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OVERVIEW OF THE CANADIAN COM PROGRAM

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JANUARY 1981

For presentation at the Third International Symposium on Coal-Oil Mixture Combustion, Orlando, Florida, April 1-3, 1981.

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
DIVISION REPORT ERP/ERL 81-07 (OP)

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ABSTRACT

The effect of the increasing differential between the cost of fuel oil and coal in Canada has led to the initiation of a program encompassing the technologies relating to the combustion of mixtures of coal and oil (COM). COM technology provides a short to medium term energy source which has significant potential in reducing oil consumption at power stations, industrial steam raising and other process equipment that was originally designed for oil-firing and cannot readily be converted to alternate fuels. Energy, Mines and Resources Canada is supporting the utilization of COM technology through the COM program, economic factors will dictate whether or not the technology is implemented.

The Canadian COM program, embraces both demonstration-scale projects and associated research and development. The demonstration projects have included the COM firing of a 10 MW(e) utility boiler at Chatham, New Brunswick with plans for the firing of a larger unit. Also in the demonstration program are the first phases of a commercial COM preparation facility and a blast furnace tuyere COM injection project. Research and development studies include COM preparation, properties and combustion. An important part of the program has been the application of the spherical agglomeration process to the beneficiation of high-ash eastern Canadian coals and its integration into COM preparation. The feed coal for the utility demonstration project has been reduced to less than 10% ash and 4-5% sulfur from 20-25% ash and 7-8% total sulfur using the process.

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INTRODUCTION

The Canadian COM program began in 1972 in the form of a research project at the Canadian Combustion Research Laboratory, CANMET, Energy, Mines and Resources Canada (1). The present COM program has been developed from those early studies, since CANMET, through the federal government Energy Research Program, is responsible for developing the technology to the demonstration stage where economics and market pressures will then dictate if it will be implemented.

Recent rapid increases in internal oil prices have stimulated a renewal of interest in COMs as one means of reducing Canada's off-shore oil dependence. This interest will certainly be intensified by the scheduled oil price increases recently announced in the Canadian National Energy Program (2) in which a fourfold increase over present prices is anticipated in the next decade.

COM's are a short to medium-term energy source which have significant potential in reducing oil consumption, especially in eastern Canada which is to a large extent directly dependent on imported oil. It is an option to direct coal or natural gas conversion of boilers designed for oil firing, especially where full conversion to coal or gas imposes a substantial derating. The Technical Information Service of the International Energy Agency (IEA) Coal Research has reviewed recently the literature on the conversion of generating stations currently burning oil to COM (3). It was concluded that whilst only boilers designed originally for coal but currently burning an alternate fuel can be retrofitted to burn coal only, COM can be burned in the majority of boilers designed for coal or oil firing with only minor modifications to combustion equipment.

Specifically, the objective of the Canadian program is to advance the commercialization of COM technology in association with industry by (i) addressing technical questions relating to potential industrial

utilization of COM combustion technology in accordance with regional coal and oil supply logistics and environmental regulatory requirements, (ii) reducing technical and economic risks with high capital cost technology demonstrations and (iii) transferring to potential users and relevant industrial sectors technical, environmental, and economic data collected in the program.

As mentioned earlier, the greatest potential for the commercialization of COM technology lies in eastern Canada. As mentioned at the last COM symposium, a 1979 Canadian Electrical Association Report [4] showed that 5-1/4 million barrels of fuel oil could be saved annually by converting a total of about 2000 MW of generating capacity in eastern Canada to a 50 wt % COM. A preliminary COM market study in Nova Scotia has indicated that oil consumption can be reduced by about 5 million barrels in the industrial, commercial and slow diesel applications in the province. The extent to which these markets can be penetrated by implementation of COM technology will be dependent on many factors, some of which are specific to one or more of the four market sectors. Apart from technical and environmental factors, the economics of COM technology at a time when there are differing views in Canada on oil pricing, will most likely be the determining factor with respect to market penetration. At the present time in Canada the widening cost differential between oil and coal now favour full conversion of oil-fired boilers to coal provided sufficient space is available for coal storage and handling.

THE CANADIAN PROGRAM

The present Canadian COM program can best be described under two headings: demonstration projects and research and development, the latter including some pilot-scale projects, see Table 1. One of the most interesting and important R & D components of the program is the association of oil agglomeration coal beneficiation with the preparation of COM's prior to utilization. The environmental and other benefits of the ash and sulfur content reduction of high-ash, high-sulfur eastern Canadian coal would be a vital factor in encouraging the penetration of COM technology based on indigenous coals into the industrial boiler process heating and, possibly, diesel markets.

In general, operating costs of the oil agglomeration coal cleaning method are sensitive to the quantity and price of the oil used. However, in the cleaning of coal upstream of the formation of coal-oil mixtures, oil cost considerations are much less important than in the general case because a portion of the oil needed in the final fuel mixture can be used in this preliminary cleaning step. This, together with the fact that oil agglomeration is particularly effective at the fine coal sizes desirable for COM combustion, makes this method very attractive for upstream cleaning of coals destined for COMs.

Table 2 - Typical operating parameters influencing COM wear evaluation, NBEPC utility boiler project

Burner Type	Duration h	No. of Burners	COM Conditions		Mean Size m	Boiler Load MW(e)	ASME Indirect Efficiency %
			Flow kg/h	wt % coal			
Y-NS	15 - 154	3	3500	10 - 20	23	4 - 5	85
Y-ST	7 - 22	2 - 3	3500	10 - 20	23	4 - 5	85
Y-WC	35 - 382	2	1600	20 - 40	23	2	83
I-AS	8 - 24	4	4100	10 - 15	12	10	87
I-TS	96	2	1600	10 - 15	12	2	83
I-440	40	2	1600	33	23	2	83
I-JS	38	2	1600	27	23	2	83

LEGEND

Y - "Y" Jet Burner - Phase III

I - Insert Type Burner - Phase II and III

NS - Nitrided Steel

ST - Stellite

WC - Tungsten Carbide

AS - Tempered Low Alloy Steel

TS - Tool Steel

440 - 440C Stainless Steel

JS - Jessups Steel

DEMONSTRATION PROJECTS

New Brunswick Electric Power Commission

The 10 MW(e) utility boiler demonstration project at Chatham, N.B. This project has been underway since 1977 and the first two phases were described in detail at the last COM symposium in Danvers [5,6].

The Phase III boiler trials which ended in April 1980 were undertaken with two major objectives, to improve the effectiveness of the oil agglomeration coal cleaning process and to test two burners for long-term performance on COM. Efforts toward achieving these objectives were curtailed due to the equipment wear problems associated with the highly abrasive New Brunswick coal used to make the COM. Nevertheless, much useful information on COM technology was generated during Phase III operation, despite this continuing problem[7].

Two types of internally steam atomized burners were assessed for abrasive wear, a replaceable nozzle insert type during Phases II and III and a "Y" jet type during Phase III. Other types of burners were tested for COM combustion characteristics, but no assessments of the abrasive wear was made.

It must be mentioned that whilst minimizing the wear of COM equipment components was an important overall objective of the Phase III trials, it was not possible to maintain the necessary control of input parameters required for a more definitive study of wear. The objectives of the trials were to improve the performance of the agglomeration system and to gradually increase the coal content of the COM up to about 40 wt %. Quite often therefore it becomes difficult to compare the wear of nozzle components because of variation in fuel flow rates and ash and coal content, all important contributors to the wear phenomenon. The wear of other components such as the wet grinding mill, and the various pumps and connecting pipe work could only be examined in general terms, since these components were used during the entire Phase II and Phase III programs, where COM coal contents varied from 10 wt % to 40 wt %, ash input from 2 wt% to 7 wt % and the power generated by the unit from 2 MW(e) to 10 MW(e). Table 2 shows the average conditions which prevailed at the various operating levels of the boiler during the Phase II and Phase III trials, together with the burner tip materials tested and the times the burner tips were in service.

The evaluation of abrasive wear has been reported elsewhere[8] but the following observations for the solution of the burner wear problem at Chatham requires consideration of many factors such as:

1) Burner design by avoiding abrupt COM directional changes and high velocities and the use of externally-atomized burners utilizing low COM efflux velocities.

Table 1 - Canadian COM projects

DEMONSTRATION PROJECTS			
Operating Agencies	Project	Duration	Funding Agencies
NBEPC	Utility Boiler	1977-1980	NBEPC/CANMET
SCOTIA LIQUICOAL	Preparation	1979-date	OSA
STELCO	Blast Furnace	1978-1979	STELCO/CANMET

R AND D PROJECTS

SRC	Rheology	1978-date	CANMET
GCI	Grinding	1980-date	GCI/CANMET
NRC	Beneficiation	on-going	NRC
SABA	Beneficiation	1979-date	OERD/REE/NRC
CES	Combustion	1979-date	NSERC
ORF	Combustion	1978-1980	GULF/STELCO/ONT HYDRO/ ONT MIN E/CANMET
OEF	Wear	1981	CANMET
GCI-NRC	Diesel	1980	GCI/NRC

Projects listed in same sequence as text. Initials correspond to agencies noted.

2) Materials selection, choice of abrasion resistant materials that can be readily machined or fabricated into burner tips. The use of harder materials such as tungsten carbide significantly reduces the burner tip erosion. There appears to be an inverse variation between material hardness and wear rate, although it is difficult to establish a precise mathematical relationship due to the inadequate control of critical operating parameters.

3) COM characteristics, use of finer particles in the COM and less abrasive coals that have been beneficiated, if necessary, to remove high levels of ash.

Other COM handling equipment such as pumps, valves and secondary grinding equipment also suffered from significant wear related damage which resulted in deteriorating performance. It is felt that this problem can be eliminated by appropriate materials and equipment design considerations. COM transfer lines were relatively unaffected by wear essentially due to the low prevailing fluid velocities.

The abrasive wear of burner tips has therefore been the main obstacle preventing the successful utilization of COM technology in a small utility boiler at Chatham, New Brunswick. The abrasive wear which results in progressive flame deterioration can be attributed to the use of highly abrasive local coal in the COM. The problem still persists even when incorporating an in-line coal cleaning process to reduce the ash and pyrites content of the coal.

The work at Chatham had been expected to lead to a 100 MW(e) demonstration project at Dalhousie, New Brunswick, but the present economic analysis indicates that it is more reasonable now to convert all units above 100 MW(e) in the province to coal firing. Nevertheless, it is still possible that a COM candidate boiler in the 100 MW(e) category can be identified elsewhere in eastern Canada.

Scotia Liquicoal

COM preparation project, Halifax, Nova Scotia. This project, to construct a coal-oil-water or coal-oil emulsion pilot-plant preparation facility was begun in early 1979 and has recently received funding under the Canada-Nova Scotia Oil Substitution agreement. The preparation facility of capacity 1 tonne/h will be constructed and the suitability of the manufactured COM emulsion established in a series of combustion trials of increasing scale. Scotia Liquicoal has obtained the Canadian licencing rights to the US Liquicoal ultrasonic mixing process and also the rights to use the National Research Council of Canada spherical-agglomeration coal beneficiation process to improve coal quality. The initial laboratory phase has been concluded and combustion COM handling and environmental evaluations are being conducted in a small 10 GJ/h industrial boiler located in Halifax. Later phases of the project will include a commercial boiler combustion demonstration and the incorporation of the SZEGO mill wet coal grinding device developed by General Comminution Inc and described in another paper at this symposium. The project is expected to demonstrate the viability of coal based emulsions as fuels and to provide marketing

information and scale-up data for a commercial-scale preparation facility.

Steel Company of Canada Ltd

Blast furnace COM tuyere injection demonstration project. This project had as a major objective the development of a COM injection system that would enable the fuel to be supplied to the blast furnace tuyeres to improve iron yield and reduce overall energy consumption. The program which was jointly funded with CANMET began in April 1978 and was concluded in December 1979. Details of the program were given at the last symposium in Danvers[6] and can be summarized as follows:

A combustion study of COMs has been completed. An experimental unit comprising a fuel handling system capacity 1-5 kg/h COM, a system to preheat air to 980°C, and a combustor was designed and built for the project. The combustor consisted of a tuyere injecting into a 1 m diameter 3 m long refractory-lined furnace with provision for flame measurement at ten locations downstream of the tuyere. The measurement capability therefore extend beyond the boundary of the simulated blast-furnace raceway. Over 50 individual flames have been assessed in this system. These flames reflect combinations of one coal in three carrier fluids, two load levels, three coal size distributions and three COM coal concentrations. These combustion trials have established that a number of COMs are acceptable for blast-furnace tuyere injection. The next phase of the project was an economic design study for a three-tuyere blast-furnace trial, incorporating the results from the combustion study. At the present time a three-tuyere trial is not planned by Stelco although the company is continuing to monitor developments in blast-furnace COM injection.

RESEARCH AND DEVELOPMENT PROJECTS

Each of the demonstration projects described earlier necessarily includes some elements of R and D such as rheological and combustion properties, coal beneficiation and COM preparation. The New Brunswick Electric Power Commission utility boiler project has included some slurry stability and viscosity determinations as well as COM combustion evaluations. As mentioned earlier the Scotia Liquicoal preparation project includes some aspects of coal cleaning and milling. In the blast-furnace tuyere injection project, pumping, fuel metering and the composition and stability of the COM were studied. In the R & D program, some projects such as the Ontario Research Foundation combustion project, have included elements of COM production, coal beneficiation and COM stability. The Nova Scotia Technical College project is basically COM preparation including coal beneficiation, but will include combustion evaluations in a small boiler. For convenience each project will be described under a heading most appropriate to the main area of activity.

Saskatchewan Research Council

COM rheological properties project. The Saskatchewan Research Council, under contract to CANMET has been measuring the rheological properties of COMs. The major objective of this study was to obtain sufficient experimental data on the physical properties of COMs prepared from selected coals to be able to design transfer pipelines for combustion equipment or gasification plants.

The three coals selected for the study, all from western Canada, were a lignite, a sub-bituminous coal and a fines refuse from a metallurgical coal cleaning plant. The coals were mixed in four size distributions, <6 mm, <840 µm, 70% <75 µm and 90% <44 µm. Two oils, No. 6 and No. 2 fuel oils from western Canadian feedstock were selected for the preparation of the slurries using the various size fractions of the three coals. Rheological data for all of the No. 2 oil COMs were collected using a vertical-tube viscometer at room temperature, but the No. 6 fuel oil slurries were too viscous at room temperature, thus requireing the use of a Brookfield viscometer. However, this instrument could not be used to provide corroborative data on the No. 2 fuel COMs since these tended to channel around the viscometer spindles. Viscosities determined at maximum and minimum shear rates for some of the COMs are given in Table 3.

Table 3 - Variation in COM viscosities at maximum and minimum shear rates for COMs

Slurry Temperature Oil Type and Viscometer \ Coal and Screen Size	Lignite				Sub-bituminous	
	100% <840 µm		90% <44 µm		70% <75 µm	
	Shear Rate					
24°C	Max µ,cp	Min µ,cp	Max µ,cp	Min µ,cp	Max µ,cp	Min µ,cp
No. 6 Oil-Brookfield	29,570	21,976	127,381	92,171	78,822	57,377
No. 2 Oil-Brookfield	*	*	3,174	369	1,986	319
No. 2 Oil-Vertical Tube	52	27	282	130	248	77
145°C						
No. 6 Oil-Brookfield	112	110	364	252	283	212
No. 2 Oil-Brookfield	*	*	343	116	278	98

*Settled too rapidly for measurement

The last phase of the work was to have been the development of a high temperature (300°C) vertical tube viscometer to measure the rheological properties of COMs made from bitumen and pitch, residual by-products of oil-sands processing. Due to instrumental and operating difficulties this phase was not successful. However, a final report on the work that has been completed is now being prepared.

General Comminution Inc

Continuous grinding of coal in oil project. A study of the continuous wet grinding of coal in oil to produce a COM is currently being undertaken by General Comminution Inc., of Toronto in collaboration with CANMET using the recently developed orbital grinding SZEGO mill. The mill, together with some data from two small prototypes producing up to 1/2 tonne/h has been previously described by Trass[9]. The objective of the current project is to obtain performance and scale-up data leading to the design of a commercial-sized SZEGO mill with a throughput of 10-30 tonne/h COM having a coal size of 80-90 wt% less than 75 μm. To obtain these data, a 1-3 tonne/h COM prototype will be constructed and operated using three different coals. If successful, use of such a mill should substantially reduce costs of grinding coal to the 10-20 μm size range resulting in improved ash and sulfur rejection during the subsequent oil agglomeration step. GCI is also collaborating in the Scotia Liquicoal project in Halifax.

National Research Council of Canada

Spherical agglomeration coal beneficiation COM project. It has already been mentioned that the NRC oil agglomeration process is an essential part of the Canadian COM program. The integration of this process, developed by Puddington and Capes [10,11,12] originally for minerals upgrading, has been incorporated in the New Brunswick Electric Power Commission utility boiler COM project at Chatham and in the Scotia Liquicoal project. It is also a key part of some of the R & D projects as will be noted later.

The advantages to the overall COM preparation-combustion systems of this method of cleaning fine coals, together with interest shown in this aspect of the program from other countries, merit special mention in this overview paper.

The principle of the oil agglomeration process is that fine particles in suspension can readily be agglomerated by the addition under agitation of a liquid which preferentially wets the solid particles and is immiscible with the suspending liquid. In the cleaning of coals by grinding in water to release impurities, the carbonaceous constituents can be agglomerated and recovered with many different oils as a collector liquid, while the inorganic constituents remain in the aqueous suspension and are rejected. Conventional gravity methods for the cleaning of coals are not practical for particles finer than about 150 μm and methods such as froth flotation which depend upon differences in surface chemistry of coal and foreign matter are used for the finer sizes. Flotation, however, becomes less effective where extremely fine sizes of coal must be processed or if there is considerable clay present. The oil agglomeration process provides an attractive method for the cleaning and recovery of these ultrafine coal particles in the form of compact, oil-bonded aggregates.

This ability to work with fine coal particles is particularly useful for coals which contain finely-disseminated impurities. These coals can be ground in water to a size sufficiently fine to liberate the required amount of impurities and reconstituted as oil-bonded agglomerates free of the liberated mineral matter. Alternatively, fines contained in waste slurries from conventional cleaning operations can be recovered by oil agglomeration as a low-cost source of clean fine coal. This latter aspect is particularly important where friable coals are being mined. The coal beneficiation ability of the oil agglomeration process may now be considered with respect to ash and moisture rejection and coal recovery. Capes(13) has shown with two Canadian bituminous coals, the ash can be reduced from an initial level of about 30% to 20% by grinding to 50 μm mean diameter and using oil agglomeration. As the particle size is reduced progressively to less than 5 μm the ash content drops to about 5% or one sixth of the input value. This is achieved with 93% to 99% combustible recovery in all cases. These laboratory data were obtained using the Minto New Brunswick coal used at the Chatham COM project and a tailings sample from a metallurgical coal cleaning plant in British Columbia.

Regional and Economic Expansion Canada
National Research Council of Canada

SABA coal beneficiation COM project. This project is being undertaken in New Brunswick and involves two federal government agencies through funding from the Office of Energy Research and Development(OERD) of Energy, Mines and Resources Canada. The main object of the project is to upgrade the high-ash, high sulfur Minto New Brunswick coal using a combined process developed at the NRC and the University of Waterloo that involves spherical agglomeration and bacterial activity hence the name SABA. The pyrites of the Minto coal is very finely disseminated throughout the coal and requires very fine grinding before the oil agglomeration process can liberate the ash containing the pyritic sulfur. Even so it is only possible to liberate part of the pyrites. Bacterial activity represents a way of improving on pyritic sulfur removal by conditioning the coal first with bacteria(14).

More specifically the major advantages of the SABA process are as follows:

i) It is designed specifically to handle finely ground particles which are necessary in order to liberate the finely dispersed pyrite typically found in New Brunswick coal.

ii) The recovery rate of carbonaceous matter can be maintained at higher levels, unlike conventional coal cleaning processes which sacrifice "yield" for marginal ash removal benefits.

iii) There is significant ash and sulfur reduction compared to specific gravity washing methods.

iv) The low-moisture content of the finished product precludes the expensive de-watering equipment usually associated with conventionally washed coal.

(v) It permits removal of trace elements from ash that are usually volatilized by combustion and emitted to the atmosphere.

(vi) It is a beneficiation process that requires minimal thermal energy input and relatively low capital investment.

The program aims to reduce the consumption of imported fuel oil in local pulp and paper industry boilers. It is expected to lead to a demonstration plant to produce COM for supply to the industry in New Brunswick.

Centre for Energy Studies, Nova Scotia Technical College

Coal beneficiation and COM combustion evaluation project. This project which began in 1979 is being funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) for a period of three years. The objective of the program is to develop a COM or COM emulsion preparation facility incorporating coal beneficiation. The facility will utilies local Nova Scotia coals including high-ash coals from open-pit mines. It is expected that the preparation/beneficiation project will lead to combustion evaluations, initially in a 300 hp boiler at NS Technical College and later a commercial demonstration in an industrial boiler or kiln.

Ontario Research Foundation (ORF)

Coal-oil mixture and coal-oil emulsion combustion project. This project was jointly sponsored by the Ontario Ministry of Energy, Ontario Hydro, the Steel Company of Canada, Gulf Oil Canada and CANMET. It began in 1978 and was concluded in 1980[15].

The project included the following elements: coal beneficiation, COM preparation, combustion evaluation slagging, fouling and emissions assessments. The three coals selected for COM evaluation were a western Canadian low-sulfur bituminous, an eastern Canadian high-ash, high sulfur bituminous and a Pennsylvania bituminous coal.

In the coal beneficiation work, samples of each coal were evaluated in both laboratory and pilot-scale coal cleaning equipment prior to COM preparation and combustion. Both conventional and spherical agglomeration coal cleaning techniques were used. In the COM combustion trials the two Canadian coals were cleaned and the US coal was simply crushed and pulverized. The COM preparation had originally included the use of a vortex mixing device so that the coal could be mixed with oil or an oil emulsion to form the COM, which would then be passed to the burner without contacting a pump. This arrangement would eliminate potential pump erosion problems such as those experienced at Chatham during Phase 1.

Preliminary work at ORF using the vortex mixer indicated that the mass throughput was too low to effectively form a COM which could be fed directly to the burner. Since the main objective of the program was the combustion evaluation, work on this aspect of COM preparation was deferred and a simple shear-mixing tank was installed to provide the COM.

However, the vortex mixing device was used to produce an emulsion which was used to form a COM containing micro-dispersed water, and this was tested and compared with COM.

In the combustion evaluation of COM, the three coals were mixed to form a 30 wt % COM and also a 30% COM containing 20% water. Tests were conducted at two firing rates, 7 GJ/h and 3.25 to 4 GJ/h and using two different types of burner, a high intensity burner developed at ORF with Gulf Oil and known as the Vortometric burner, and a standard Peabody burner. Both burners performed well in the tunnel furnace arrangement of the test facility despite the fact that the Vortometric produces a highly rotating flame resulting in some wall flame impingement. A continuation program involving further work on COM preparation and combustion is currently being negotiated.

Ontario Research Foundation (ORF)

COM combustion trials/abrasive wear of burner components project. It is clear that the COM technology evaluation program currently being undertaken in Canada has resulted in some areas of concern not the least of which is the abrasive wear of burner nozzle components particularly when using high-ash eastern Canadian coals such as that used at Chatham. This problem, which possibly cannot be entirely eliminated, can be minimized by burner design considerations, choice of appropriate materials of construction and the use of less abrasive and smaller size coal particles in the COM. In order to address this problem, CANMET in cooperation with ORF has started a burner wear evaluation project in a 10 GJ/h boiler located at ORF. Two 300 h combustion tests will be undertaken using the two burners used in the previous COM combustion evaluations at ORF. The tests will be conducted at 5 GJ/h or half-load using a 40 wt % COM comprising beneficiated eastern Canadian coal. Burner wear assessments will be made during the tests and the objective is to minimize or eliminate the abrasive burner tip wear associated with eastern Canadian coals. It is expected that this project will be completed by mid 1981.

General Comminution Inc
National Research Council of Canada

Slow diesel engine COM exploration tests. This project is in the development stage and involves the fine grinding capabilities of the GCI mill and the oil-agglomeration process of NRC to produce a suitable COM diesel engine fuel. An eastern Canadian coal has been reduced to about 15 μm by the SZEGO mill and then to 5 m using an agitated media mill. The coal is then cleaned by spherical agglomeration to 1.2% ash which means the COM diesel fuel will contain about 0.6% to 0.7% ash. It is anticipated that this fuel will be suitable for a slow-speed diesel engine (up to 300 rpm) trial in the NRC diesel test facility.

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