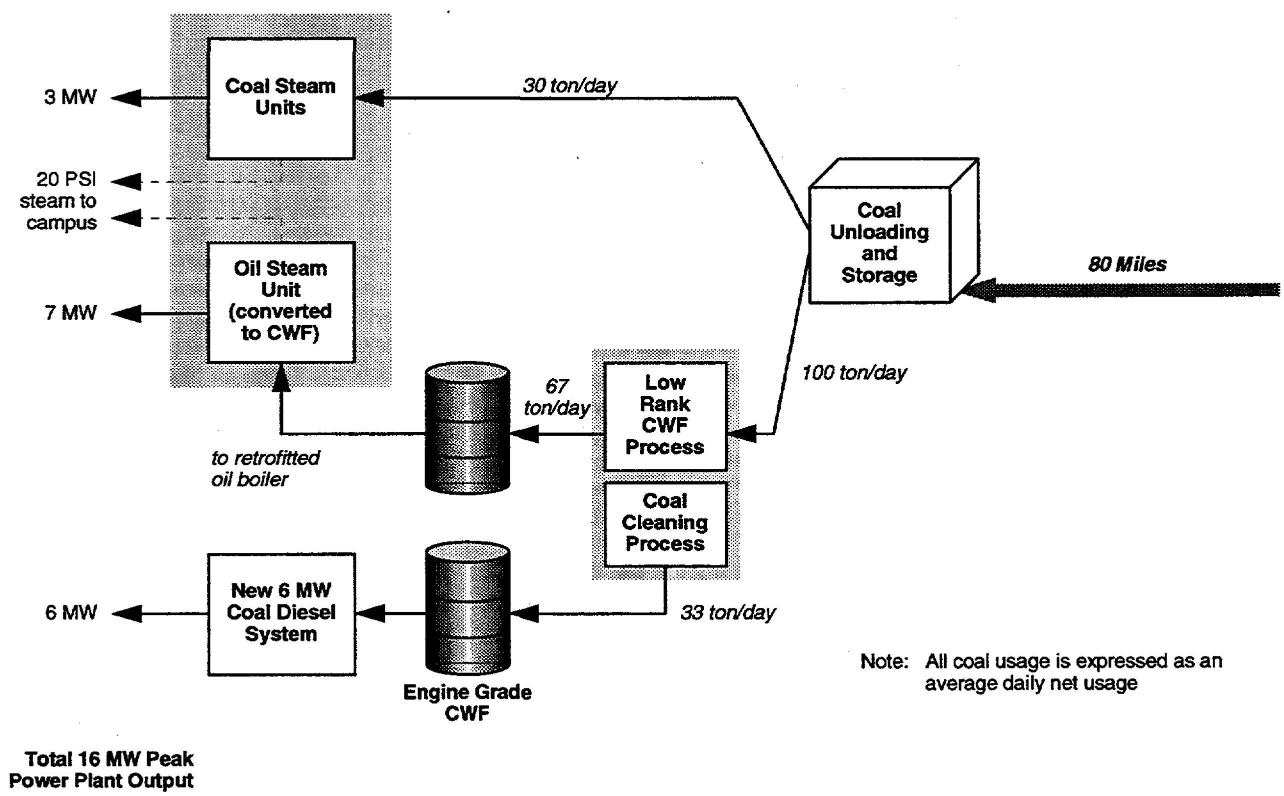
The University will construct and operate the Coal Diesel System, which will serve as a 6.2 MW diesel powerplant addition (to the existing two oil-fired boilers and two stoker-type coal-fired boilers). The Clean Coal Diesel System includes a 20-cylinder, 400 rpm Cooper-Bessemer LSVC type engine, generator, integrated emission control system and standard auxiliary systems. Engine exhaust will be fed to a waste heat boiler to generate steam for additional power generation and for UAF heating. Figure 3-1 provides a schematic of this novel Coal Diesel System.

Figure 3-1. Coal Fueled Diesel Power Plant (6 MW)



The University will also assemble and operate a 5-ton per hour coal-water fuel processing plant. The plant will utilize local coal brought by truck from Usibelli's mine in Healey (approximately 80 miles from UAF). Figure 3-2 shows the powerplant arrangement during the Coal Diesel System demonstration and how two types of coal-water fuel will be produced (one for use in the new coal diesel-engine demonstration and one for use in a modified oil boiler).

Figure 3-2. Schematic of Proposed CCT-V Project at University of Alaska, Fairbanks



The Clean Coal Diesel will offer substantial benefits for UAF's powerplant:

- UAF needs to install new generating capacity of approximately 6 MW electrical power output in order to become self-sufficient on coal fuel at peak load.
- The new fuel-flexible diesel engine to be tested during the demonstration would provide the additional capacity and provide for black start capability, eliminating power purchases during start-up.
- Reduction in the use of fuel oil by using more coal may reduce UAF fuel costs. Today, UAF experiences relatively high cost for fuel oil and has access to relatively low cost coal.

3.1 Selection of A&E Firm

The preliminary and detailed designs for the powerplant and coal processing facilities will be developed by an A&E firm to be added to the project's team. To initiate selection of the project's A&E firm, the University of Alaska prepared and issued a request for proposals. Three responsive proposals were received by UAF. The proposing teams were as follows:

- R W Beck with subcontractors Design Alaska, Loftus Engineering, Great Northern Engineering, and Shannon & Wilson
- USKH with subcontractors Foster Wheeler, Estimations, and Shannon & Wilson
- VECO with subcontractors SFT, Kumin, and Shannon & Wilson

Based on interviews held with each of these A&E teams, the project team selected R. W. Beck as the best qualified bidder. Their preliminary design activities will be initiated early in 1997.

4.0 Coal Water Fuel Technology

4.1 Coal Water Fuel Production Plant

In order to make coal-water fuel from Alaska coals (which are more reactive low-rank coals), it is necessary to use a continuous hydrothermal coal treatment process. One such version is known as hot water drying (HWD). The technical feasibility of producing moderately loaded CWF, with a dry solids content of around 60%, from Alaskan low-rank coal without the use of costly additives was demonstrated in a 7.5 tpd pilot plant at the Energy and Environmental Research Center in 1990-91. Alaska CWFs were shown to be premium fuels superior to heavy fuel oils in a pilot-scale boiler giving essentially complete carbon burnout. Sulfur dioxide (SO_2) emissions were well below compliance levels because of the remarkably low sulfur content of most Alaskan coals. A remaining barrier to widespread commercial applications of this technology is operation at a commercial scale to obtain realistic process economics data and thus enable potential CWF users to validate the process. This is the primary objective of the coal-water fuel plant portion of the CCT demonstration project at UAF.

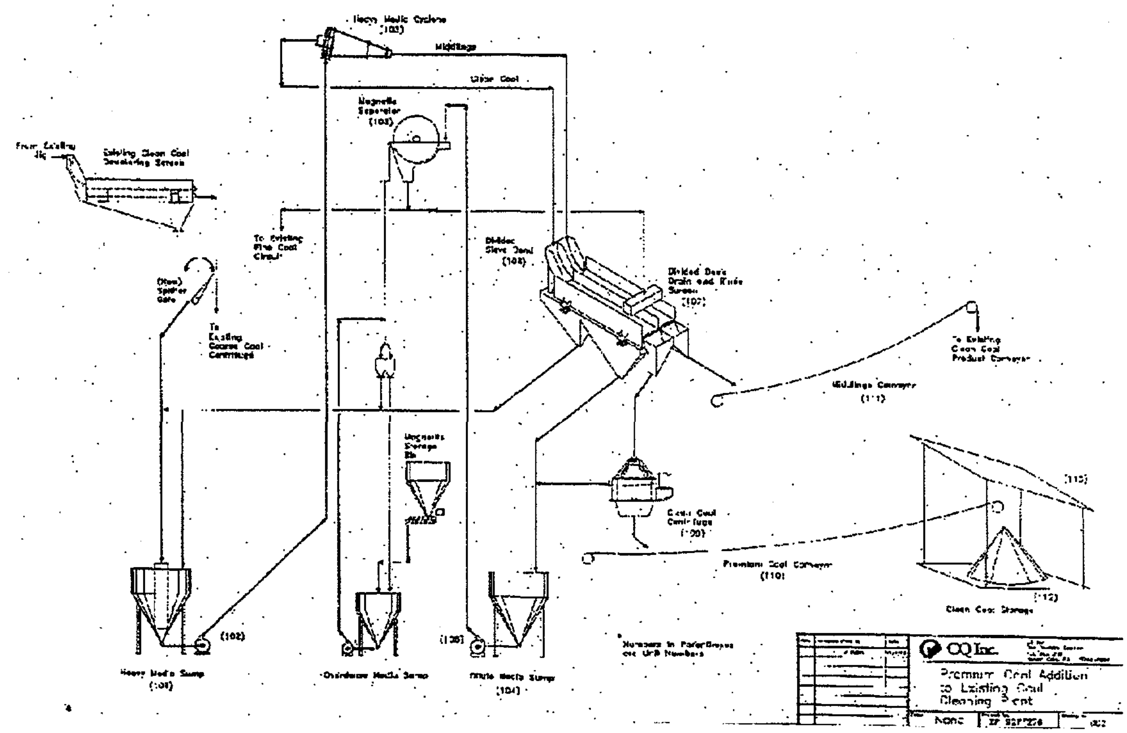
Coal Source The source coal will be supplied by Usibelli and is the same low-rank coal as is currently supplied to the UAF for boiler use in their powerplant. This coal, depending on the specific mining pit, ranges from 7 to 9% ash and 0.1 to 0.5% sulfur, with a heating value of approximately 8500 Btu/lb (with 20-25% moisture).

The Alaska coal fields comprise the largest accumulations of low-sulfur bituminous and subbituminous coal in the world. The coals here generally average less than 0.5 percent sulfur, but may contain values as low as 0.1 percent. Analyses of Alaskan coals indicate that they nearly all fall into the low-sulfur category. The coal of the Beluga field of the Cook Inlet-Susitna province, which have the lowest sulfur range of any U.S. coal (<0.1-0.3 percent), meet the Environmental Protection Agency's emission standards for direct combustion. The Nenana basin contains 8 billion tons of identified resources with total sulfur averaging 0.2 percent.

CWF Production The coal processing will include three successive operations at the UAF site:

1. Physical coal cleaning (Figure 4-1), including size reduction to ¼ inch by 200 mesh. The physical coal cleaning is accomplished by heavy media separation. This step will produce engine-grade product (3-5% ash) and a byproduct middling stream of 8% to 10% ash. Once the coal has been cleaned, it will then be metered, along with water, to a ball mill where it will be reduced to approximately 250 microns.

Figure 4-1. Physical Cleaning Process (CQ, Inc.)



2. Hot-water drying (Figure 4-2) of coal according to the process which has been designed and run at pilot plant scale by EERC in 1985-1988. Similar thermal hydrotreatment processes have been demonstrated by over twenty different investigators since the 1920's. In this process, the coal water mixture is fed through a series of reactors that ensure proper residence time, the proper temperature (approximately 280 to 300°C) and pressure conditions to convert the raw coal slurry to hot water dried coal.
3. Fine-grinding and formulation of a coal-water fuel. That portion of the CWF intended for diesel engine fuel is subjected to fine grinding to 10 microns mean size (65 microns maximum).

Figure 4-2. Hot Water Dry and Slurry Process

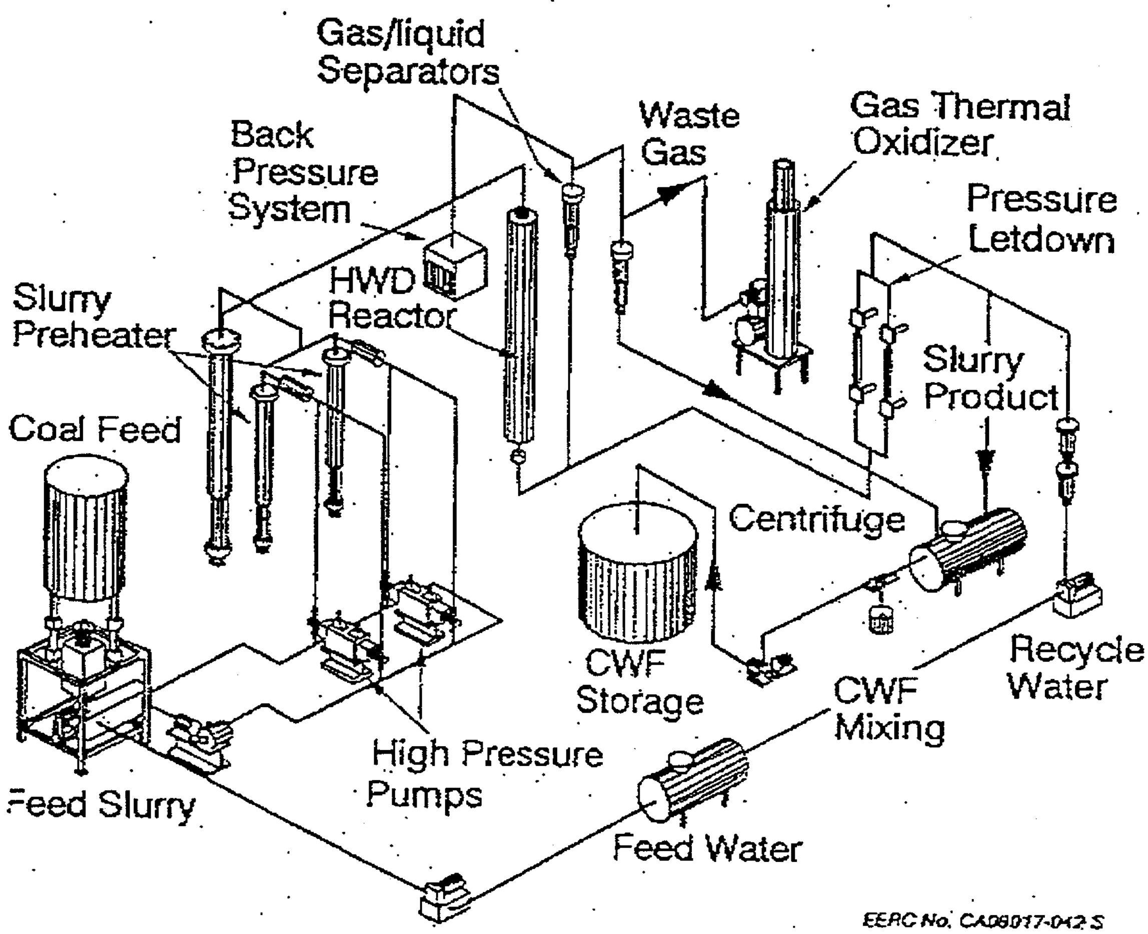


Table 4-1 provides the demonstration project's coal processing requirements (input and output) for 6000 total hours of coal diesel engine operation.

Table 4-1. Coal Fuel Requirements for CCT Demonstration (Assumes 2 Ton/hr* Clean Dry Coal Input to Engine)

Year	At 33% Yield, Input Coal (tons)	Hours of Engine Operation	Clean Dry Coal Usage by Engine (tons)	Physical Cleaning Plant Operation to Produce Engine-CWF Hours (at 3.4 ton/hr output)	Hours to Process Reject Coal (into CWF for boiler use)
1999	3400	500	1000	300	600
2000	10300	1500	3000	900	1800
2001	27500	4000	8100	2400 (1 to 2 ratio)	4800 (1 to 2 ratio)
	41200 (tons input coal)	6000	12100	3600 (for engine grade HWD coal slurry)	7200 (for boiler-grade HWD Coal Slurry)

*This is full load or maximum coal input. It is likely that part-load engine-operation will reduce the average coal input to 1.8 ton/hr

4.2 Coal Water Fuel Testing

EERC completed the preparation of CWF in their hot water drying pilot plant facility from samples of Alaska coal. Six drums having coal with ash contents of 6.2 - 9.6 % were produced. Specifically, the following batches are available:

Description	Ash (%, dry)	No. of Drums	Total Weight (lb.)
Usibelli coal	9.60	3	1364
Physically cleaned Beluga coal	6.24	1	516
Beluga coal	8.66	1	356
Beluga coal	8.11	1	478

This fuel, starting with the lowest ash content, will be tested in the Model JS-1 Cooper engine to validate combustion performance and to evaluate initial wear characteristics. Samples of each CWF will also be evaluated in ADL's wear rig to obtain direct comparisons to the wear characteristics of coals that have been successfully utilized in the JS and LS engines. These tests have been scheduled to take place early in 1997.

Discussions were held with CANMET's Western Research Center regarding their ability to clean 5 - 10 tons of Usibelli coal for Phase I testing at Cooper. This facility appears to have a heavy media cyclone cleaning circuit that is better sized than CQ's to handle this amount of coal. CANMET's Western Research Center prepared a proposal to clean 10 tons of Usibelli coal for Phase I testing at Cooper. We are now planning the remaining activities (coal shipment from Usibelli to CANMET, hot water drying at EERC, transport of cleaned coal and CWF) required to deliver CWF to Cooper for more extensive engine testing in Phase I.

5.0 Demonstration Plant Emission Control System Design

5.1 Emission Control System

Effective controls for NO_x , SO_x, and particulate emissions are essential for the successful commercialization of stationary Cooper-Bessemer coal-fueled diesel engines. We have established emission control system performance targets based on the projected needs of 10 to 100 MW cogeneration and independent power production sites in the year 2000 to 2030 timeframe. Table 5-1 summarizes the emissions targets (based on utilization of Alaska Coal) and the control methods that will be implemented to reach these levels. The Clean Coal Diesel will include an exhaust gas treatment system, including a cyclone, selective catalytic reduction (SCR), sorbent injection for SO_x control, a baghouse and new exhaust stack to assure appropriate control and dispersion of air emissions. During the prior DOE-METC funded development program, a full scale emission control system was demonstrated to be capable of meeting all of these performance goals.

Table 5-1. Emission Control Target Levels (Alaska Coal)

Pollutant	Control Methods	Emission Target
NOx	• Water Injection (CWF) • Combustion Optimization • Selective Catalytic Reduction • Dry Sorbent Injection	0.15 lb./MMBtu
SOx	• Coal Cleaning • Dry Sorbent Injection	0.12 lb./MMBtu
Particulates	• Cyclone • Baghouse	0.08 lb./MMBtu

The CCD project is expected to result in significant reductions to overall annual emissions from the UAF powerplant. In the year of maximum coal-diesel utilization, the four criteria pollutants (SO_2, NOx, particulates and CO) are estimated to be 35-50% lower than emission levels that would be experiences without the CCD project.

PSI has prepared preliminary specifications for the coal diesel's emission control system that will be installed at UAF. Included in this document are conceptual arrangements, heat and material balances, and performance requirements for the silencer, cyclone, SCR reactor, sorbent injection system, and baghouse. This information will provide the basis for the A&E team's preliminary and detailed designs.

6.0 Coal Diesel Engine Technology

6.1 Coal Diesel Engine

The CWF engine to be demonstrated is a modified four stroke diesel engine based on the Cooper-Bessemer LSB production engine (Figure 6-1). The demonstration engine is a 20-cylinder version with modified block, camshaft, cylinder heads, pistons, and a unique injection system specifically designed and built for CWS. Table 6-1 lists key engine parameters.

Table 6-1. Key Parameters of the Demonstration Engine

Model	LSVC-20
Bore	15.5 in
Stroke	22 in
Nominal Speed	400 rpm
No. of Cylinders	20
BMEP (nominal)	208 psi
Cycle	4 stroke
Power Output (nominal)	6200 kW

The novel technologies incorporated into this design to allow utilization of coal-water fuels and achieve target component life are as follows:

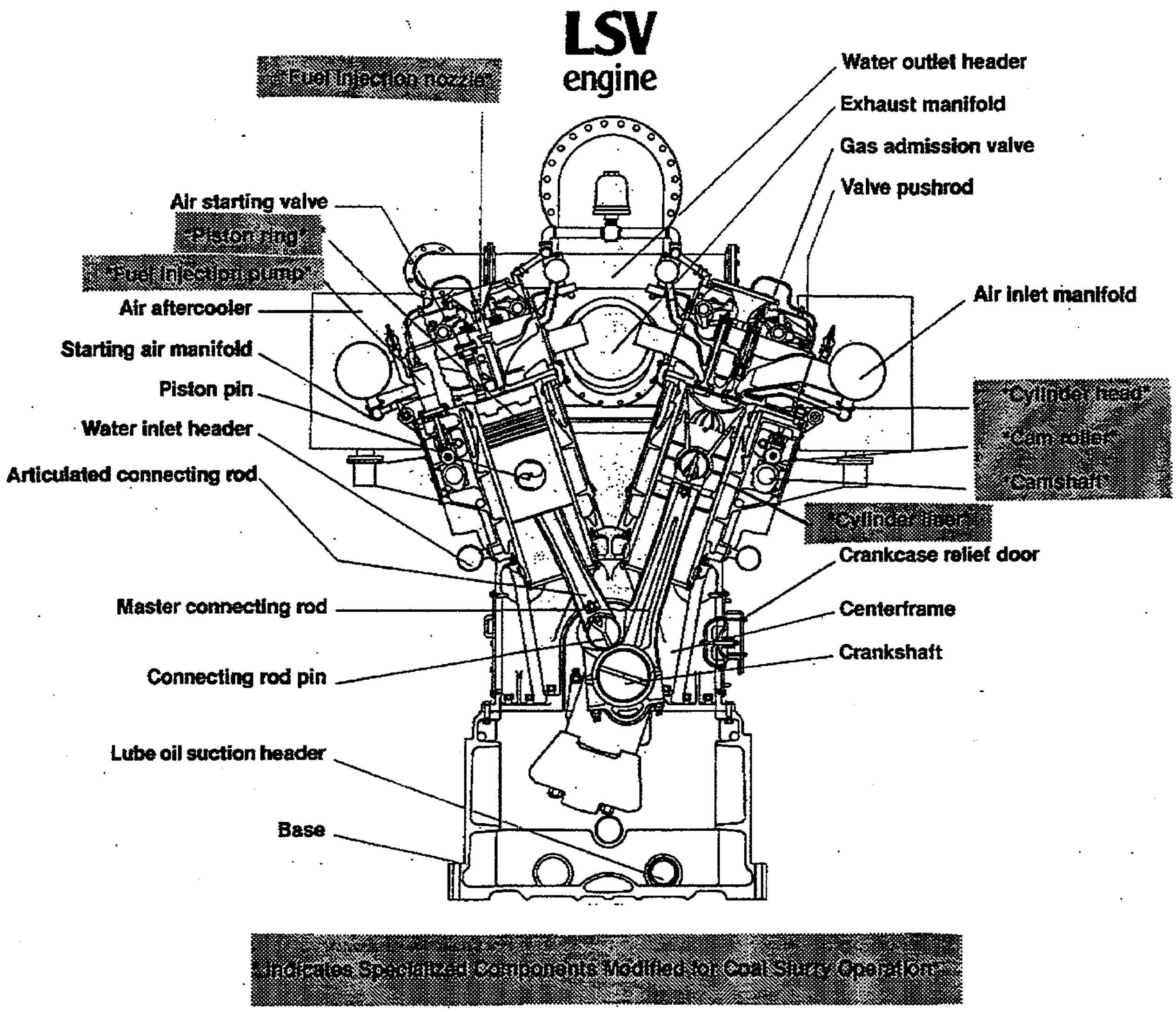
- modified "fast rate" fuel injection cam
- larger fuel injection jerk pump
- coal-slurry tolerant fuel injection system
- nozzle tip with sapphire inserts
- ceramic-coated piston rings
- ceramic-coated cylinder liner
- ceramic-coated exhaust valves
- ceramic-coated turbocharger blades
- modified engine block

6.2 Coal Diesel Engine Testing

Engine Operation and Performance

In 1996, the project team completed the initial series of coal-water fuel performance tests on Cooper's full-scale LSC-6 engine at their Mt. Vernon, Ohio test facility. This engine was operated with one cylinder burning Ohio CWF and the remaining five firing diesel fuel. About 34,000 pounds of CWF were consumed. Individual cylinder instrumentation allowed us to monitor the performance of the CWF cylinder. In these tests, the fuel efficiency, exhaust temperature and peak cylinder pressure for CWF firing were all within desired ranges. Overall, these test results indicate that Ohio CWF meets our requirements for satisfactory engine performance.

Figure 6-1. Highlights of Novel Coal-Fueled Diesel Engine Technology Elements



As part of this test series, Cooper evaluated the performance impact of reducing the pilot fuel quantity. A small amount of diesel fuel is normally injected into the cylinder by a separate pilot nozzle to provide a positive ignition source for the CWF fuel spray. Typically, the amount of pilot fuel has been 7 to 8% of the total fuel energy injected into the cylinder at full load conditions. Tests in February showed that the pilot fuel can be reduced by 40% with little impact on engine performance. Peak cylinder firing pressure, indicated power, cylinder exhaust temperature, etc., all indicated that the lower pilot fuel quantity reliably ignited the CWF fuel spray. Additional testing may show that even lower pilot fuel quantity can be used which would increase the CWF / DF2 consumption ratio.

6.3 Durable Components

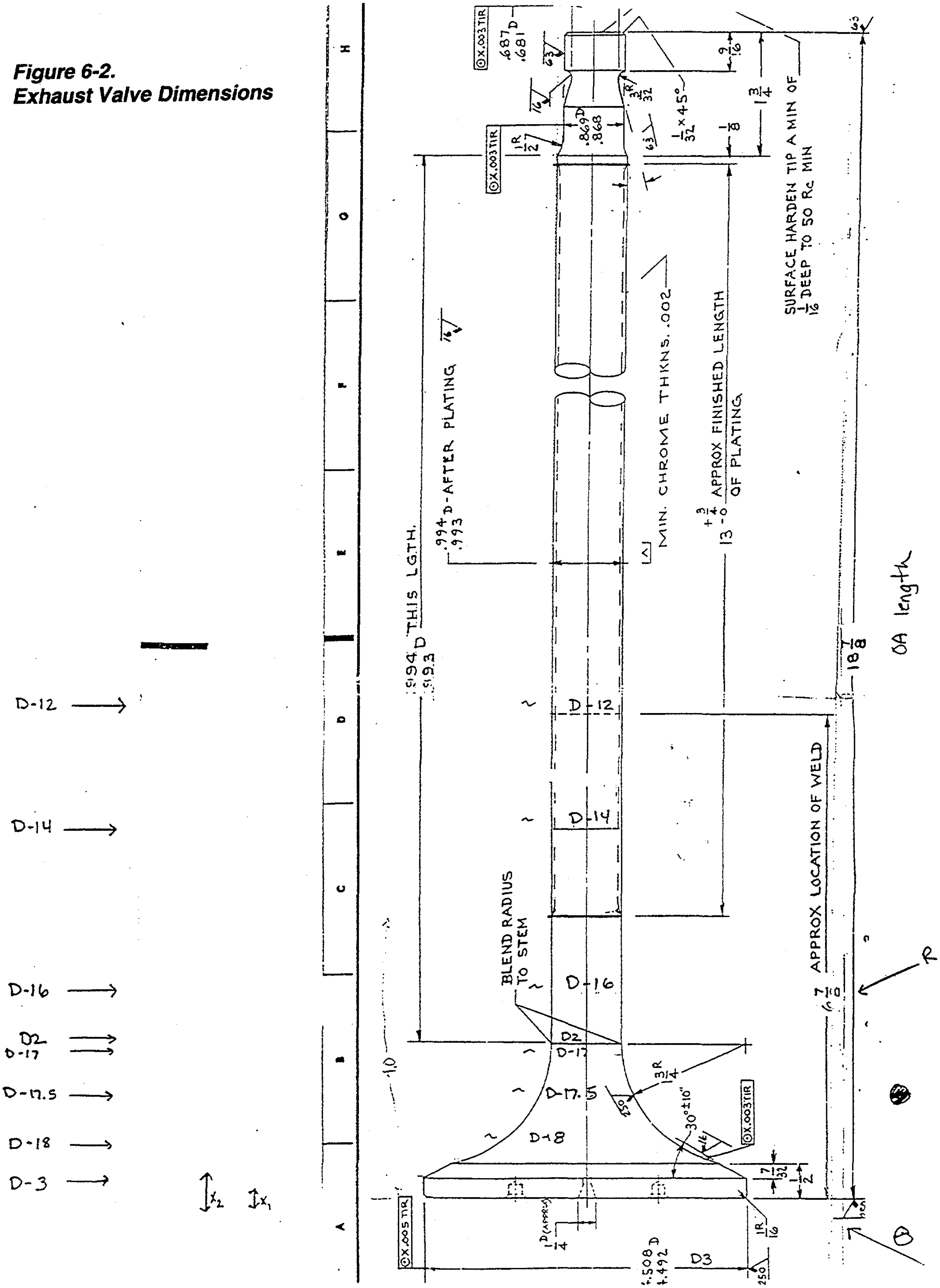
Through the test series completed in 1996, Cooper accumulated durability experience on the two chromium carbide exhaust valves installed in the #1 (CWS) cylinder on the LSC engine. The valves accumulated 180 hours of operation (91 hours on CWS). The CWS operation consumed slurry which had an ash content between 2.0 and 2.7% by weight. Engine operation was at rated speed (400 rev/min) and covered a range of loads from 150 to 208 psi brake mean effective pressure. Much of the operation was at the high load condition.

Valve Inspection

Coating Description. The chrome plated stems of two exhaust valves were surface ground to remove 0.015" of the plating prior to chromium carbide coating with Praxair Surface Technologies' "LC-1H" coating. Valve and coating material characteristics are described in Tables 6-2 and 6-3. The coating was applied by a detonation gun in which the gun is stationary and the part is both rotated and translated in front of the gun. This process results in a very uniform coating thickness over the entire part. The initial coating thickness was 0.021/0.023". The valve stem was ground and polished to a coating thickness of approximately 0.015", yielding a shaft diameter of 0.993/0.994". The valve seat was also ground and polished to a surface finish of 9-11 microns, removing only 0.003" of coating.

Wear Performance. The exhaust valves were inspected before and after the 90 hour CWF test was conducted. The initial and final dimensions of the valve are summarized in Table 6-4. The results indicate that the coated part experienced little or no wear. For example, the diameter of the stem remained within the original tolerance of 0.993/0.994" (refer to Table 6-4 and Figure 6-2, TC1 and TC2: D-12, D-14, D-16). Furthermore, the valve dimensions at 17, 17.5 and 18" from the valve end opposite the head remained the same (refer to Table 6-4 and Figure 6-2, TC1 and TC2: D-17, D-17.5 and D-18). Figure 6-3 shows a slight build-up of reddish-brown material on the edge of the valve head. Figure 6-4 shows the same material on the valve head as well as well-defined and evenly spaced wear tracks cutting through the debris. This small amount of material deposited on the valve is easily removed by light scraping and is probably coal ash. The circumferential wear tracks results from valve rotation (valve rotators were used). The deposits did not appear to affect engine operation. Figure 6-5 shows the surface texture along the length of the valve. The absence of wear on these coated valves after 90 hours of CWF operation is a dramatic improvement compared to past results.

Figure 6-2.
Exhaust Valve Dimensions



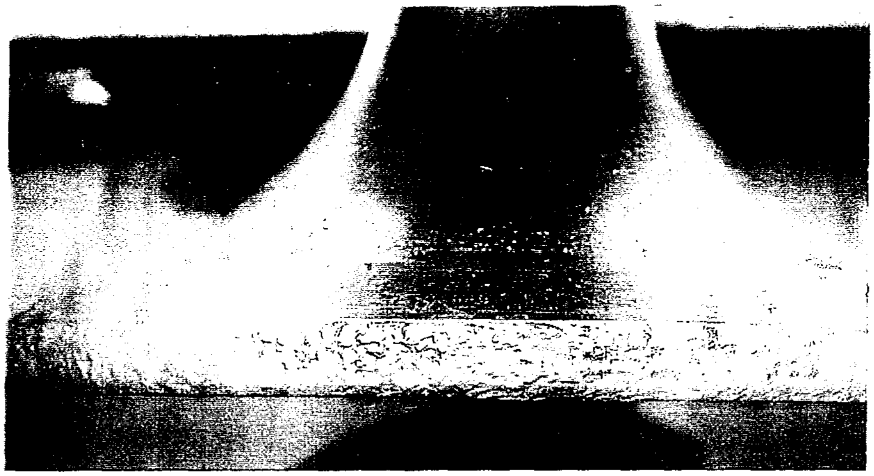


Figure 6-3.
Edge of Exhaust Valve Head with Slight Build-up of Reddish-Brown Material

Figure 6-4.
Exhaust Valve Head with Wear Tracks Cutting Throu Reddish-Brown Material

Figure 6-5.
Surface Texture Along the Length of Exhaust Valve

Table 6-2. Valve Materials Characteristics

Section*	Material	Heat Treatment	Hardness R_c	Notes
Head	Inconel 750	1500°F for 24 hours and air cool	30 (minimum)	
Stem	Alloy Steel AISI-3100	Liquid Quenched and tempered	25 minimum 36 maximum	Chrome-plated**

*Note: the head and stem are welded together and stress relieved at 1100°F minimum for 2 hours. The weld is checked by fluorescent penetrant inspection.
**Chrome plating is removed before chromium carbide coating is applied.

Table 6-3. Coating Material Characteristics

Coating Designation	Principal Constituents	Nominal Composition (wt. %)	Hardness (R_c)	Hardness (HV.3) (kg/mm^2)
LC-1H	Chromium Carbide	80% (92Cr-8C) + 20% (80 Ni-20Cr)	64	775

Table 6-4. Exhaust Valve Dimensions Before and After 90 Hours of CWF Operation (see Figure 6-2 for locations of measurements)

		TC1 = Left Valve		TC2 = Right Valve	
Location	Print	Initial (0 hrs.)	90 hrs.	Initial (0 hrs.)	90 hrs.
D-12	.993/.994	0.994	0.994		0.994
D-14	.993/.994	0.994	0.994		0.994
D-16	.993/.994	0.994	0.994		0.994
D-17		1.116/1.121	1.121	1.091/1.096	1.090
D-17.5		1/503/1.508	1.504	1.435/1.440	1.437
D-18		2.367/2.374	2.374	2.200/2.225	2.236
D-3	4.534/4.554	4.519/4.525	4.573/4.586	4.521/4.525	4.559/4.563

In-Cylinder Components Inspection

A number of in-cylinder components were inspected and measured for wear after Cooper completed a key segment of the Phase I CWS tests (which ran from August 1995 to May 1996).

Piston Rings

The top three compression rings for this test series were tungsten carbide coated rings which had already accumulated 100 to 230 hours of CWF operating time from previous tests. After 121 hours of additional CWF operation, much of which was at full load (200 to 208 psi bmep), these rings experienced only 0.007 to 0.014 inch end gap increase, as shown in Table 6-5. For comparison, a new standard ring (not coated with tungsten carbide) was installed as the 4th compression ring and it experienced a 0.148 inch end gap increase. The end gap increase would likely have been 2 to 3 times greater for the standard ring if it were installed as the top compression ring. The wear rates for the tungsten carbide coated rings were one to two orders of magnitude less than standard material piston rings.

A special chrome plated oil control ring was installed in the piston as the bottom ring for evaluation. It's initial wear rate was approximately 20 times less than the standard oil ring.

Table 6-5. Preliminary Ring Wear Data

Ring Position	Ring Type	CWS time on ring at start of test series	End gap increase after this test series (121 hours on CWS)
Top compression	WC coated	183 hours	0.014 in.
#2 compression	WC coated	232	0.010
#3 compression	WC coated	103	0.007
#4 compression	Standard	new	0.148
Top oil control	Standard	new	0.484
Bottom oil control	Chrome plated lands	new	0.028

Piston

There was no significant wear measured on the piston or piston skirt. A few vertical scratches were observed but no hot spots on the piston were seen. The ring lands showed a slight increase in size -- approximately 0.010 to 0.012 inch for the compression ring lands and 0.003 to 0.009 inch for the oil control ring lands.

Nozzle Tip

There was no significant wear measured on the sapphire inserts in our CWF nozzle tip. Nozzle hole wear was measured with wire gages. The starting hole diameter was 0.6330mm -- a 0.025 inch wire gage (0.635mm) would not fit any of the 18 inserts. This nozzle tip now has approximately 263 hours of CWF operation.

6.4 Durable Component Findings

Arthur D. Little materials specialists visited Cooper's engine laboratory to inspect in-cylinder components after Cooper completed a key segment of the Phase I CWF tests. Their preliminary findings are summarized below:

Exhaust Valves

The most recent set of chromium carbide coated exhaust valves appear to be wearing at a low rate during the first 90 hours of CWF operation. This is a substantial improvement compared to our first set of coated valves or the standard valve material. However, additional operating experience is needed to develop component life estimates.

Piston Rings

The top three piston compression rings for this test series were tungsten carbide coated and have accumulated 220 to 350 hours of CWF operating time. The overall wear rates for these test rings, based on end gap increase, was very low compared to conventional ring materials (one to two orders of magnitude lower overall wear rate). The compression rings are showing some signs of material distress, as revealed by the loss of coating in some areas and cracking in others. The cracking is probably due in part to rings with coatings that are too thick and therefore susceptible to cracking. Additional improvements in material integrity and ring life may be obtained by optimizing the coating process.

A special chrome plated oil control ring was installed in the piston as the bottom ring for evaluation The chrome plated oil control rings show wear resistance substantially greater than the resistance provided by standard rings.

Cylinder Liner
The tungsten carbide coated cylinder liner is in excellent condition.

Nozzle Tips
The nozzle tip hole diameter (nominal size = 0.633 mm) has increased less than 0.002 mm (< 0.3%) based on wire gage measurements taken after 263 hours of CWF operation. Detailed microscopic evaluation of each sapphire orifice showed some signs of chipping at the discharge side and erosive wear along the inner surface. Although the degree of wear appears to have increased since our last detailed inspection, it does not appear to affect important overall engine performance measures such as fuel consumption or emission rates.