DEC

Another significant result of using this system is that 90% of HCl present in raw fuel gases was removed. HCl is becoming a key concern in combustion of d-R off-gases continues to be detected in test studies. A negative factor related to lime use is that it may increase the solids (ash) disposal volume from combustion. Sig found that all bottom ash and fly ash samples from the EP Toxicity tests which were done on 103 fly ash samples that were analyzed.

From just a combustion standpoint, however,

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PHASE I: BACKGROUND STUDY RESULTS UNDER
THE COUNCIL OF GREAT LAKE GOVERNORS PROGRAM TO
PERFORM STACK SAMPLING AND ANALYSIS OF
EMISSIONS FROM DENSIFIED REFUSE DERIVED FUELS (d-RDF)

Contract CGLG-88-001
Under a grant from the U.S. Department of Energy

Submitted to:

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April 7, 1989
3582/72

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CHAPTER 1

INTRODUCTION

The disposal of municipal solid waste is a major problem worldwide. It is particularly acute in the United States where per capita solid waste generation is high, as is public awareness of the problems associated with existing disposal technologies, especially landfilling and mass burn incineration. Landfilling only postpones the problem, often leading to later groundwater contamination and sometimes causing air quality deterioration from escaping gases. Typical large mass burn facilities are not efficient combustion devices, often achieving only 70 to 80% reduction of the solid waste charged. Mass burn facilities have frequently been sources of air pollutants and nuisance odors. Tests conducted by the EPA and by foreign agencies have demonstrated that chlorinated dibenzo dioxins (dioxins) and chlorinated dibenzo furans (furans) are present in municipal waste incinerator flue gas and ash. The EPA has also determined that dioxin and furan emission levels can be reduced by increased combustion temperatures and longer gas residence times.

Because the opposition to new landfills is so great and because improvements have been made in incineration designs, many large metropolitan areas are planning and/or building new incinerators. Such incinerators are not practical for small municipalities and rural areas, however. One potential alternative is to process municipal solid waste into pelletized fuel which could be burned in small solid fuel burners at municipal, commercial, institutional, and industrial facilities. This offers the potential opportunity to minimize disposal costs of municipal wastes as well as reduce energy costs for burner owners/operators. Regulatory agencies are faced with the need to maintain or improve ambient air quality and protect public health. As a result of past studies of larger waste burning facilities which emit dioxin and furan emissions, regulatory agencies have been reluctant to issue permits for small d-RDF burning facilities without having substantiating data on potential toxic emissions.

The Council of Great Lakes Governors has awarded a contract to Pacific Environmental Services, Inc. (PES), under the Subcontractor Program of the Great Lakes Regional Biomass Energy Program, to evaluate the feasibility of burning densified refuse-derived fuel (d-RDF) in small burners and power boilers. Pacific Environmental Services, Inc. (PES) is providing engineering and source testing services to the Council of Great Lakes Governors to support their efforts to promote the development and use of densified refuse derived fuels (d-RDF) and pelletized wastepaper fuels in small steam generation facilities.

The primary objective of this project is to provide regulatory agencies, within the Great Lakes Region, a complete air emissions profile for pelletized waste fuels produced in the Great Lakes Region and burned in small commercial/industrial, institutional, and utility boilers.

If the results demonstrate that combustion of d-RDF is environmentally sound, then the agencies should be less reluctant to issue permits to sources wishing to burn d-RDF. That would lead to the following benefits: 1) an alternative to siting new landfills; 2) a reduction in municipal waste volumes; 3) production of energy through use of alternative fuels technology; and 4) reduced energy costs for burner owners/operators.

This project is divided into two major parts. The first part of the study requires the assembly and assessment of information on d-RDF combustion from other d-RDF research studies; compilation of existing and proposed d-RDF regulations for the seven States in the Great Lakes Region; identification of all d-RDF and wastepaper pellet manufacturers in the Region; the selection of pellet producers to supply fuel for test burns; and the selection of a site to conduct test burns.

The second part entails conducting test burns of two types of d-RDF and one type of wastepaper pellets at a small boiler rated between 5,000 and 7,000 pounds of steam per hour in the Great Lakes Region. Coordination of the testing with Federal and State regulatory personnel is also included in this phase.

The test at this facility will provide a complete air pollution emissions profile for the combustion of three different refuse fuels. Pretest selection survey, and test planning will also be done for a second, larger scale power generation facility to lay the groundwork for a follow-on test program comparable to that done in the small boiler. Funding for this continued work is being sought from potential d-RDF fuel users, suppliers, and government agencies interested in supporting the development of d-RDF technology to meet energy and environmental conservation objectives.

This report covers the results of the first part of the study. Chapter 2 contains a summary of the d-RDF literature which was surveyed. Chapter 3 contains a compilation of existing and proposed regulation information from the seven participating Great Lakes States. Chapter 4 includes identification of pellet producers in the region. Chapter 5 contains a description of the pellet producers and test burn facilities selected for the experimental work to be undertaken in the second part of the program study. Chapter 6 contains a list of references.

CHAPTER 2

TASK 1 - RESULTS OF d-RDF LITERATURE SEARCH

INTRODUCTION

The main purpose of the literature search was to gather and document prior research conducted on d-RDF combustion. The following discussion includes a review of the d-RDF technology status, fuel characterization and manufacturing information, boiler operating considerations, a description of test equipment used in earlier studies, and a summary of combustion emissions data from those studies.

RDF TECHNOLOGY DEVELOPMENT STATUS

With information obtained from key people active in development of the technology, both in industry and various government agencies, as well as from available reports and technical literature, it has been confirmed that there have been very few tests done like those planned under the existing program. Much of the work done in the past did lead to progress in the evolution of refuse derived fuel (RDF) technology and laid the groundwork for the current opportunities for densified refuse fuel (d-RDF) development.

Municipal solid waste (MSW) has been used for several decades as a source of raw material for incineration-power generation. RDF has been cofired in various boiler designs with conventional fuels such as coal, oil, and natural gas. Raw MSW has also been used to fuel "mass-burn" resource/energy recovery systems as the sole fuel source, but these require special design and handling equipment tailored to MSW-fuel burning operation. RDF, on the other hand, can be used as a supplemental fuel, e.g., cofired with coal, in retrofitted boilers. The processing of waste materials for energy recovery or reuse is becoming more widely accepted and practiced in the solid waste handling industry, both for environmental and energy conservation reasons.

MSW is generally processed to RDF by size reduction, ferrous removal, screening, and air classification. There are a number of categories of RDF and they are defined in Table 2.1 (reference 13). The technical literature contains a considerable amount of information on RDF combustion experience in large scale power generation equipment.

EPRI, for instance, in cooperation with Argonne National Laboratory (ANL), has conducted an extensive study of RDF combustion. EPRI's final

TABLE 2.1
ASTM CLASSIFICATION OF RDFs

Class	Form	Description
RDF-1	Raw	Municipal solid waste (MSW) with minimal processing to remove oversize bulk waste
RDF-2	Coarse	MSW processed to coarse particle size with or without ferrous metal separation such that 95% by weight passes through a 6-in.-square mesh screen
RDF-3	Fluff	Shredded fuel derived from MSW processed for the removal of metal, glass, and other entrained inorganics; particle size of this material is such that 95% by weight passes through a 2-in.-square mesh screen ^a
RDF-4	Powder	Combustible MSW fraction processed into powdered form such that 95% by weight passes through a 10-mesh screen (0.035 in. square)
RDF-5	Densified	Combustible MSW fraction densified (compressed) into pellets, slugs, cubettes, briquettes, or similar form
RDF-6	Liquid	Combustible MSW fraction processed into a liquid fuel
RDF-7	Gas	Combustible MSW fraction processed into a gaseous fuel

Source: Thermal Systems for Conversion of Municipal Solid Waste: Overview. Chicago, IL: Argonne National Laboratory, May 1983. CN5V-TM-120, Volume 1.

^a Measured RDF particle size distributions indicate that 95% by weight of the RDF is smaller than 2 in. and that over 99% by weight of the RDF is smaller than 2.5 in.

contract report (reference 13) and the earlier reports by ANL (reference 6), as well as proceedings from various EPRI-sponsored seminars and meetings provide an excellent source of technical and practical experience.

In the actual tests that were done, however, most of the fuel from municipal solid waste (MSW) was not pelletized but sized to an ASTM Class RDF-3. This is a "fluff" form of shredded material less than 2.5 inches in diameter. Other fuel processing was done with even less sizing done and some with novel processing into liquid or gaseous fuels.

The equipment of interest to electric power generating companies is also much larger than that used in smaller industrial boilers, e.g., 35 MW - 364 MW (nominal 120×10^6 Btu/hour - 1248×10^6 Btu/hour or 120,000 lbs. steam/hour - 1,248,000 lbs. steam/hour) versus the relatively small 1.5 MW (nominal 5×10^6 Btu/hour or 5,000 lbs steam/hour) planned for use in the current program. These smaller units would normally be used in schools, apartment buildings, hospitals, and small industrial/office facilities. Because of the scale differences, there are significant differences in operating requirements relative to large power boilers. Furthermore, State air permitting regulations for smaller boiler units are generally different from those applied to larger scale units, frequently being indexed to tons of fuel burner per hour (which is directly proportional to power output).

Lastly, almost all testing was done using RDF fuel cofired with coal (or another supplemental fuel) so there were a number of introduced variables that complicated the operation. Under the present program, it is intended to fire d-RDF alone and under conditions suited for isolating the effect of d-RDF use without interactions from other fuels or additives.

d-RDF MANUFACTURE

Densified RDF (d-RDF) is classified as RDF-5 and defined as "combustible MSW fraction densified (compressed) into pellets, slugs, cubettes, briquettes, or similar forms," as shown in Table 2.1 (reference 13). It is normally made from RDF-3 "fluff" raw material which has already undergone size reduction using vertical or horizontal hammer mills and/or shear shredders, combustibles separation using trommels (rotating cylindrical or conical screens) and air classifiers, and magnetic separators for ferrous material removal. There may be a number of other steps associated with materials classification and collection for recycle/ reuse and, in some cases, hand sorting may be necessary, e.g., to remove plastic material for manufacture of >99% plastic-free fuel pellets. (While plastics add fuel value, a number of them contain chlorine, most of which may then appear as HCl in the combustion flue gases.)

Although a number of sequential processing schemes have been tested and used successfully, generally, the steps followed in MSW processing to RDF are:

- Receipt and storage of MSW.
- Removal of unacceptable material.

- Prescreening to remove bottles and metal cans prior to shredding.
- Primary shredding.
- Ferrous material separation.
- Screening for fines removal and combustibles recovery using disc or trommel screens.
- Potential aluminum and/or glass recovery.
- Surge flow storage.
- Separation for combustible recovery using air classifier or air knife.
- Air classifier cyclone for dust control.
- Secondary shredder.
- Secondary shredder cyclone for dust control.
- RDF-3 outloading to storage or transfer bins.

This RDF-3 fluff is then fed to a screw conditioner for presentation to the pellet mill where RDF-5 cylindrical extrudates are formed. (Pellet mills rather than cuber or other processing machine options have become standard in the industry.) After cooling and screening, the RDF-5 pellets are transferred to storage bins for shipment to customers.

During the past ten years, densification technology has developed to the stage where manufacturing procedures and quality control guidelines have been established. Buhler-Miag, Inc., Lundell Mfg., Inc., and California Pellet Mill equipment for pelletizing MSW have emerged as improved, viable, and commercially available systems for manufacturing d-RDF in the Great Lakes Region. The Buhler-Miag technology originated from the corporate headquarters in Uzwil, Switzerland. There are fuel processing companies in Europe and North America, including Reuter Resource Recovery in Minnesota, who are using Buhler-Miag equipment for manufacture of 3/4" diameter (cylindrical) fuel pellets. The Lundell Manufacturing Company of Cherokee, Iowa also markets pellet mill equipment for 3/4" diameter fuel pellet extrudates which range from 1 to 2 1/2 inches in length. The California Pellet Mill Division of Ingersoll Rand Corporation, San Francisco, California markets equipment used by General Fuels Corp., Neenoh, Wisconsin to make fuel pellets with are 1/2" diameter extrudates. Their raw material source is actually industrial waste paper rather than MSW.

Other equipment manufacturers include the Esbjerg Matador Maskiner Company of Esbjerg, Denmark; the Amandas Kahl Mills Corp., Hamburg, West Germany; Simon-Barron Ltd., Gloucester, Great Britain; and the Sprout-Waldron Division of the Koppers Company, Inc., Pittsburgh, Pennsylvania. Information on this equipment has been summarized previously and is available in reference 22.

Fuel Characterization

Fuel characterization of d-RDF pellets is done following procedures developed for coal and documented in the ASTM Standards for Coal and Coke. The proximate analysis determines, by prescribed methods, the moisture, volatile matter, fixed carbon, and ash content by weight on samples in three forms: 1) as received; 2) moisture-free; and 3) moisture and ash-free bases. An ash fusion temperature determination

should be made also. Another simple but important measurement routinely made is that for fuel pellet density and bulk density expressed as lb/ft³.

The ultimate analysis includes the determination, by prescribed methods, of the weight percent of ash, carbon, hydrogen, nitrogen, oxygen (by difference) and sulfur. The calorific heating value as Btu/lb of fuel is also a key associated parameter which must be accurately determined. The quantitative determination of fuel chlorine content is important for MSW-derived fuels because of the possible presence of chlorinated hydrocarbon polymers in the raw material. Finally, from the ultimate analysis, the F-Factor expressed as dry SCF/10⁶ Btu is derived for a particular fuel sample and this value is used to relate fuel heating value to acceptable particulate emissions levels, commonly expressed as lb. particulate/10⁶ Btu fuel input heat value.

Basic fuel characterization data including bulk density, heating value, chlorine, proximate, and ultimate analysis are summarized in Table 2.2 for comparison purposes. There is really a very limited amount of d-RDF characterization data available. Fuels from the Northwest Medical Center, Thief River Falls, Minnesota tests (references 5, and 12) and Dordt College, Sioux Center, Iowa test (reference 11) were from the same source (i.e., Future Fuels of Thief River Falls, Minnesota using Lundell processing equipment) and, as expected, show similar properties.

Fuels from two Warren Spring Laboratory, U.K. reports (references 1 and 17) are also from similar source processing using Buhler-Miag processing equipment in the U.K. and have comparable properties. The fuel used in the University of Wisconsin-Oshkosh test (reference 25) is made from an industrial paper raw material which is considerably different from the MSW and therefore has some different properties. It is made by General Fuels Corp. of Neenah, Wisconsin using California Pellet Mill equipment.

d-RDF pellets in references 1, 17, and 25 have generally higher bulk density (≈ 37 lb/ft³) and calorific heat content (8400-10,000 Btu/lb), reflecting higher particle density, than from fuels used in references 5, 11, and 12 (≈ 27 lb/ft³ and 7500 Btu/lb). This is because Buhler-Miag pelletizing equipment was used in the first group whereas Lundell pelletizing equipment was used in the second group. The U.K. d-RDF (references 1 and 17) was seen to contain 1% chlorine versus a lower value for reference 5 of 0.16%, and a very low value for reference 25 of 0.01%. Only industrial cardboard/ paper was used as raw material for this last d-RDF pellet. Finally, it is evident that the ash content of the U.K. d-RDF material was relatively high at 14% and 17% versus all others which contained 6% or lower ash contents. This may have been part of the reason that the boiler fouling problems were so extensive in the U.K. test program (reference 1).

Although a number of fairly extensive elemental analyses have been reported in the literature for various coal and non-densified RDF, such extensive and detailed analyses for densified RDF were not found. The chlorine content of d-RDF was determined in the two Warren Spring Lab reports (references 1 and 13) and the August 1988 Interpol report from Thief River Falls, Minnesota testing (reference 5). Analysis for lead

TABLE 2.2

RESULTS OF d-RDF CHARACTERIZATION ANALYSES

Characterization Parameter	5	11	Reference Report Number				17	25
			12	1	1	1		
Bulk Density (lb/ft ³)	27	27	27	37	37	37	34.3-37.4	37
Heating Value (Btu/lb)	7,547	7,497(U)	7,497(U) 7,224(P)	8,781	8,781	8,781	8,437	9,966 8,912
Chlorine (wt. %)	0.16	ND	ND	1.11	1.11	1.11	0.9	0.01
Ultimate Analysis (as received wt. %)								
Moisture	8.06	11.60	11.60	ND	ND	ND	12	5.86
Ash	5.79	1.89	1.89	ND	ND	ND	17	5.07
Carbon	ND	42.69	42.69	45.4	45.4	45.4	40	51.38
Hydrogen	ND	5.46	5.46	6.2	6.2	6.2	5	7.79
Oxygen (by difference)	ND	38.05	38.05	31.25	31.25	31.25	26	29.10
Nitrogen	ND	0.12	0.12	ND	ND	ND	0.4	0.72
Sulfur	ND	0.19	0.19	0.19	0.19	0.19	0.3	0.07
Proximate Analysis (as received wt. %)								
Moisture	8.06	ND	12.41	7.0	7.0	7.0	ND	2.82
Ash	5.79	ND	2.20	14.3	14.3	14.3	ND	3.09
Volatile Matter	72.12	ND	71.21	69.5	69.5	69.5	60	89.50
Fixed Carbon (by difference)	14.03	ND	14.18	ND	ND	ND	11	4.59
Sulfur	0.59	ND	0.19	ND	ND	ND	ND	0.07

ND = No data were presented in this report.

In addition to those two elements, the concentration of arsenic, barium, beryllium, chromium, copper, mercury, nickel, antimony, selenium, thallium, and zinc was determined in the solid fuel used in the O.O. Ohlsson Argonne National Laboratory (ANL) study (reference 15) but the results are not yet available because the final data report has not been completed. Other chemical characterization data was gathered in the same ANL study on their fuels included organic concentration measurements for compounds such as PCB's, polyaromatic hydrocarbons, dioxins, and furans, but again these data have not yet been formally issued in a final report.

All d-RDF fuel analysis data taken from key combustion test reports have been compiled in their original form and are given in Appendix A. Material has been gathered from test reports at the Northwest Medical Center, Thief River Falls, Minnesota (references 5 and 12); Dordt College, Sioux Center, Iowa (reference 11); the Warren Spring Laboratory, United Kingdom (references 1 and 17); and the University of Wisconsin at Oshkosh (reference 25). This compilation has been done because each report contains different fuel characterization data obtained by different analytical techniques. Until fuel characterization becomes a routine matter, the source of data must be carefully considered before using for comparison with other results.

Boiler Operating Problems using d-RDF

There are no known boilers generating 5,000-7,000 lb. steam/hour, the scale planned for Phase II testing, which have been specifically designed for firing d-RDF exclusively since this is a relatively new technology application. Previous test work, uncovered in the literature, which has been carried out in units of this size and larger, was all done with equipment designed originally for coal. The boilers or furnaces were subsequently modified in various ways to accommodate d-RDF firing.

Some problems that were encountered during d-RDF firing tests in coal boilers are noted and discussed below:

Fuel Pellet Breakup (lack of physical strength)

The past 5-10 years have been effectively used by technology developers to identify and solve processing problems related to physical integrity of pellets. One key factor is the need to provide a uniform and standardized raw material feedstock to the pellet mills. The composition of the feed material is also critical since, for example, the plastic content can make a significant difference in the pellet integrity, density, and fuel heat content (Btu/lb of fuel).

Work done by the Argonne National Laboratory (reference 15) has shown that use of a lime (Ca(OH)_2) binder for d-RDF adapted well with coal cofiring and gave some synergistic benefits in that pellet stability and strength was enhanced but also the introduction of lime assisted in decreasing coal baseline SO_2 and NO_x emissions. The Argonne lab facility was particularly well suited to the binder fuel since it already was equipped with a lime processing system for flue gas emissions control.

Another significant result of using this system was that approximately 90% of HCl present in raw fuel gases was removed by the lime spray dryer. HCl is becoming a key concern in combustion of d-RDF as its presence in off-gases continues to be detected in test studies. The only potential negative factor related to lime use is that it may increase the total solids (ash) disposal volume from combustion. Significantly, it was found that all bottom ash and fly ash samples from all test runs passed the EP Toxicity tests which were done on 103 fly ash and 131 bottom ash samples that were analyzed.

From just a combustion standpoint, however, the use of a binder for d-RDF is not necessary to obtain a sufficiently durable fuel for firing in a coal stoker boiler. All references have reported that physical strength is directly proportional to bulk density. Thus a more dense pellet will be more resistant to breakage and disintegration during handling than a less dense material. This is also an advantage from the standpoint of heat content, allowing the d-RDF to more closely simulate the typically higher fuel heat content of coal. There may be, however, a tradeoff with the ease of suspension burning of the d-RDF which must be considered for each boiler facility and its fuel feed-combustion chamber operation.

Fuel Pellet Deterioration Over Time, e.g., From Moisture Contact

Excessive moisture contact will lead to fuel degradation and is to be avoided during storage, shipping, and transfer to feed bins. It will also decrease the effective fuel content by consuming energy during vaporization of water present in the fuel. From the ultimate analysis data summarized in Table 2.2, moisture contents of the actual fuels used for testing ranged from 6 to 12% by weight.

For densification of RDF in pellet mills, however, a certain minimum amount of water is required for lubrication and to assist cohesion of pellets during processing. Water management is therefore an important aspect of d-RDF preparation technology and must be carefully monitored throughout the manufacturing process from raw material (MSW) delivery to the processing plant all the way through pellet mill processing, silo storage, and finally customer firing in a boiler.

Unburned Material in Bottom Ash (incomplete combustion)

Incomplete combustion in a stoker boiler may occur if the solid fuel bed depth, fuel delivery speed, or combustion air supply are not adjusted properly for the fuel being fired. To some extent, this is a function of the boiler equipment being used and the instrumentation available for monitoring combustion efficiency. It is well worth the time to make a series of brief adjustment tests of these variables to establish stable, complete combustion without causing excessive clinker formation or overheating the grate or other boiler internals by firing at too high a temperature.

Unit Derating (lower power output)

Typical spreader stokers are designed for a coal heat content of 12,900 Btu/lb (reference 22) but d-RDF has a heat content ranging from

7500 (from MSW) to 10,000 (from pressed paper) Btu/lb. Thus, part of the retrofit adaption process of using d-RDF in place of coal requires adjusting the volumetric fuel feed rate according to the bulk density and the specific heat content of the d-RDF pellets being fired.

Corrosion of Boiler and Flue Equipment

Corrosion problems arise in coal boiler retrofit applications from the introduction of acidic (or basic) compounds from the fuel which then may interact with boiler equipment. For d-RDF, the compound of greatest concern is HCl in the flue gas. This is the form in which most of the Cl present in the fuel will exit the boiler. Other corrosive compounds may be found in the flue gas and combustion product ash. Their composition and concentration will be controlled by the chemical composition of the d-RDF fuel and the combustion reactions.

Boiler Tube/Wall Fouling

This was found to be a serious problem in one test study by Warren Spring Laboratory (reference 1) which required shutdown and boiler cleaning after one week's operation. An analysis of the boiler deposit material from this test compared with that from a coal deposit sample is given in Table 2.3. Lead and cadmium were present in the fuel as given in Table 2.4, and concentrations present would require use of protective equipment during boiler cleanout. Parameters which have a key impact on the extent and nature of fouling include the d-RDF chemical composition, ash content, boiler geometry (flue gas velocity), combustion efficiency, boiler output, and air supply/distribution.

Chain Grate or Pneumatic Stoker Fouling and Clinker Formation

This may be caused by exceeding the ash fusion temperature of a particular d-RDF material which is typically lower than that for coal, e.g., 1000-1100°F versus 1100-1200°F, respectively (reference 22).

The ash composition of the d-RDF pellet is the key parameter governing the fusion temperature. The presence of well distributed excess air does help minimize these problems, however.

Determination of fuel sample ash fusion temperature prior to firing is essential for providing guidelines for successful boiler operation if they have not been firmly established.

Adverse Interaction with Existing Pollution Control Equipment.

Although the purpose of the test program is to carry out measurements upstream of control equipment, it is clear that the potential impact of using d-RDF instead of coal may render some equipment, e.g., electrostatic precipitators or cyclone separators less efficient than with the coal fuel for which they were designed. For this reason, the fly ash from d-RDF combustion should be fully characterized in terms of particle size distribution and composition, if possible, before attempting to install new control equipment or assuming that existing control equipment will be effective with d-RDF combustion.

TABLE 2.3
BOILER DEPOSIT COMPOSITION

Component	Concentration (%)	
	RDF	Coal
Carbon	1.5	-
Sulfur	13.0	0.5 - 3.5
Chlorine	0.18	0.003 - 0.025
Calcium	5.3	-
Silicon	8.0	10 - 16
Aluminum	4.0	-
Iron	1.7	-
Lead	0.13	8×10^{-3} - 2×10^{-2}
Cadmium	0.007	2×10^{-4} - 5×10^{-4}

TABLE 2.4
FUEL ANALYSIS

Caloric value, Gross as-fired (Btu/lb)	8,781
Ash content (%)	14.3
Moisture content (%)	7.0
Volatile matter (%)	69.5
<u>Ultimate Analysis (%)</u>	
Carbon	45.4
Hydrogen	6.2
Oxygen	31.25
Sulfur	0.19
Chlorine	1.11
Lead	0.0051
Cadmium	0.0006

Another factor to be considered is flue duct size and design velocity/pressure drop interactions. Entrained unburned particles and sparks may trigger a fire in air pollution control systems because of differences in particle size, composition, and flow velocity in ducts compared to that from coal combustion. Often referred to as "tail-end" fires, they occur when accumulated combustible mixtures combine with oxygen and ignite from a spark or entrained burning char. Waste-derived fuels inherently contain more combustible mixtures and char than conventional fuels such as coal, so the threat of fire is greater.

d-RDF Combustion Tests

The scope of the literature search has been focused to obtain information which is relevant to the planned emissions tests, although a considerable amount of other related data has been gathered and is listed in the references.

Eight test reports have been singled out for more careful review because they are relevant to the current program and they have been carried out recently. They are listed below and the following discussion refers to these test studies in more detail.

d-RDF - Coal Cofiring

Hecklinger, R.S. (Charles R. Velzy Associates, Inc.) et al., "Coal/d-RDF Co-Firing Project, Milwaukee County, Wisconsin" under EPA Grant No. R806336-01-2, December 1981. (reference 7.)

"Hubinger Demonstration Test Burn," test dates: September 29-30, 1987 (unsigned report material from Lundell Mfg., Inc.). (reference 8.)

Ohlsson, O.O. (Argonne National Laboratory) et al., "Emission Studies of Full-Scale Cofiring of Pelletized RDF/Coal at Argonne National Laboratory," 23rd Intersociety Energy Conversion Engineering Conference (IECEC), Denver, Colorado, July 31 - August 5, 1988. (reference 15.)

"Utilization and Evaluation of Refuse Derived Fuel at UW-Oshkosh," prepared by: State of Wisconsin, Department of Administration, Division of State Facilities Management, Bureau of Engineering Services, Craig A. Weiss, project manager, December 1987. (reference 25.)

d-RDF Combustion

Burnley, S.J. (Warren Spring Laboratory), "Refuse Derived Fuel Combustion Trials on a Single Chain Grate Stoker Shell Boiler," LR 573 (MR), U.K. Department of Energy's Energy Technology Support Unit (ETSU), Report No. ETSU-B-1136(d), 1987. (reference 1.)

Eickstadt, K. (Interpoll Labs, Inc.), Results of the August 1988 Particulate Emission Compliance Test on the No. 4 Boiler at the Northwest Medical Center Located in Thief River Falls, Minnesota," September 20, 1988. (reference 5.)

Lonnes, P. and K. Eickstadt (Interpoll Labs, Inc.), "Results of the March 31, 1987 Particulate Emission Compliance Test at the No. 1 boiler at Dordt College in Sioux Center, Iowa," April 13, 1987. (reference 11.)

Lonnes, P. (Interpoll Labs, Inc.), "Results of the June 1987 Test Burn of Future Fuel d-RDF at the Northwest Medical Center in Thief River Falls, Minnesota," August 4, 1987. (reference 12.)

The first four reports listed above involved d-RDF-coal cofiring in medium scale power generation equipment rated at 45,000-150,000 lb steam/hour output. The last four reports were done using only d-RDF (without coal cofiring) in small ($5-10 \times 10^6$ Btu/hour) boiler equipment.

Of those last four test reports, only reference 12, done by Interpoll Laboratory regarding the June 1987 test burn at the Northwest Medical Center in Minnesota, was found to contain a comprehensive set of emissions measurements of a quality comparable to that planned under the current study. The Warren Spring Laboratory work was as rigorously carried out but all the emissions data was not readily available because all the results have not been formally released in a report. The other two reports by Interpoll laboratory were for particulate compliance only, however, one is of particular interest because it was carried out at the prime candidate site for our current tests, Dordt College in Sioux Center, Iowa.

Test Report Overview

Every test report that was reviewed had a different series of objectives and constraints. Of the seven reports specifically related to d-RDF testing, the June 1987 emission evaluation work done by Interpoll Laboratory at the Northwest Medical Center in Minnesota was the most comprehensive in terms of data reports, and rigorous in terms of emissions test procedures used. Fuel feed composition was assumed to be the same as that obtained from a sample taken earlier during the Dordt College, Iowa test program in April 1987. It would have been more desirable to have analyzed samples taken during the actual test. The discussion of operating procedures and logistic/engineering factors was limited in scope, but this was apparently not a primary study objective.

The EPA Grant test study done by Hecklinger et al. for Milwaukee County and the Argonne National Laboratory program, both cofiring d-RDF with coal, and the Warren Spring Laboratory, U.K. study all went into more detail about the actual test procedures, fuel preparation/handling, operating problems and engineering analysis of the combustion system, e.g., energy and material balance calculations. The Warren Spring Laboratory reports were most thorough in this last respect but they did report significant analytical measurement error of effluent gas chlorine, sulfur, cadmium, and lead. The Cl and S discrepancies were thought to be due to use of wet chemical rather than continuous instrumental analysis techniques. The cadmium and possibly lead errors were thought to be due to the product stream material analyses being too close to detection limits for the methods used.

The ANL and EPA reports contained a good deal of information about d-RDF-coal cofiring. The Argonne work, done jointly with North Texas State University, has not been continued due to a cutback in funding but the analytical work done was quite extensive. The final report may contain less data analysis than they originally planned, however. Also of interest was the fact that they successfully introduced lime (Ca(OH)_2) as a binder for the d-RDF. This was appropriate at the Argonne facility since it already had a lime treatment/recovery system for flue gas emissions control. It was found that SO_2 emissions upstream of the pollution control equipment decreased as the amount of binder added to the d-RDF was increased.

d-RDF Combustion Test Facilities

The small scale ($5\text{--}10 \times 10^6$ Btu/hour) combustion test facilities used for successful d-RDF testing (without coal cofiring) are limited to two basic types of fuel delivery systems, one is a chain grate stoker used at the Warren Spring Laboratory in the U.K. and the other is a pneumatic solid fuel injection system used at the Northwest Medical Center in Minnesota and Dordt College in Iowa.

Warren Spring Laboratory Boiler (Reference 1)

The test unit used was an Edwin Danks wet back economic shell boiler (fire tube boiler) rated at 15×10^6 Btu/hr with two smoke tube passes and incorporating a single "Oldbury" chain grate stoker as shown in Figure 2.1. The 120 fire (smoke) tubes were each 14.6 feet long and 2.24 inches OD and surrounded by water at 120 psig. Underbed primary air was supplied to the grate by a forced draft (FD) fan with a manual control setting.

A separate and independently controlled secondary air system was specially installed for firing trials. It consisted of two 4-inch pipes running from the front of the boiler, between the grate and ash conveyer, and emerging before and after the back firebrick wall as shown in Figure 2.2. Orifice nozzles were added to one of the pipes to create an air jet swirling acting to enhance mixing. It was found that increasing the primary air flow rate tended to cool the bed and interfere with complete combustion of fuel pellets. Increasing the swirling, high velocity secondary air flow was found to promote increased turbulence and improved combustion efficiency.

The flue gas, after passing through smoke tubes, exited from the back end of the boiler, passing through a particulate (grit) arrestor and induced draft fan and was finally vented to a 245 foot stack.

The fuel input to the boiler is controlled by manual adjustment of the grate speed and the fuel bed depth. The primary air fan damper is linked to the grate speed but can also be adjusted manually. Combustion pressure gauges are used to give indication of air flow.

Figure 2.1. Schematic of Chain Grate Stoker Boiler

17635

17378

Figure 2.2. Arrangement of Secondary Air System

Northwest Medical Center (References 5 and 12)

The boiler used was a Kewanee Scotch Marine Boiler converted to fire d-RDF by installing a Sidewinder Solid Fuel burner SFSM 1200 manufactured by Northwest Iron Fireman of Fargo, North Dakota. It is a pneumatic stoker.

The d-RDF pellets are automatically augered from a storage bin to a 1200 pound surge hopper. The pellets are then metered into the airstream and pneumatically injected into the furnace. It is a fully modulating system which senses steam demand and automatically adjusts the feed rate of fuel proportionally. The burner is designed to provide partial suspension burning. The degree of suspension burning varies with the fuel type. In the case of the d-RDF pellets, the burner manufacturer estimated that approximately 50% of the pellets were burned in suspension.

The maximum rated capacity of this boiler is 188 BHP which corresponds to a boiler output of 6.3×10^6 Btu/hour. Particulate emissions from the boiler are controlled by a Breslove mechanical collector. Cleaned flue gas is exhausted to the atmosphere via a 60-foot high brick stack which is common to five boiler units.

A sketch of the boiler is given in Figure 2.3.

Dordt College (Reference 11)

The boiler used was a Kewanee 200 HP boiler which was built in 1970. It is equipped with a Sidewinder burner manufactured by Northwest Iron Fireman and has an economizer. The rated steaming capacity is 6900 lb/hr of saturated steam. The boiler is not equipped with pollution control equipment. Flue gas is exhausted to the atmosphere via a 16-foot high square steel stack.

A fact sheet on the boiler from Biomass Energy is given in Figure 2.4 and schematic drawings of the firebox/boiler and the system are shown in Figures 2.5 and 2.6.

Emissions Data Review

All the sampling and analytical procedures used in combustion emissions testing have not been fully standardized in the industry. Furthermore, emissions measurements are frequently made for a variety of reasons to obtain different specific information. Therefore, a summary of sampling and analytical procedures used in prior reference d-RDF studies is given in Table 2.5, along with those procedures planned for use in the experimental part of the current program.

EPA Method 5 defines a manual procedure that is widely used for general particulate measurement. It is thought important for research studies to use continuous analyzers for normal products of combustion, including CO, CO₂, O₂, NO_x, SO₂, and uncombusted hydrocarbon (UHC). The continuous monitoring instruments are very helpful in following test burn progress on an immediate, real time basis.

Figure 2.3. No. 4. Boiler Northwest Medical Center
Thief River Falls, Minnesota

BIO-MASS ENERGY

304 North Main Ave
Sioux Center, IA 51250
(712) 722-3709

"Working to solve the
future's problems TODAY!!"

FACT SHEET: DORDT COLLEGE

Project; Sioux Center, Iowa Solid Fuel Burner System.
Completion Date; March 3, 1987
Contractors; Van Beek Inc., Walstra Plumbing & Heating,
Kosters Repair & Four Winds Enterprises.
Burner Make; Northwest Iron Fireman Inc., "SIDEWINDER"
Fargo, North Dakota
Burner Company; 36 previous installations, first one
January 1983. Dordt first unit in Iowa.
Boiler Specs; Kewanee 200 Horse Power Scotch Marine
Catalog # H25200-X, 2 pass
Rated output 6,695,000 BTU
Rated Max firing rate 8,370,000 BTU
Rated 80 percent efficient, Operating
pressure 19 PSI, 1000 square ft heating
surface, Boiler equipped with spinner type
turbulators, Soot blowers and stack fan.
Burner Specs; Dutch-Oven type combustion chamber.
Stepped stationary grate, with under & over
combustion air.
Variable speed metering system, complete
load follow capability.
Fuel Input, 7,650,000 Max BTU per Hour
Aprx. 900 pounds dRDF Fuel = 7,650,000 BTU
Burn Temperature, 2200°-2600° F
Stack Temperature, 300°-400° F
Estimated average yearly use, 1325 Ton
Heating 357,900 Sq Ft. & domestic water
Boiler Controls; The boiler's steam pressure, regulates the
amount of fuel & air needed to match the
boiler's demand of steam.
Fuel Supply; E-Z Fuels Ltd., Sioux Center, Iowa
Type Fuel; dRDF - Densified Refuse Derived Fuel,
or Cardboard, paper products etc.
3/4 inch round pellets. 1-2 inches long.
Average BTU value, 8500 BTU per Pound
Average moisture content, 8.31%
Average ash content, 2.04%
Ashes are being tested for value.
Emissions; Particulate test passed, June 10, 1987.
Benefits; Dependable safe low cost fuel. Decreases
tonnage to Landfills, Keeps energy money
in the community. Creates jobs.
General; Dordt enrollment aprx. 950 students.
Documentation; Pictures, and video tape are available.
Awards; APPA Energy Innovator Award, 1987
US WAPA Administrator Award, June 1987
Iowa Community Education Award, Nov 1987
NOTICE: For more information call or write address above.

Figure 2.4. Fact Sheet: Dordt College Boiler

TYPICAL FIREBOX OR CAST IRON BOILER

ADVANTAGES:

1. Will efficiently fire Scotch Marine and Firebox Type Boilers
2. Self-cleaning grates.
3. Complete Combustion — Minimal cleaning.
4. Adaptable to automatic ash removal.
5. No moving parts to wear out in combustion area.
6. Full Modulation. Automatic fuel air mixture from Lo to Hi firing.
7. No major changes required to change fuels.

Figure 2.5. Drawing of Typical Firebox or Cast Iron Boiler

LEGEND

1. TYPICAL SCOTCH MARINE BOILER SERVING AS HEAT RECOVERY BOILER
2. STEEL ENCASED REFRACTORY LINED "OVEN" COMBUSTION CHAMBER
3. UNDERGRATE COMBUSTION AIR FAN DAMPER MODULATED
4. CAST IRON STEP GRATES (SELF-CLEANING)
5. FIRE DOOR ACCESS
6. "U" TROUGH CROSS AUGER FOR OPTIONAL ASH REMOVAL
7. FUEL HOPPER
8. ADJ. VENTURI FUEL INJECTION NOZZLE
9. FUEL/AIR INJECTION FAN
10. FUEL METERING SCREW
11. FUEL SUPPLY AUGER
12. INDUCED DRAFT FAN
13. SYSTEM CONTROL PANEL
14. BIO-MASS FUEL STORAGE

SIDEWINDER

Figure 2.6. Schematic of Sidewinder System

TABLE 2.5
SAMPLING AND ANALYTICAL PROCEDURES

Emission	Planned Sampling/ Analytical Procedures	Reference Report Number			
		1	5	11	12
Particulates	EPA Method 5	EPA Method 5	Condensable wet catch required by Minnesota PCA and EPA Method 5	EPA Method 5	EPA Method 5
PM ₁₀	Andersen Cascade Impactors	-----	-----	-----	-----
CO, CO ₂ , O ₂ , NO _x , SO ₂ , UHC	Continuous Analyzers	Yes	ORSAT - Method 3	EPA Method 3	EPA Method 3 Continuous CO, CO ₂ , O ₂
HCl	NaOH Soln-Method 5 impingers and ion chromatography HCl determination	Wet chemical analysis (sample and analysis problems)	-----	-----	Modified EPA Method 6 and ion chromatography (also SO ₂)
Dioxins, furans, PCBs	EPA Semi-VOST (formerly known as modified Method 5) and GC/MS analysis	Warren Spring Laboratory procedure (results not yet published)	-----	-----	EPA Semi-VOST with XAD-2 resin and HRGC/LRMS analysis per EPA Method 8280
Heavy metals	Inductively Coupled Plasma Argon Spectroscopy (ICAP) analysis of Method 5 filters	Atomic Emission Spectroscopy (AES)	-----	-----	EPA Method 12 (for lead) used as guideline. AAS analysis
Opacity	-----	Ringelmann	EPA Method 9	-----	-----
Total Gaseous Non-Methane Organics (TGNMO) or VOC	-----	-----	-----	-----	EPA Method 25
Selected Polynuclear Aromatic Hydrocarbons (PAHs) and Hexachlorobenzene (HCB)	-----	-----	-----	-----	MRI-type Modified Method 5 (MM5) with post-impinger florisil absorbent cartridge analysis for PAH by HPLC with fluorescent and UV detectors. EPA Method 610. HCB analysis by HRGC and Hall Detector.

One objective of the Council study is to determine the total amount of particulate matter that is less than 10 micro meters in diameter. This is because ambient air quality standards are being considered for these PM_{10} particles which will then be used to specify point source emission guidelines. Another objective of is to better define the particle size distribution of particulate matter present in effluent gases. For this purpose, the Andersen cascade impactor train will be used to quantify PM_{10} (particulate matter less than 10 microns in diameter). This information is useful for design of particulate removal/control equipment such as cyclones, baghouses, etc.

NaOH absorption of HCl using Method 5 impingers and ion chromatography for analysis is standard procedure for HCl determination and is an important measurement to be done. EPA guidelines will similarly be used for dioxins, furans, and PCBs according to modified Method 5 (also known as EPA Semi-VOST). State-of-the-art Inductively Coupled Argon Plasma (ICAP) spectroscopic analysis of Method 5 filter catch samples will be used for heavy metals determination because it allows quantification of 15 elements from one sample.

Results of emissions measurements from d-RDF combustion test reports are summarized in Table 2.6.

Particulate matter measurement results (as grains/dry scf) are in the same ballpark for all reference reports, in spite of differences in fuel raw material, processing, and test boilers used. The lowest level obtained at Dordt College (reference 11) (0.14 grains/dscf) may be the result of underfiring since CO_2 emissions are also lower than in other tests (approximately 6% CO_2 versus 10-12% CO_2 in other trial burns).

It is anticipated that more data from the Warren Spring Laboratory (reference 1) testing may become available in the near future and the Table 2.6 data summary can then be updated to reflect the new information and report it in terms comparable to the data from other references.

Reference 12 contains the only total dioxin and total furan emissions data immediately available, yielding 50 and 100 nanograms/dscm values, respectively. This and other results that may become available in the near future will be compared with results to be obtained under the current program.

Finally, in the heavy metal category, lead appears in the Northwest Medical Center, Thief River Falls, Minnesota test (reference 12) data at very significant concentrations relative to the other metals. Since it, (as well as several other heavy metals) are potentially harmful air contaminants, they will be sampled for and analyzed for carefully in the upcoming emissions measurement work.

TABLE 2.5

SUMMARY OF d-RDF EMISSIONS DATA

EMISSIONS MEASURED	REFERENCE NUMBER		
	1	5	11
			12
Particulate (grains/dSCF) (lb/10 ⁶ Btu)	@/STP & CO = 10% 0.225	@/STP & CO = 12% 0.140	@/STP & CO ₂ = 12% 0.194
	(avg of 2)	(avg of 3)	(avg of 3)
	5.28	3.25	3.40
Boiler Capacity (15x10 ⁶ Btu/hr)		(6.3x10 ⁶ Btu/hr)	(6.3x10 ⁶ Btu/hr)
VOC ppm, d			189
SO ₂ ppm, w			108
NO _x			212
HCL ppm, w			
VHC			
CO (vppm)	≈100	(<200)	(<200)
CO ₂ (vol. %)	10-12	9.81	9.70
O ₂		8.16	8.26
N ₂		71.49	71.84
H ₂ O		10.54	10.20
			(avg of 3 runs)
Total			49.8
Dioxins (ng/dscm)			
Total			99.0
Furans (ng/dscm)			
Total			
PCB's (ng/dscm)			4253
Lead (μg/dscm)			54
Arsenic (μg/dscm)			267
Cadmium (μg/dscm)			105
Chromium (μg/dscm)			20
Mercury (μg/dscm)			
Opacity	(Ringelmann 1)	9.1%	5.0%

CHAPTER 3

TASK 2 - COMPILE EXISTING AND PROPOSED d-RDF REGULATIONS

INTRODUCTION

The objective of this task is to determine the existing and potential air emission and ash disposal regulations for d-RDF combustion. The information obtained will be summarized and included in this Background Review report and then revised/updated for inclusion in the final project report. Personnel in both Air Quality and Hazardous Waste (solids disposal) groups will have to be contacted. The necessary information is being obtained by phone and mail communication rather than traveling to each State to conserve project funds. Procedures which have been followed to date are summarized below.

All of the seven states' biomass coordinators (listed in Appendix B) have been contacted by phone and follow up letter requesting details of the state regulatory posture regarding air emissions from d-RDF combustion as a substitute for coal in small 5-10 x 10⁶ Btu/hour boilers. Follow up phone calls were made to regulatory agency officials and letters were also sent to some of them. Response has been different from each state, as might be expected, since this is an active field of debate and public concern.

The initial response of state regulatory officials is to classify d-RDF combustion as waste incineration and therefore apply the same stringent regulations that are applied to hazardous waste incineration. This is a normal, conservative response to the introduction of a new combustion technology which has not been widely practiced and proven as safe to the public as coal combustion. The potential for reduced SO₂ emissions using d-RDF versus coal, for example, are generally acknowledged but not given much weight because of concerns about other potentially toxic emissions from d-RDF firing which have not been extensively quantified. A major goal of this program is to gather information on d-RDF combustion and substitute data and knowledge for fear of the unknown.

d-RDF combustion in small industrial boilers as a substitute for, or supplement of coal should be regulated, most logically, according to the guidelines established and planned for coal-firing compliance. The fact that some volume reduction of solid waste will occur in the process, alleviating landfill disposal problems, is a positive, secondary benefit. d-RDF fits in well with recycling/reuse concepts which will continue to grow in significance.

Some work remains to be done to fully define the regulatory stance of each State, and in particular, the ash disposal policies need to be determined (only limited information has been obtained yet regarding solids disposal). An interim compilation of State policies regarding air quality regulations has been made, however, and is presented for review on an individual State basis.

Illinois

The regulatory approach of Illinois is that use of d-RDF fuel in any coal-firing facility would require application for a operating permit from the Division of Air Pollution Control. If the primary use of the d-RDF is to provide an economical fuel source for steam power generation in a boiler, then an argument could be made that it will be a "Fuel Combustion Emission Source" and governed by Section 212.204 - New Sources Using Solid Fuels Exclusively. The particulate emission limit would be 0.1 lbs/10⁶ Btu input (0.15 kg/MW-hr). Criteria pollutants, including particulates, NO_x, SO₂, CO, and total uncombusted hydrocarbon would have to be measured as part of the air permit application.

If it is concluded by the Illinois air quality officials that the source is to be regulated as a modified incinerator, firing less than 1 ton/hour of municipal solid waste (MSW), then the particulate standard limit is 0.2 grains/dscf. A new incinerator under 1 ton/hour must emit less than 0.1 grains/dscf. Below 1 ton/hour of MSW burning, no CO limit is applied. Below 25 tons/day firing of MSW, particulate matter BACT, SO₂, NO_x, CO, acid gas, heavy metals, and organic materials analyzes may not be required, depending on operating permit requirements. However, since Illinois, reportedly, has no d-RDF-fired boilers in operation and no official permit requests have been made to the State EPA, there have been no opportunities for establishment of a State policy precedent regarding d-RDF combustion.

Iowa

The policy of the Iowa Department of Natural Resources (DNR), regarding combustion of waste paper/cardboard pelletized fuel at the 6.7 million Btu/hour output boiler at Dordt College in Sioux Center, has been to require a limit (maximum) of 0.6 lbs. total particulate matter/million Btu heat input (0.6 lb/10⁶ Btu) and a stack gas opacity of 5% or less. Concerns exist, however, about the use of MSE raw material containing plastics for d-RDF pellet burning in small boilers. An operating permit policy is enforced on a case-by-case basis and emissions standards have not been formulated for all other criteria and potentially harmful air pollutants.

Due to the uncertainty regarding the emissions from combustion of pelletized refuse, Iowa DNR is requiring testing for the following air pollutants as part of the air permitting process:

1. Particulates
2. NO_x
3. CO₂
4. HCl, HF

5. CO
6. Metals: As, Ba, Be, Cd, Cr (total), Cr⁺⁶, Cu, Hg, Ni, Pb, Sb, Se, Tl, Zn
7. PCBs
8. Dioxins/Furans
9. Total hydrocarbons

Also required are an ultimate analysis of the fuel and E.P. toxicity analysis of the ash.

Testing requirements for future projects will depend upon the results of the testing currently being planned.

One final guideline mentioned by Iowa officials is that a risk assessment must show that less than one additional cancer death in one million population be incurred from operation of the "new" air pollution source.

State DNR officials including the Governor of Iowa are promoters of the development of d-RDF technology in the state of Iowa. They have taken a cooperative and encouraging stance towards carrying out emissions tests in state facilities.

Several facilities in Iowa are either using d-RDF or conducting test burns for feasibility. Dordt College in Sioux Center has demonstrated particulate compliance while burning 100% d-RDF in their converted natural gas boiler. Sioux Center Community High School is adding particulate control equipment to their gas fired boiler in order to fire d-RDF. Ag Processors of Eagle Grove have conducted a test burn of d-RDF at 5-10% in combination with coal in their industrial boilers.

John Deere of Waterloo, Iowa has also received a conditional permit to test the feasibility of burning d-RDF in two of their coal fired boilers. Permission has been given for a three-week test burn at various percentages of d-RDF in combination with coal.

Indiana

Feedback from Indiana officials has not yet been received but is forthcoming.

Michigan

The state of Michigan requires that a permit be issued by the state Air Pollution Control Commission before any process alteration of fuel-burning equipment is undertaken (R 336.1201, Rule 201).

An outline description of the minimum permit application information required is given by R 336.1203, Rule 203 as follows:

R 336.1203. Information required. (1/18/80)

Rule 203. (1) An application for a permit to install shall include information required by the commission on the application form or by written notice. If considered by the commission to be pertinent to evaluation of the equipment for which a permit is sought, the information shall include, but is not necessarily limited to, the following:

(a) The expected composition of air contaminant stream, both before and after installation of an air-cleaning device, including emission rate, concentration, exhaust gas volume, and exhaust gas temperature.

(b) The expected physical and chemical characteristics of air contaminants.

(c) Details of air pollution control measures and air-cleaning devices, if any, including a description, design parameters, and anticipated performance.

(d) The location and elevation of the emission point and other factors relating to dispersion and diffusion of the contaminant in the outer air; the relation of the emission point to nearby structures and window openings; and other information necessary to appraise the possible effects of the air contaminant.

(e) The method of disposal of wastes resulting from operation of the process equipment or air-cleaning devices.

(f) A plan for reduction of emissions during air pollution alerts, warnings, and emergencies as required by subrule (1) of rule 1307.

(g) Information, in a form prescribed by the commission, that is necessary for the preparation of an environmental impact statement if, in the judgment of the commission, the equipment for which a permit is sought may have a significant effect on the environment.

(h) Data demonstrating the effect of the air contaminant emissions on human health and the environment.

State air pollution regulatory requirements are extremely stringent, being defined as those used for new process or new process equipment firing combustion (e.g., wood and coal) fuel or combination fuel/waste material (regardless of size) as follows:

Particulates	:	<0.001 grains/dscf
SO ₂	:	<3.4 mg/m ³
NO _x	:	<2.0 mg/m ³
CO	:	<20 ppm
CO ₂	:	<1% of total combustion gases
Opacity	:	<3%
HCl	:	<5 mg/m ³
Total dioxins	:	
Total furans	:	
Total PCBs	:	

No d-RDF-firing facilities are in operation or in the process of applying for a permit to operate in Michigan according to state officials. There is concern that d-RDF pellets may contain organic raw materials which may cause the emission of potentially harmful or toxic pollutants. It is felt that baghouse control equipment will be a minimum state requirement for operating facilities. Definition of fuel raw material composition and relationship with emissions is of interest for compliance analysis. Sampling and measurements of emissions from d-RDF combustion would probably be required for the first d-RDF installation in Michigan, although a review of data obtained from tests in other States would be of interest to officials.

Recently, Michigan officials have decided that the burning of fuel using only cardboard as the raw material source must meet a particulate limit of 0.10 lb/1000 lb exhaust gas. The raw material may not include newspapers since there is concern regarding heavy metal components in newsprint ink which may be emitted in flue gases. For bleached (processed) paper raw material combustion, a standard of 0.01 grains/dscf at 12% CO₂ is the particulate emissions limit. Total dioxins, furans, and PCBs are a concern but an actual emissions limit level has not been set.

Minnesota

Current policy is to regulate emissions from a d-RDF fired boiler as if it was a municipal waste incinerator and to require extensive test burn and emissions measurement work to satisfy compliance requirements for operating permit application. Two test burns with emissions tests have been performed at the Northwest Medical Center, Thief River Falls, Minnesota. One test was done in June, 1987 with extensive emissions measurements (reference 12) and one in August 1988 just for particulate emissions compliance (reference 5).

Minnesota Pollution Control Agency officials have been contacted by PES and requested to provide permit application standards for coal boiler firing of d-RDF in small 5-10 x 10⁶ Btu/hour unit. There is reportedly some negative public opinion in Minnesota regarding waste incineration and the regulatory climate, including the state legislature, is inclined toward conservative (very strict) compliance guidelines.

Another requirement is that a risk assessment must show less than one additional cancer death in 100,000 population be incurred from operation of the "new" air pollution source. On this and the bases established in the written Minnesota Air Pollution Control Rules and Standards, it is clear that extensive test burn emission measurements and other compliance studies would be required for larger, e.g., 50-100 x 10⁶ Btu/hour boiler facilities desiring to use d-RDF.

Ohio

Feedback from Ohio officials has not yet been received.

Wisconsin

Wisconsin has had an operating d-RDF-coal cofiring operation ongoing at the University of Wisconsin-Oshkosh (reference 25) for the past two years. At a minimum, a small $5-10 \times 10^6$ Btu/hour boiler would have to meet a particulate limit of 0.15 lbs/ 10^6 Btu input and opacity of 20% (visible). Beyond that, facilities are required to "evaluate," i.e., test for, criteria pollutants which the Wisconsin Department of Natural Resources (DNR) has reason to believe may be a problem.

New rules (Wisconsin NR 445) will be applied on a fairly site-specific basis and therefore generalized guidelines for regulation of d-RDF burning are not immediately available. Meetings among regulatory and technical personnel are scheduled in March 1989 to discuss and develop consensus guidelines. Results of these discussions will be incorporated into the data base of regulations as they become available.

One exemption currently in effect (used by the University of Wisconsin-Oshkosh) is that "a source which combusts refuse derived fuel in a boiler and obtains less than 50% of its heat input from the refuse derived fuel" doesn't have to meet the lowest achievable emission rate (LAER) required of waste incinerators. Raw material for d-RDF used at University of Wisconsin-Oshkosh is industrial waste paper materials free of Cl content, not really municipal waste. This is also considered an "existing" source. All other sources not existing, i.e., in operation burning d-RDF before October 1, 1988, are considered new or modified sources and generally must meet more stringent emissions test requirements than existing sources.

CHAPTER 4

TASK 3 - IDENTIFICATION OF PELLET PRODUCERS

A series of steps were taken to identify d-RDF producers in the region. Initially, as part of the literature gathering process, the people contacted over the phone were asked to identify pellet producers that they had worked with or knew were in operation (or had been in operation). These contacts naturally led to other sources who were also asked to identify producers of d-RDF who were active in the region. After follow-up phone contacts were made and literature was requested and obtained from various people, letters were mailed out to all the state biomass coordinators requesting information on d-RDF producers and/or users who would know of producers in the region. Finally, state air pollution regulatory officials were contacted by phone and letter to solicit permit activity in their states related to d-RDF combustion which could then lead to information regarding local producers of d-RDF.

Illinois

No manufacturers or boiler facility operators are known to be using or considering the use of d-RDF as a fuel supply.

Indiana

No manufacturer or operation involving d-RDF has been reported.

Iowa

Two manufacturing sites are in operation in Iowa. One is E-Z Fuel Ltd. (a subsidiary of Bio-Mass Energy), in Sioux Center and the other is Waste Resource Recycling Company (WRRRC) in Iowa Falls. Both use Lundell Manufacturing Company (Cherokee, Iowa) equipment. The WRRRC has a contract to receive municipal waste for disposal from the local county. The State governor and the Department of Natural Resources are also proponents for the development of the Lundell Manufacturing Company's recycling and fuel pelletizing hardware systems.

Michigan

Presently there are no d-RDF manufacturers or boiler facility operators who are using or considering use of d-RDF as a fuel supply.

Minnesota

Pennington City, Thief River Falls (formerly Future Fuels, Inc.); and Reuter, Inc., Eden Prairie are two d-RDF manufacturers in the State. Waste to energy facilities of all types are listed in the following table (Figure 4.1) from a brochure titled "Decision Maker's Guide to Resource Recovery," prepared by the Minnesota Department of Public Service.

Wisconsin

General Fuels of Neenah, Wisconsin is providing waste paper pellets to the University of Wisconsin-Oshkosh on a routine basis.

Table 4. Waste to Energy Facilities in Minnesota (Status as of April 1988)

Developer/Location	On Line	Type	Size	Market	Construction Cost	Emission Control*
1. Richard's Oil/Shakopee 612/894-8000	1980	Modular	63 tpd	Richard's Oil	\$ 4.5M	C/ESP
2. City of Red Wing 612/388-1402	1982	Modular	72 tpd	S.B. Foot Tannery	3.5M	ESP, WS
3. WLSSD/Duluth 218/722-3336	1985	RDF/Co-incineration	120 tpd	Incinerate sewage sludge	12.0M	C/WS
4. Pennington Cty/Thief River Falls 218/681-3710	1985	dRDF	40 tpd	Various small markets	1.6M	n/a
5. Quadrant, Inc./Perham 218/739-8411	1986	Modular	100 tpd	Land-O-Lakes and Tuffy's Inc.	7.0M	ESP
6. Olmsted County/Rochester 507/285-8231	1987	Mass Burn	200 tpd	Former state hospital complex	27.0M	ESP
7. Pope-Douglas Counties Alexandria 612/762-2381	1987	Modular	70 tpd	3M plant and Douglas County Hospital	6.0M	ESP
8. NSP/Newport 612/337-2256	1987	RDF	900-1200 tpd	NSP		n/a
9. Rueter Inc./Eden Prairie 612/935-6921	1987	dRDF	400 tpd	Various markets	15.0M	n/a
10. Fergus Falls 218/739-2251	1988	Modular	75 tpd	State Hospital	4.5M	WS
11. Polk County/Fosston 218/281-3952	1988	Modular	80 tpd	Land-O-Lakes	6.8M	ESP
12. Winona County/Winona 507/457-6460	1990	Modular	150 tpd	Electric to NSP	19.4M	DS/B
13. Hennepin County/Mpls. 612/333-7303	1989	Mass Burn	1000 tpd	Electric to NSP	120.0M	DS/B
14. Dakota County	?	RDF	600 tpd	undetermined		
15. NSP/Anoka County	1989	RDF	500-1000 tpd	NSP		
16. East Central Solid Waste Comm. 612/358-3635	1989	pre-RDF	250 tpd	WLSSD	2.8M	

* C = Cyclone
 WS = Wet Scrubber
 DS = Dry Scrubber
 B = Fabric Filter
 ESP = Electrostatic Precipitator

Figure 4.1. Excerpted Table from "Decision Maker's Guide to Resource Recovery" by the Minnesota Department of Public Service

CHAPTER 5

TASK 4 - SELECT PELLET PRODUCERS AND TASK 5 - SELECT TEST BURN FACILITIES

TASK 4 - SELECT PELLET PRODUCERS

Pellet producers from Iowa, Minnesota, and Wisconsin have been willing to provide fuel to the program at no charge or for a reasonable fee. The cost and logistics of shipping, however, could not be readily defined within the compressed program time schedule without limiting the supply source to an area close to the planned combustion test site. Although it would be desirable to have a pellet fuel supplied from Minnesota or Wisconsin, no provisions have been made in the contract for shipping arrangements or to pay shipping costs.

All three types of fuel pellets, i.e., two RDF fuels, one containing plastic and one without plastic content, and the pelletized waste paper fuel material can be obtained from E-Z Fuel in Sioux Center and Waste Resource Recycling Company (WRRRC) in Iowa Falls.

Arrangements are being made to obtain and store the 40 ton supplies of each of the three fuel pellet types through those two Iowa-based d-RDF suppliers so that testing may be begun on May 15, 1989.

TASK 5 - SELECT TEST BURN FACILITIES

The Dordt College, Sioux Center Iowa site has been selected as the best available facility to conduct the planned test program. It meets all the specifications for the proposed experiments and is well supported logistically and by regional government and industrial organizations. A pretest site survey visit has been made to Dordt College and the Pretest Survey report and the Site Specific Test Plan are being prepared with the objective of starting the d-RDF combustion emissions measurement program on May 15, 1989.

CHAPTER 6

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APPENDIX A

RESULTS OF FUEL ANALYSES
FROM REFERENCES 5, 11, 12, 1, 17, AND 25

REFERENCE 5

NORTHWEST MEDICAL CENTER TEST
AUGUST 1988
THIEF RIVER FALLS, MINNESOTA

interpoll

INTERPOLL LABORATORIES, INC.
4500 BALL ROAD N.E.
CIRCLE PINES, MINNESOTA 55014-1819
TEL. 612/786-6020
FAX 612/786-7854

Interpoll Laboratories, Inc.
Field Testing Department

Attention: Dr. Perry Lonnes

PROJECT: Future Fuels

LABORATORY REPORT: #6643

September 15, 1988

SAMPLES COLLECTED: August 25, 1988

SAMPLES RECEIVED: August 29, 1988

Laboratory Log No.	Sample Identification	Sample Type	Chlorine, %/w/w ⁽¹⁾
6643-16	Test #1	RDF Pellets	0.16

Respectfully submitted,

Gregg W. Holman,
Inorganic Chemistry Department Manager

GWH/cg

(1) Analysis method: EPA 300.0

All units are on an "as received" basis unless otherwise indicated.

Results of the Proximate Analysis

Sample Identification: RDF Pellets, Test 1

Date Analyzed: September 7, 1988

Parameter	Moisture & Ash Free	Moisture Free	As Received
<u>PROXIMATE ANALYSIS, WT%</u>			
Moisture (Total)			8.06
Ash		6.30	5.79
Volatile Matter	83.71	78.44	72.12
Fixed Carbon (by difference)	16.29	15.26	14.03
Sulfur	0.68	0.64	0.59
Heating Value (BTU/LB)	8,761	8,209	7,547

REFERENCE 11

DORDT COLLEGE PARTICULATE COMPLIANCE TEST
MARCH 1987

Interpoll, Inc.
Fuel Laboratory
(612) 786-6020

Date: 4/10/87

JOB: Van Beek/Dordt College

SAMPLE LOG NO: 4749-16-4219

SAMPLE DESCRIPTION: RDF Run 2 3/31/87

ULTIMATE ANALYSIS WT %

Parameter	Moisture & Ash Free	Moisture Free	As Received
Moisture, Total			11.60
Ash		2.14	1.89
Carbon	49.35	48.29	42.69
Hydrogen	6.31	6.17	5.46
Oxygen (by difference)	43.98	43.05	38.05
Nitrogen	0.14	0.14	0.12
Heating Value, BTU/LB	8,666	8,481	7,497
Sulfur	0.22	0.21	0.19

9044

REFERENCE 12

NORTHWEST MEDICAL CENTER EMISSIONS TEST
JUNE 1987
THIEF RIVER FALLS, MINNESOTA

Interpoll Inc.
Fuel Laboratory
(612) 786-6020

DATE: 4/10/87

JOB:

SAMPLE LOG NO: 4749-15-4218

SAMPLE DESCRIPTION: RDF Run 1 3/31/87

PROXIMATE ANALYSIS WT %

Parameter	Moisture & Ash Free	Moisture Free	as Received
Moisture, Total			12.41
Ash		2.51	2.20)
Volatile Matter	83.39	81.30	71.21
Fixed Carbon (by difference)	16.61	16.19	14.18
Sulfur	0.22	0.21	0.19
Heating Value, BTU/LB	8,460	8,248	7,224

Interpoll Inc.
Fuel Laboratory
(612) 786-6020

DATE: 4/10/87

JOB:

SAMPLE LOG NO: 4749-17-4220

SAMPLE DESCRIPTION: RDF Run 3 3/31/87

PROXIMATE ANALYSIS WT %

Parameter	Moisture & Ash Free	Moisture Free	as Received
Moisture, Total			11.97
Ash		2.06	1.81
Volatile Matter	81.31	79.64	70.11
Fixed Carbon (by difference)	18.69	18.30	16.11
Sulfur	0.25	0.25	0.22
Heating Value, BTU/LB	8,371	8,198	7,217

Interpoll, Inc.
Fuel Laboratory
(612) 786-6020

Date: 4/10/87

JOB:

SAMPLE LOG NO: 4749-16-4219

SAMPLE DESCRIPTION: RDF Run 2 3/31/87

ULTIMATE ANALYSIS WT %

Parameter	Moisture & Ash Free	Moisture Free	as Received
Moisture, Total			11.60
Ash		2.14	1.89
Carbon	49.35	48.29	42.69
Hydrogen	6.31	6.17	5.46
Oxygen (by difference)	43.98	43.05	38.05
Nitrogen	0.14	0.14	0.12
Heating Value, BTU/LB	8,666	8,481	7,497
Sulfur	0.22	0.21	0.19
9044			

REFERENCE 1

WARREN SPRING LABORATORY d-RDF TEST BURN
1987
UNITED KINGDOM

TABLE 1. - Fuel Analysis

Calorific value, Gross as-fired (MJ kg ⁻¹)	20.40
Ash content (%)	14.3
Moisture content (%)	7.0
Volatile matter (%)	69.5
<u>Ultimate Analysis (%)</u>	
Carbon	45.4
Hydrogen	6.2
Oxygen	31.52
Sulphur	0.19
Chlorine	1.11
Lead	0.0051
Cadmium	0.0006

REFERENCE 17

WARREN SPRING LABORATORY FUEL CHARACTERIZATION DATA
1988
UNITED KINGDOM

Tables A7 to A10 present characteristic data available for RDF.

TABLE A7. - Typical RDF Characteristics
(on the as received basis)

	US ^{A4}	UK ^{A5}	WSL RDF ^{A6}
<u>Analysis of RDF</u>			
Bulk Density (kg m^{-3})	128.3 ^a	a	550-600
Heating Value (MJ kg^{-1})	13.05	10.7	19.6
<u>% by weight</u>			
Moisture	23.03	nd	12
Ash	17.37	22.00	17
Volatile Matter	54.65	nd	60
Fixed Carbon	4.94	nd	11
Carbon	30.86	25.4	40
Hydrogen	4.77	3.7	5
Oxygen	22.88	nd	26
Sulphur	0.43	0.3	0.3
Chlorine	0.24	0.6	0.9
Nitrogen	0.42	0.8	0.4
<u>Particle Size</u>			
Mean Diameter, mm	10.7	nd	16
Per cent larger than 63 mm	1.7	nd	0
<u>Analysis of RDF Ash</u> (% by weight)			
SiO ₂	48.19	51.6	47
Al ₂ O ₃	11.75	11.5	22
Fe ₂ O ₃	4.29	4.7	12.5
TiO ₂	1.45	nd	2.2
P ₂ O ₅	0.79	nd	2.1
CaO	12.71	14.9	7.6
MgO	2.38	0.3	1.9
Na ₂ O	4.3	5.7	2.8
K ₂ O	1.80	1.9	2.3
Cl	nd	nd	0.09
S	nd	nd	0.89
Pb (ppm)	nd	983	800

a = not densified
nd = not determined

REFERENCE 25

UNIVERSITY OF WISCONSIN-OSKOSH TEST
1987

IS TESTING inc.

1301 NORTH THIRD STREET ■ SUPERIOR, WISCONSIN 54880 ■ (715) 392-7114

OCT 22 1987

CAW

DATE RECEIVED: 10/09/87
DATE TESTED: 10/12/87

UW - OSH KOSH
OSH KOSH
WISCONSIN 54901

SAMPLE LOG NO:
SAMPLE DESIGNATION:

1853-87C
PELLETIZED FUEL ANALYSIS #63

PROXIMATE ANALYSIS WT. %

	MOISTURE & ASH FREE	MOISTURE FREE	AS RECEIVED
MOISTURE TOTAL			2.82
ASH		3.18	3.09
VOLATILE MATTER		92.10	89.50
FIXED CARBON BY DIFFERENCE		4.71	4.59
SULFUR		0.07	0.07
HEATING VALUE BTU/LB	9471	9170	8912

DENSITY (lb/ft³)

ASH FUSION:

INITIAL DEFORMATION
SOFTENING SPHERICAL
SOFTENING HEMISPHERICAL
FLUID

PREPARED BY:

Linda Tallberg

DATE:

10/21/87

MATERIALS TESTING ■ CHEMICAL ANALYSES

One (1) Fuel Sample
Received June 9, 1986

Our Report No. B-86091
Issued June 20, 1986
Phone Confirmation

GENERAL FUELS
P.O. Box 732
Neenah, WI 54956

Att'n: Mr. Scott Fleming

Request: Ultimate analysis and BTU determination of the above sample.

Results:

Ultimate Analysis:

	<u>As Rec'd</u>	<u>Dry Basis</u>
% Moisture	5.86	---
% Carbon	51.38	54.58
% Hydrogen	7.79	8.28
% Nitrogen	0.72	0.77
% Chlorine	0.01	0.01
% Sulfur	0.07	0.07
% Ash	5.07	5.39
% Oxygen (diff.)	29.10	30.91
 <u>BTU/lb.:</u>	 9966	 10586

Note: Analysis performed for Badger Labs by a cooperating laboratory.

BADGER LABORATORIES & ENGINEERING

Thomas R. Schmidt

Thomas R. Schmidt
Lab Analyst

TRS:mv

BADGER LABORATORIES & ENGINEERING INC

1110 S. ONEIDA STREET • APPLETON, WISCONSIN 54915 • (414) 739-8213
TOLL FREE PHONE IN WISCONSIN 1-800-242-3556

One (1) Sample
Received July 7, 1986

Our Report No. 162504
Issued July 11, 1986
Phone Confirmation

GENERAL FUELS
P.O. Box 732
Neenah, WI 54956

Att'n: Mr. Scott Fleming

Request: Analyze the above sample for the methods listed below.

Results:

Pressed Papers Fuel

Arsenic, Total	<0.1 ppm.
Beryllium, Total	<0.2 ppm.
Cadmium, Total	<0.1 ppm.
Chromium, Total	31.6 ppm.
Lead, Total	2.3 ppm.
Mercury, Total	<0.1 ppm.
Nickel, Total	0.8 ppm.
Zinc, Total	49.6 ppm.

Method: Test Methods for Evaluating Solid Waste, EPA, 1982, SW-846.

BADGER LABORATORIES & ENGINEERING

Stephen C. Taylor
Chief Chemist

SCT:mw

BADGER LABORATORIES & ENGINEERING CO. INC.

1110 S. ONEIDA STREET • APPLETON, WISCONSIN 54915 • (414) 739-8213

TOLL FREE PHONE IN WISCONSIN 1-800-242-3556

One (1) Fuel Sample
Received May 22, 1986

Our Report No. B-86082
Issued May 28, 1986
Phone Confirmation

GENERAL FUELS
P.O. Box 732
Neenah, WI 54956

Att'n: Mr. Scott Fleming

Request: Analyze the above sample for the parameters listed below.

Results:

Moisture, %	2.6
Ash, %	6.3
Sulfur, %	< 0.05
Chlorine, %	0.08
BTU/lb. - as received	14382
BTU/lb. - dry basis	14766

BADGER LABORATORIES & ENGINEERING

Tom Schmidt

Thomas R. Schmidt
Lab Analyst

hj

TRS:HW

APPENDIX B

GREAT LAKES STATES'
BIOMASS COORDINATORS

**GREAT LAKES REGIONAL BIOMASS ENERGY PROGRAM
STATE BIOMASS COORDINATORS**

David Loos
Illinois Department of Energy and Natural Resources
325 West Adams, 3rd Floor
Springfield, IL 62706
(217) 785-3969

Narv Somdahl
Minnesota Department of Public Service
150 East Kellogg Boulevard
St. Paul, MN 55101
(612) 297-2117

Bob Berlin
Division of Energy Policy
Indiana Department of Commerce
One North Capitol
Indianapolis, IN 46204
(317) 232-8961

Claude Eggleton
Division of Energy & Water
Ohio Public Utilities Commission
180 East Broad Street, 6th Floor
Columbus, OH 43215
(614) 466-7707

Kitty Sibold
Energy & Geological Resources Division
Iowa Department of Natural Resources
Wallace Building
Corner of East 9th and Grand
Des Moines, IA 50319
(515) 281-6486

Dan Moran
Wisconsin Division of State Energy
Post Office Box 7868
Madison, WI 53707
(608) 266-1067

Tom Stanton
Michigan Public Service Commission
Post Office Box 30221
6545 Mercantile Way
Lansing, MI 48910
(517) 334-6264

END

DATE FILMED

11 / 07 / 90

SiO ₂	48.12
Al ₂ O ₃	11.75
Fe ₂ O ₃	4.29
TiO ₂	1.45
P ₂ O ₅	0.79
CaO	12.71
MgO	2.38
Na ₂ O	4.3
K ₂ O	1.80
Cl	nd
S	nd
Pb (ppm)	nd

a = not densified
nd = not determined