WMU POWER GENERATION STUDY

TASK 2.0 CORN COB CO-COMBUSTION STUDY

FINAL REPORT

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Contents

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Executive Summary

Much attention has been focused on renewable energy use in large-scale utilities and very small scale distributed energy systems. However, there is little information available regarding renewable energy options for midscale municipal utilities. The Willmar Municipal Utilities Corn Cob-Coal Co-Combustion Project was initiated to investigate opportunities available for small to midscale municipal utilities to "go green". The overall goal of the Project was to understand the current renewable energy research and energy efficiency projects that are or have been implemented at both larger and smaller scale and determine the applicability to midscale municipal utilities. More specific objectives for Task 2.0 of this project were to determine the technical feasibility of co-combusting corn cobs with coal in the existing WMU boiler, and to identify any regulatory issues that might need to be addressed if WMU were to obtain a significant portion of its heat from such co-combustion. This report addresses the issues as laid out in the study proposal.

The study investigated the feasibility of and demonstrated the technical effectiveness of co-combusting corn cobs with coal in the Willmar Municipal Utilities stoker boiler steam generation power plant. The results of the WMU Co-Combustion Project will serve as a model for other midscale utilities who wish to use corn cobs to generate renewable electrical energy. As a result of the Co-Combustion Project, the WMU plans to upgrade their stoker boiler to accept whole corn cobs as well as other types of biomass, while still allowing the fuel delivery system to use 100% coal as needed. Benefits of co-combustion will include: energy security, reduced Hg and CO2 air emissions, improved ash chemistry, potential future carbon credit sales, an immediate positive effect on the local economy, and positive attention focused on the WMU and the City of Willmar.

The first step in the study was to complete a feasibility analysis. The feasibility analysis anticipated only positive results from the combustion of corn cobs with coal in the WMU power plant boiler, and therefore recommended that the project proceed.

The study proceeded with a review of the existing WMU Power Plant configuration; cob fuel analyses; an application for an Air Quality Permit from the Minnesota Pollution Control Agency to conduct the co-combustion test burns; identification of and a site visit to a similar facility in Iowa; an evaluation of cob grinding machines; and agreements with a corn grower, a cob harvester, and the City of Willmar to procure, harvest, and store cobs.

The WMU power plant staff constructed a temporary cob feed system whereby the cobs could be injected into the #3 Boiler firebox, at rates up to 40% of the boiler total heat input. Test burns were conducted, during which air emissions were monitored and fuel and ash samples analyzed.

The results of the test burns indicated that the monitored flue gas quality improved slightly during the test burns. The WMU was able to determine that modifications to the #3 Boiler fuel feed system to accept corn cobs on a permanent basis would be technically feasible and would enable the WMU to generate electricity from renewable fuels on a dispatchable basis.

INTRODUCTION

Increasingly the United States (US) has grown concerned about the continued use of fossil fuels and their potential effect on the atmosphere and climate through emissions of CO_2. The State of Minnesóta has pledged to decrease CO_2 emissions by enacting the Minnesota Renewable Portfolio Standard (RPS). The RPS requires that 25% of the state's electricity comes from renewable power sources by 2025. Currently, half of Minnesota's power is coal-generated, and renewables account for only about 5%. The potential to utilize biomass materials to derive electricity is higher than it has ever been.

In an effort to support the RPS, Willmar Municipal Utilities (WMU) has undertaken an initiative to understand the current renewable energy research and energy efficiency projects that are or have been implemented at both larger and smaller scale and determine the applicability to midscale municipal utilities. The overall project goals are to investigate opportunities available for small to midscale municipal utilities to "go green". Specific objectives for the Co-Combustion Study were to evaluate and demonstrate the feasibility of co-combustion of coal with corn cobs as a means to reduce fossil fuel use at its power generation facility in Willmar. The use of corn cobs as a fuel was chosen for several reasons: corn cobs contain on average as much as 75% of the heat content of the subbituminous coal which is currently being combusted at WMU; the local agronomy supports a large corn production industry which can provide the necessary supply of cobs that may be required; and the cob has historically been the least valued portion of the corn plant - the recalcitrant nature of the lignin content of the cob (1) requires fertilizer to be utilized to degrade the cob in the soil .

SECTION I

Sub-Task 2.1 Feasibility Analysis

Evaluation of the Suitability of Corn Cobs as Coal Co-Combustion Fuel

Listed in Table 1 are typical ranges for heat content in corn cobs relative to moisture and coal of various ranks. The range of heat content in the coal reflects differences in moisture and ash content and variability of coal quality in mines and seams within the mine. Typical as-received Powder River Basin (PRB) subbituminous coal is approximately 8,800 Btu/lb and it can be seen that at a moisture content of 15% moisture by weight, the corn cob has approximately 75% of the heating value of the PRB coal. For biomass fuel types, this is at the upper end of heat content of available fuels and is quite acceptable.

Physical Aspects of Corn Cobs

Corn cob moisture content can have a large effect on storage of the cob with degradation of the cob due to mold or rot and increased moisture having a deleterious effect on the heat evolved during combustion. Corn cob moisture typically reduces in the field from pre-harvest levels of as much as 75% to late harvest levels as low as 15%. When kernel moisture is ~30%, cob moisture is ~60%; when kernel moisture is ~15%, cob moisture is ~15-25% and this is variety dependent (2). Cob size varies by variety and can be up to 10 to 12 inches in length and 1 to 3 inches in diameter. The bulk density of the cobs was presumed to run approximately 10 lbs/ft^3 (3) as whole cobs in bulk, and when size reduced for firing in combustion systems can be as high as 21 lbs/ft^3 (4). Specific sizing was a factor of the equipment used for delivery to the combustion system.

Table 1. Comparison of heat content of corn cobs and coals.

Heat Content of Corn Cobs and Various Coals			
Corn Cobs			
	Moisture Content	Btu/lb	Source
	0.00%	7911	AURI
	7.12%	7369	AURI
	14.24%	6827	extrapolation
	21.36%	6285	extrapolation
Coal			
	Lignite	4500-8500	various literature sources
	Subbituminous	8500-11000	various literature sources
	Bituminous	10500-15000	various literature sources
	Anthracite	11000-14000	various literature sources

WMU Fuel Volume Requirements

In the year 2007 WMU utilized on average, approximately 132 tons per day (tpd) of coal. It was assumed that corn cobs delivered to the plant would have an average heat content equal to 75% of the coal and that the target heat replacement at the plant would be 20% of the coal input. Corn cobs required by WMU would thus be 36 tpd or 14,000 tons per year (tpy), at a cob moisture content of approximately 15%. Cob yield per acre will vary with corn variety and moisture content and was assumed to range from 9 to 14 lbs of cob per bushel of corn kernel (2). According to the National Agricultural Statistics Service 2006 data for Kandiyohi County, the average yield of corn was 160 bushels per acre, equating to 0.72-1.1 tons cob/acre using the assumed yields. This equates to 17,600 acres of corn grown to supply the needed amount of corn cobs to replace 20% of the current heat requirement in the WMU boiler assuming a corn Btu value at 75% of coal, 160 bushels of corn per acre, and 0.72 tons per acre of cobs. In Kandiyohi County in 2006, the National Agricultural Statistics Service states that 140,000 acres were planted to grain corn. Nominally, 17,600 acres equates to 13% of the total acreage planted to corn and would appear to be an achievable and sustainable amount of land and material.

Harvest

There are currently several systems that are under development for corn cob harvesting –the two that are currently commercially available are the Stukenholtz system and the Vermeer "Cob Caddy®". Both systems are designed to operate simultaneously with traditional methods of corn harvest. Detailed descriptions of the systems can be obtained elsewhere (1 and 1.5) but are illustrated in Figures 1 and 2. The Stukenholtz system utilizes mechanical components added on to an existing harvester, consisting of a "CleanBoot®" to separate the cobs from the chaff and a hopper tank or "TopTank®" on top of the harvester to receive the cobs. The system is sized to hold an amount of cob material equal to approximately 80% of the hopper capacity of a large commercial harvester and when full, takes less than a minute to unload. By comparison, the Cob Caddy is a pull behind wagon that receives the cobs via a belt system positioned beneath the rear discharge of the corn combine. The Cob Caddy is self powered by a 100 hp engine that can dump a full wagon of cobs, 4 to 5 tons in less than a minute by hydraulically lifting the box and tilting it over a truck or trailer.

Figure 1. Stukenholtz cob harvester (1)

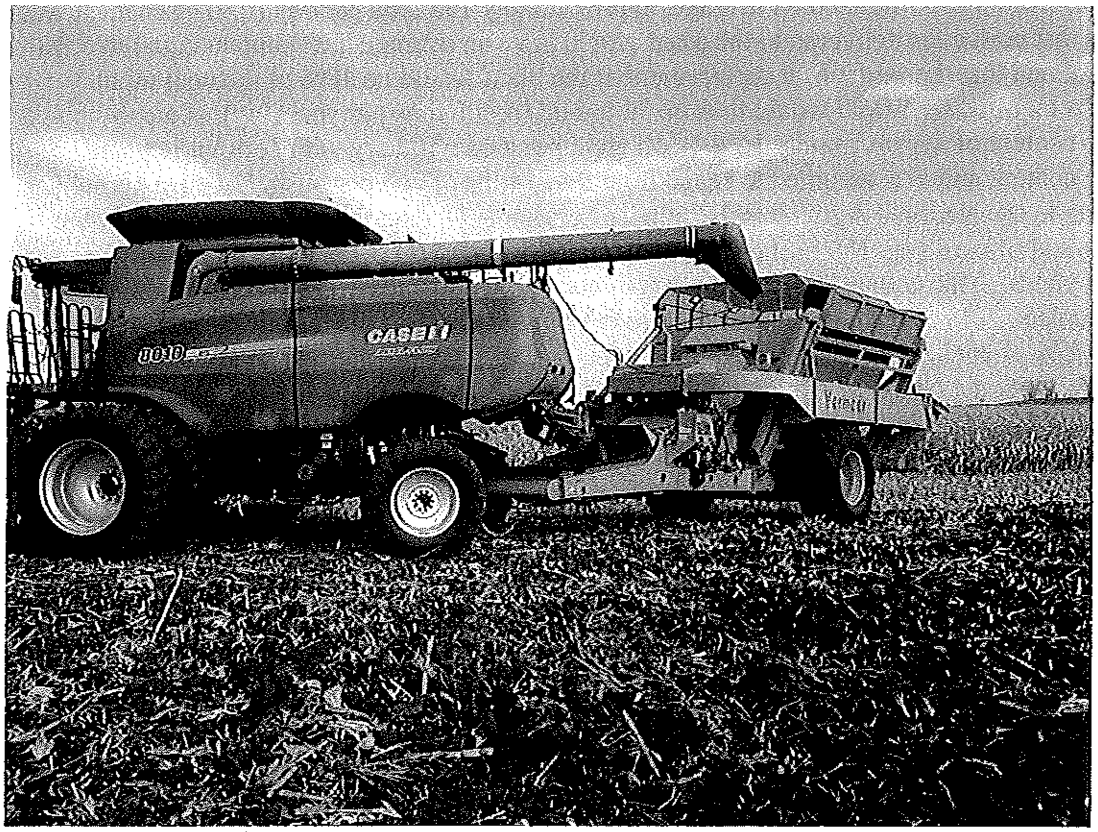


Figure 2. Cob Caddy harvest system

The most desirable cob harvest locations are those that minimize the cost to transport the cobs to the WMU selected storage location(s). In order to minimize the cost of hauling the cobs to storage, the harvest locations needed to be as near as possible to the storage location(s). In order to minimize the cost of hauling the cobs to the power plant, the storage location(s) should be as near as possible to the WMU power plant. Therefore, the most desirable harvest locations were those nearest to both the storage location and the power plant.

Storage

Cob storage requirements are dependent on the size of the material being stored. If the material were to be stored as whole cobs, a large volume of storage would be required. For the study a density of 7lb/ft^3 was assumed; thus 4,000,000 ft^3 was calculated to be required to store the 14,000 tpy that would be used by WMU given the above-described assumptions. If the cobs were sized prior to storage such that the density was doubled from that of whole cobs, the storage volume would be halved and if we assumed further sizing to that reported by others (4) the storage volume required would be even less.

Storage options included on the farm in the field, on the farm not in the field, a distributed collection point or points not on the farm, and on the power plant site. On the farm in the field storage would seem reasonable if each 160 acre field yielded a maximum of about 116 tons of cobs. At 7 pounds per cubic foot, assuming a 15 foot rectangular pile height, approximately 0.057 acre (50' x 50') would be required to store the cobs from each quarter section field. On the farm not in the field storage is probably also achievable on a typical Kandiyohi Co. farm with 320 acres in corn, assuming the above conditions, resulting in a storage requirement of 0.11 acre, or about 5000 sf.

Outlying distributed collection points such as local grain elevators or purpose-built piling stations such as used by sugar beet processors might also be an option but would add additional cost of storage to be paid to the elevator or landowner. Offsetting the additional cost of storage would be expected lower per-ton costs for the cobs due to lower producer transportation costs. The number and size of potential piling stations would depend on negotiated contracts for cobs and the number and location of the field's proximity to such storage sites.

Storage of the entire volume of cobs, approximately 6 acres required for 20% of one year's total power plant production, is not available at the power plant site but WMU could potentially provide as much as one acre on site to serve as a staging area prior to loading into the power plant.

The most desirable storage location(s) are those that provide secure storage and adequate truck access, at a low cost, nearest the power plant. With respect to the 2008/2009 pilot study, a single collection point to store the volume required for the study was made available at the former city airport site. With regard to potential longer-term larger-volume use and storage of cob material, the City of Willmar would likely provide a storage area on the western end of the former airport property at a favorable rental rate.

<u>Transportation Options</u>

To Storage

The corn cob producer(s) could use their own trucks to haul cobs at the time of harvest, directly to on-farm or off-farm storage or directly to the WMU power plant, but many producers may not have enough trucks available to haul cobs in addition to their kernel corn. In that event, harvest would be slowed. One option would be to dump the cobs on the ground in the field, then scoop and load them into grain trucks as time allowed.

A second option would be to use a contract hauler. A contract hauler using multiple live bottom trailers capable of hauling approximately twenty tons of cobs each would likely be sufficient to keep up with hauling from harvest location to storage location; the number of truck-trailer combinations would depend on distance.

To the WMU Power Plant

From Field

Hauling cobs from the field to the WMU power plant by the producer would likely not be a good option for the WMU pilot project due to lack of storage space at the power plant. The producer likely wouldn't be allowed to haul directly to load into the power plant fuel delivery system for immediate combustion due to fuel in-loading constraints. In addition there remains unresolved on-site ash storage permitting issues. A contract hauler would face the same issues as the producer in hauling directly to the power plant from the field.

From Storage

The WMU could potentially haul cobs from off-site storage to the power plant for the duration of the pilot project since the requirements of time and tonnage would be limited. However, use of a contract hauler may be the best option even for the pilot project since, if the pilot project is successful and the amount of cob combustion grows, WMU may not then wish to haul cobs on a constant daily basis as would be required if the power plant was to combust as much as 14,000 tpy of cobs.

Permitting Requirements

Harvest

There are no permits required to harvest corn cobs at this time. The US EPA is in the process of determining whether cobs used for off-farm purposes will be considered a "waste" product and thus subject to federal and state waste rules. The Minnesota Pollution Control Agency (MPCA) is waiting for the EPA decision, but did proceed with the Air Quality permitting process regardless.

Transport

If the WMU decided to use a contract hauler then the hauler would be responsible to obtain all required permits and licenses.

Storage

The City of Willmar allowed cob storage at the old Willmar Municipal Airport on a former taxiway for the duration of the pilot project – no permit required, no fee charged.

Combustion

Based on conversations with MPCA Air Quality personnel, it appeared certain that WMU could obtain permitting for co-combustion of corn cobs with coal, with the cobs adding an unspecified percentage to the heat currently supplied by coal. However, efforts to determine the specific steps required to obtain the permits required lengthy and numerous discussions and decisions that involved additional outside consultants and concerned the WMU's desire to increase the tonnage of permitted coal usage in the WMU Air Quality Permit. Air Quality permitting for coal combustion is outside the scope of this Phase 1.1 activity and is being addressed separately from this report.

Ash Disposal

Current ash disposal involves removal of ash by local agriculture entities for use in soil stabilization at livestock feedlots. Corn cob co-combustion with coal decreases the amount of ash produced on a Btu basis. The cob ash content was estimated to equal less than 25% of PRB subbituminous coals. Handling less ash reduces cost. A lesser volume of ash reduces potential disposal problems. The chemistry of the corn cob/coal ash was not expected to be deleterious to current ash disposal applications and therefore no additional regulatory action was expected.

Current Power Plant Characteristics

PCi Management and Consulting Company was contracted by WMU to evaluate the available options and design a permanent system for feeding corn cobs into the boiler and to design all necessary modifications to plant equipment. As such the feasibility report did not review the power plant design and options for feeding corn cobs into the boiler on a permanent basis.

Cofiring Biomass Tests in the Literature

Several biomass co-firing tests have been reported in the literature for large scale power generation facilities (5 – 11). Results from these tests indicate that nominal modifications to the feed systems were all that was required for successful replacement of coal feedstock with biomass. Most large scale power generation facilities utilize a small size pulverized material as the fuel, unlike WMU which fires chunk coal onto a grate. The grate system and feeders designed for lump coal are quite suitable to firing chunked corn cobs and as such the cobs required only minimal sizing. In a study by J-L Lin et al, on the combustion characteristics of corn cobs in fluid bed combustions systems, the authors showed that corn cob combustion was very reproducible, similar to coal combustion in fluid beds and well described by traditional boundary layer diffusion (BLD) theory (13). Work by Morey and Morey et al have shown the practicality of utilizing corn cobs to produce hot air for corn drying applications (14) (15). Riggins et al have also looked at the use of corn cobs for drying applications (16). However no information was found on cofiring of corn cobs with coal in a combustion process utilizing a grate system. The work of Lin et al (13) is encouraging in that in fluid bed combustion systems, corn cobs behaved very similar to coal. Grate systems, such as the system at WMU, are more like fluid beds than pulverized coal combustion (PC) systems which means the combustion characteristics on the grate should provide few unexpected results. However, this work had not previously been performed and it was essential to get actual test results from the system to be used - WMU in this case - from which to make decisions and judgments. Questions remained as to the effect of the inorganic fraction of the corn cobs on ash formation and subsequent fouling and slagging issues which are discussed below.

Chemical Characteristics of Corn Cobs with Respect to Use as a Fuel

Coal and biomass can be very different fuels compositionally speaking, with respect to the ash or inorganic content. Biomass fuels tend to have lower sulfur, fuel nitrogen, inorganic content and fixed carbon than coals and will usually have more oxygen. The additional oxygen has the effect of lowering the heat content of the biomass. While the ash content of biomass will generally be lower than coal, the composition of that ash material can be significant in its propensity to initiate and build strength in any ash deposits that may occur in a boiler. The elements of particular concern are the alkali and alkaline earth elements such as sodium and potassium and calcium and magnesium along with chlorine. The alkali alkaline earth elements tend to flux silicate materials that can be found in coal ash lowering their melting temperature allowing them to form deposits more readily in a boiler and once formed, to gain strength and become harder to remove from the heat transfer surfaces. Chlorine can behave badly by forming complexes with the alkali and sulfur in coal and can cause corrosion problems. Table 2 illustrates a Proximate/Ultimate analysis for corn cobs (12) and Table 3 shows the same for a PRB subbituminous coal (Black Thunder).

Table 2. Proximate Ultimate analysis of corn cobs (12)

Ultimate analysis (wt% daf)					**Proximate analysis (wt% ad)**			
C	**H**	**N**	**S**	**O***	**Moisture**	**Ash**	**Volatile**	**Fix-carbon**
* 47.63	4.91	0.84	0.14	46.48	3.64	1.53	77.67	17.16
** 46.94	4.83	0.38	0.06	44.13	2.21	1.25	80	18.5

* Reference 12

** Reference 13

Table 3. Proximate Ultimate analysis of PRB subbituminous coal (Black Thunder)

Ultimate analysis (wt% daf)					**Proximate analysis (wt% ad)**			
C	**H**	**N**	**S**	**O***	**Moisture**	**Ash**	**Volatile**	**Fix-carbon**
50.71	6.85	0.73	0.38	36.69	27	4.62	33.55	34.81

At the time of the feasibility analysis, laboratory data was not available indicating the distribution of the inorganic or ash material in the corn cobs. At the time of completion of the feasibility report, two half-bushel batches of cob material – one from Nebraska in 2007 and one from Texas in 2008 – were undergoing analysis at a contract laboratory (Minnesota Valley Testing Laboratories of Bismarck, ND) for the above constituents plus bulk ash chemistry and cob bulk density. However, based on the information available, it was predicted that the sulfur emission would decline because of replacement of a higher (relatively) sulfur fuel of coal with a lower sulfur level fuel of cobs. Nitrogen oxide emissions were expected to be lower even thought the analyses show higher nitrogen content in the fuel. It has been shown that higher levels of volatiles in biomass materials can have the effect of lowering NO_x emission levels through well established stoichiometric means. The lower ash content will obviously reduce the amount of ash generated overall. However, because ash generated using biomass and biomass co-firing is not regulated by the American Institute of Standards for use as a replacement for cement, this ash may be less saleable than current ash material.

SECTION II

Sub-Task 2.2 Implementation Plan, Sub-Task 2.3 Acquisition, and Sub-Task 2.4 Construction of Corn Cob Co-Combustion Facilities

The objectives of Subtasks 2.2, 2.3, and 2.4 addressed in this report were 1) to review the feasibility of available options for co-firing of corn cobs at WMU, 2) to develop an implementation plan for co-firing including permitting, 3) completion of a plan for the acquisition of corn cobs for co-combustion, and 4) the design and construction of loading, storage, and fuel delivery systems. The following sections describe the results of the Subtasks 2.3 – 2.4 activities.

A. Feasibility Review

Current Power Plant Configuration

The current power production facility exists as depicted in Figure 1 on the page following. Coal is fed to the #3 Boiler – #3 is currently the only coal-fired boiler and thus was selected for the co-combustion study - through a series of Detroit Stoker Roto-Grate feeders (indicated as a coal hopper on Figure 1). It can be seen in Figure 2 that the coal is gravity fed to the Roto feeders from above through a concave distributer system. The Roto feeders throw the coal feed to the back of the furnace traveling grate system and combustion occurs as the grate travels toward the feeders. Just below the feeders are doors for access to the end of the grate. Ash falls off the grate through to the lower level of the building to a collection system.

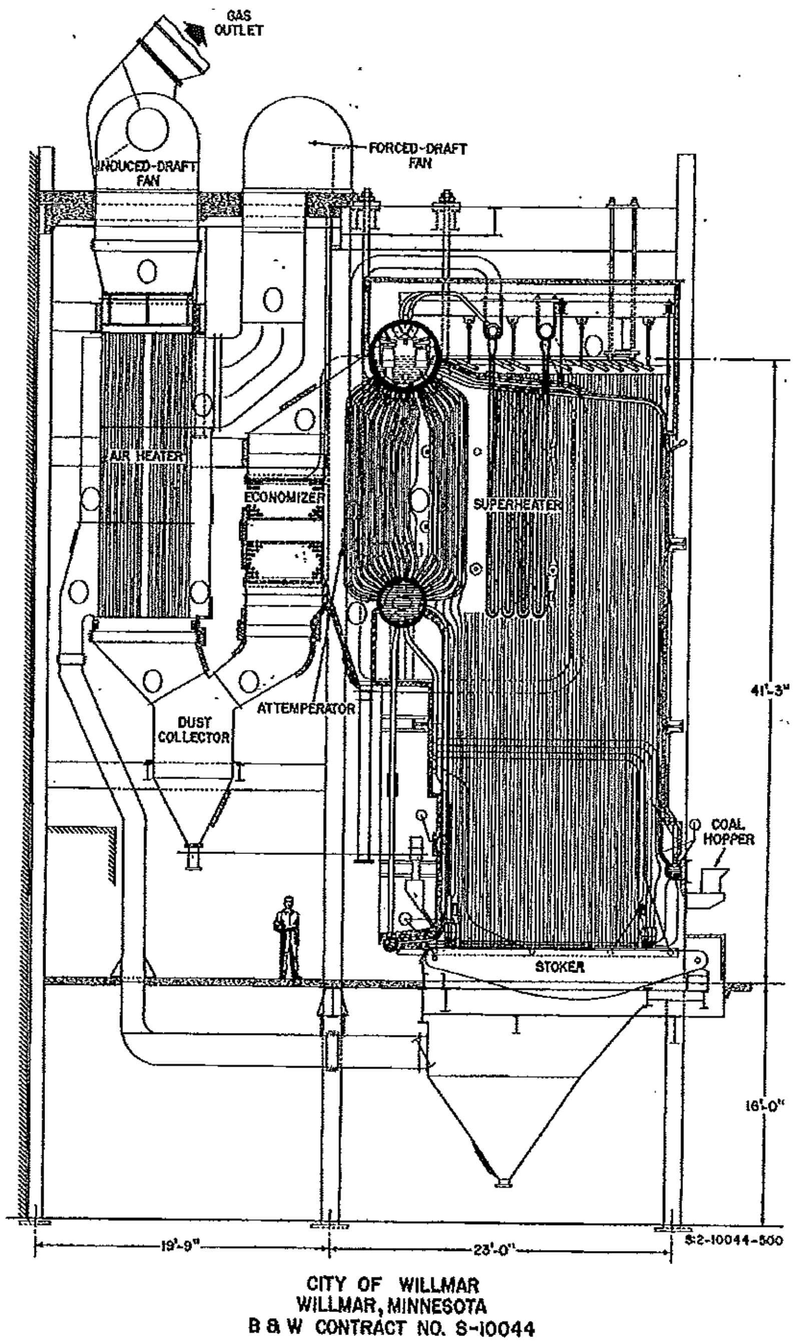


Figure 1 Cross-section sketch of WMU Boiler #3.

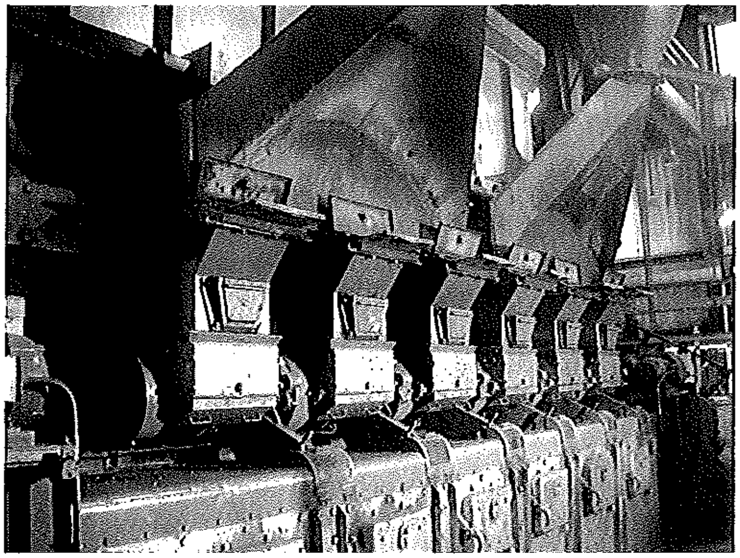


Figure 2a Photo of the WMU Detroit Stoker Roto Grate Feeders.

In December of 2008, WMU, FCI, and PCi personnel traveled to Pella, IA to observe a corn cob-coal co-combustion test run at the Pella Municipal Electric Utility. The Pella Utility mixed coal and ground corn cobs at the point of loading onto a conveyor belt that fed the fuel into hoppers above the boilers. From that point, the fuel feed system was very similar to WMU.

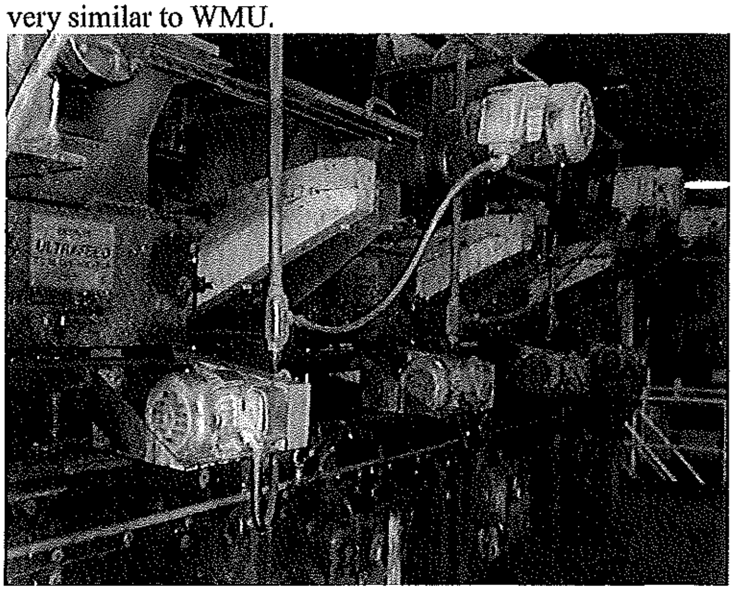


Figure 2b Photo of the Pella Detroit Stoker Feeders

The Pella test burned cob material in a ratio of approximately 5-10% cob-to-coal, by weight. The fuel mixing system was successful in delivering the desired amount of cobs to the plant, but the cob material segregated on the belts and in the hopper and as a result only one of the Pella boilers received all of the cobs. The cob material had been ground to a size approximately two inches and minus and the mix was observed to be uniformly distributed across the furnace grate. Both the coal and the cob material burned completely to ash without any apparent adverse effects and the test was considered successful. PCi prepared Meeting Notes for the visit; a copy of the document is included in Appendix B.

Based on the observations made at the Pella Utility, it seemed apparent that a stoker type fuel feed system would be suitable to feed corn cob material with coal into a traveling grate furnace of the type used by the WMU. However, fuel segregation problems were observed which made it seem likely that the same problems would occur if WMU attempted to mix cob material with coal in the WMU coal silo.

WMU Fuel Analysis

Corn cob and coal analyses were performed to determine potential corn cob/coal fuel mixture ranges, as well as possible interactions of the ash produced by the two fuels that could lead to bed agglomeration, fouling and slagging within the boiler and potential harmful emissions. Tables 1 through 5 below compare the Proximate/Ultimate and Trace Element analyses of selected samples of PRB coal and cobs from three locations. Three things of significance should be noted from the Prox/Ult analyses. 1) The ash from the cobs equals just 13% of the ash from the coal. This much smaller volume of ash will have the tendency to reduce any detrimental effects caused by interaction between the coal and cob ash, such as reducing viscosity of the ash which will make the ash stickier and more likely to cause or exacerbate bed agglomeration and fouling and slagging of heat transfer surfaces. 2) The moisture content of the cobs analyzed was significantly higher than the coal which will have the effect of lowering the heat content of the cobs to much less than that of the coal, as illustrated in the Tables below. This in turn means the volume of cobs will need to be considerably greater than that of the coal for the same heating value. 3) The density of the cobs is approximately 20-25% of the coal which further increases the volume of cobs that must be combusted to achieve the same heating value.

Throughput of cobs to the furnace for any significant amount of heat replacement was evaluated in the test burns to ensure that the required volume of cobs required could be handled by the furnace and by the fuel feeding equipment. Additionally, it should be noted that the inorganic constituents nitrogen, sulfur, and mercury, are found in much lower concentrations in the cobs compared with the coal. This implies that on a strictly heat replacement basis, the cobs should have fewer emissions of concern. The ash chemistry presented in Table 5 shows the Willmar cob sample to be higher in phosphorus and lower in silica, sulfur and potassium. However, the effect on ash chemistry in the boiler was expected to be minimal due to the dramatically lower ash content of the cobs when compared to the coal.

Table 1. Prox/Ult and Trace Element Analysis of WMU composite coal sample 4-1-09

WMU Composite Coal sample 4/1/09		
Proximate Analysis		
	As Recv'd (wt%)	Dry Basis (wt%)
Total Moisture	28.12	
Ash	9.3	12.94
Volatile Matter	26.54	36.92
Fixed Carbon	36.04	50.14
Total Sulfur	0.87	1.21
BTU/lb	8334	11594
Ultimate Analysis		
Carbon	48.77	67.85
Hydrogen	6.53	4.71
Ash	9.3	12.94
Nitrogen	0.77	1.07
Oxygen	33.76	12.22
Sulfur	0.87	1.21
Trace Element Analysis (ug/g)		
Mercury	0.079	0.11

Table 2. Prox/Ult and Trace Element Analysis of WMU composite cob sample 4-1-09

WMU Composite Cob sample 4/1/09		
Proximate Analysis		
	As Recv'd (wt%)	Dry Basis (wt%)
Total Moisture	46.72	
Ash	1.23	2.31
Volatile Matter	42.31	79.41
Fixed Carbon	9.74	18.28
Total Sulfur	0.03	0.06
BTU/lb	4167	7821
Ultimate Analysis		
Carbon	23.65	44.39
Hydrogen	8.2	5.58
Ash	1.23	2.31
Nitrogen	<0.02	<0.38
Oxygen	66.69	47.29
Sulfur	0.03	0.06
Trace Element Analysis (ug/g)		
Mercury	< 0.02	NA

Table 3. Prox/Ult and Trace Element Analysis of Nebraska cob sample 8-21-08

Nebraska Cob sample 8/21/08		
Proximate Analysis		
	As Recv'd (wt%)	Dry Basis (wt%)
Total Moisture	10.42	
Ash	1.52	1.7
Volatile Matter	71.66	80
Fixed Carbon	16.44	18.31
Total Sulfur	0.11	0.12
BTU/lb	7078	7901
Ultimate Analysis		
Carbon	39.99	44.64
Hydrogen	6.44	5.89
Ash	1.52	1.7
Nitrogen	0.61	0.68
Oxygen	51.33	46.97
Sulfur	0.11	0.12
Trace Element Analysis (ug/g)		
Mercury	< 0.02	NA

Table 4. Table 3. Prox/Ult and Trace Element Analysis of Texas cob sample 8-21-08

Texas Cob sample 8/21/08		
Proximate Analysis		
	As Recv'd (wt%)	Dry Basis (wt%)
Total Moisture	23.99	
Ash	0.88	1.16
Volatile Matter	62.19	81.82
Fixed Carbon	12.94	17.02
Total Sulfur	0.05	0.07
BTU/lb	5852	7699
Ultimate Analysis		
Carbon	33.98	44.7
Hydrogen	7.09	5.8
Ash	0.88	1.16
Nitrogen	0.31	0.41
Oxygen	57.69	47.87
Sulfur	0.05	0.07
Trace Element Analysis (ug/g)		
Mercury	< 0.02	0.026

Table 5. Comparison of Cob Ash Analyses and Bulk Densities

Cob Ash Analysis (wt%)	Willmar	Texas	Nebraska
Silicon Oxide	33.08	41.9	39.77
Aluminum Oxide	0.88	0.67	1.82
Titanium Oxide	0.09	0.04	0.08
Iron Oxide	1.11	1.31	2.95
Calcium Oxide	3.52	6.34	2.62
Magnesium Oxide	5.6	5.06	5.21
Potassium Oxide	12.58	20.31	33.5
Sodium Oxide	6.42	11.25	4.93
SO_3	2.65	5.98	3.48
P_2O_5	11.09	6.46	8.36
Strontium Oxide	0.02	0.02	0.02
Barium Oxide	0.06	0.03	0.03
Mangenese Oxide	0.08	0.09	0.08
Bulk Density (lbs/ft$^{3)}$	10	10.4	9.3

B. Permitting

The following document was prepared for the WMU Power Generation Study by Wenck Associates, Inc., of Woodbury, Minnesota, and describes the requirements, justification and decisions regarding Minnesota Pollution Control Agency (MPCA) permitting for a test burn of corn cobs with coal at the WMU.

Technical Support Document for Draft/Proposed Air Emission Permit No. 06700005-004

This technical support document is intended for all parties interested in the draft/proposed permit and to meet the requirements that have been set forth by the federal and state regulations (40 CFR § 70.7(a)(5) and Minn. R. 7007.0850, subp.1). The purpose of this document is to provide the legal and factual justification for each applicable requirement or policy decision considered in the preliminary determination to issue the draft/proposed permit.

1.0 General Information

1.1. Applicant and Stationary Source Location:

Applicant/Address	Stationary Source/Address (SIC Code: 4931)
Willmar Municipal Utilities 704 Litchfield Ave SW PO Box 937 Willmar, Minnesota 56201	Willmar Municipal Utilities 710 Benson Ave SW Willmar, Minnesota 56201 Kandiyohi County
Contact: Kenneth Nash Phone: (320) 235-4422	

1.2. Description of the Permit Action

Willmar Municipal Utilities is an electricity and steam generating facility. The facility supplies electricity and steam for heating to residents and businesses of the City of Willmar. The facility is located in an area that is designated in attainment with ambient air standards or unclassified for all pollutants. The facility is a major source under 40 CFR Section 52.21 (Prevention of Significant Deterioration), a synthetic minor for HAPs, and considered a major source under the federal operation permits program (40 CFR pt. 70).

Emission sources at the facility include Boiler No.1 (coal-fired), Boiler No. 2 (natural gas-fired), Boiler No. 3 (coal and gas-fired), Boiler No. 4 (gas and oil-fired), and fugitive sources including coal and ash handling systems. Boilers 2 and 3 serve generators producing electricity; Boiler 4 supplies steam only. Boiler 1 has been out of service for over 10 years and is not currently authorized to operate as it will require major physical modifications in the event the facility chooses to operate it in the future. Boiler 2 has the ability to use a Multiclone to remove PM but it is not in use because Boiler 2 is limited to burn only natural gas and it is seldom used. Boiler 3 is the main emission unit and has coal usage limits in order to remain minor for HAPs. Boiler No.3 has a Multiclone as control equipment which removes PM. The fuel oil tank has been removed from the facility, but a transport could be hooked up to boiler 4 and fuel oil burned without a permit amendment. A major permit amendment would be needed to install a new fuel oil tank.

This permit action authorizes the use limited amounts of corn cobs and other defined biomass as supplemental renewable fuel source for Boiler No.3. The limited amounts of biomass will be used to conduct trial burns to evaluate operational feasibility and emission factors.

1.3 Description of the Activities Allowed by this Permit Action

This permit action is a major amendment.

Permit No. 06700005-003 included federally enforceable restrictions on fuel usage and fuel type for Boiler 3. It allowed natural gas and limited amounts of subbituminous coal. This permit amendment authorizes up to 500 tons of defined biomass as a cumulative total over the life of the permit amendment. For the test burns, the biomass would be introduced with air through an existing observation port near the rear of the boiler grate. No modifications to the boiler are necessary for short term testing purposes.

The facility will temporarily add equipment to receive, handle and store biomass. Corn cobs (the principally-desired item for testing) and other authorized biomass are being harvested and stored at an off-site location. WMU will transport limited quantities (e.g., sufficient for 1-2 days of test burns) to the WMU power plant site via dump trucks or farm trucks. The cobs and other authorized biomass will be stored in an outdoor pile at the plant site. The expectation is that most of any loose material would be separated from the authorized biomass at the time of harvesting; therefore, minimal windblown dust issues are expected from biomass storage in a pile. Authorized biomass will be moved from the on-site pile to the plant via front end loader. The means of getting the biomass into the plant will involve the addition of temporary equipment (e.g. use of a sileage blower and temporary ductwork up to a boiler observation port, use of a portable electric screw conveyor through a plant opening up to the desired boiler elevation). These temporary emission units are being added to the list of insignificant activities as their associated emissions are expected to be no higher that the emissions associated with coal handling at the facility.

Synthetic minor limits on biomass will ensure that this modification remains non-major under NSR and that the entire facility remains non-major under 40 CFR part 63 and 40 CFR pt 52.21.

This permit action incorporates a mandatory permit reopening action (DQ # 1968) to set limits for Boiler No.4 pursuant to Minn. R. 7017.2025, subp. 3. The Letter of Compliance dated 3/20/08 served as the 30-day notice to the permittee of the MPCA's intent to amend the permit. No other permit amendments or notifications are authorized or incorporated into this permit action.

Facility Emissions:

Table 1. Title I Emissions Increase Summary

Pollutant	Limited Emissions Increase from the Modification (tpy)	Source-wide Contemporaneous Increases and Decreases* (tpy)	Net Emissions Increase (tpy)	PSD/112(g) Significant Thresholds for major sources	NSR/112(g) Review Required? (Yes or No)
PM	2.1	N/A	2.1	25	No
PM_{10}	0.77	N/A	0.77	15	No
$PM_{2.5}$	0.48	N/A	0.48		No
NO_x	0.78	N/A	0.78	40	No
SO_2	0.09	N/A	0.09	40	No
CO	2.12	N/A	2.12	100	No
Ozone (VOC)	0.06	N/A	0.06	40	No
Lead	3.7E-04	N/A	3.7E-04	0.6	No
H_2SO_4	2.9E-03	N/A	2.9E-03	7.0	No
Individual HAPs (**)	1.3	N/A	1.3	10	No
Total HAPs,	1.4	NA	1.4	25	No

* Other emission changes during the contemporaneous period as defined by 40 CFR § 52.21, 40 CFR § 52.24 or 40 CFR pt. 51.

** The largest change in individual HAP is for HCl. There is a large variability in Cl content values reported in current data bases for biofuels. This number represents a reasonably conservative estimate based on the very limited available information for corn cobs.

Table 2. Total Facility Potential to Emit Summary

	PM tpy	PM_{10} Tpy(*)	$PM_{2.5}$ tpy (**)	SO_2 tpy	NO_x tpy	CO tpy	VOC tpy	Single HAP tpy	All HAPs tpy
Total Facility Limited Potential Emissions	599.1	323.7	329.5	1936.4	622.6	267.6	7	1.8	13.1
Total Facility Actual Emissions (2006)	76.91	31.81	Not Reported	834.6	173.39	136.82	1.23	HAPs not reported in emission inventory	

(*) Emission factors and control efficiencies for PM_{10} from coal for Boiler No. 3 were updated and corrected to account for organic condensibles and this accounts for the difference in the documented potential to emit.
(**)$PM_{2.5}$ for the operation authorized by permit No. 06700005-003 is considered equal to PM_{10}. Emissions data for the modification authorized by this permit included $PM_{2.5}$ and thus, this emissions increase was added to the emissions rate of PM_{10} for the existing facility as a conservative estimate of $PM_{2.5}$ authorized by this permit action.

Table 3. Facility Classification

Classification	Major/Affected Source	Synthetic Minor	Minor
PSD	SO_2, PM, PM_{10}, NO_x, CO	NA	VOC's, Pb
Part 70 Permit Program	SO_2, PM, PM_{10}, NO_x, CO	NA	VOC's, Pb
Part 63 NESHAP	NA	HAPs	NA

2.0 Regulatory and/or Statutory Basis

2.1 New Source Review

The facility is an existing major source under federal New Source Review/Prevention of Significant Deterioration (PSD) program (40 CFR § 52.21). The facility is located in an area that is designated as attainment or unclassified for all pollutants. As of the time of this permit, no modifications requiring Best Available Control Technology (BACT) have been made or proposed at the facility. Boiler No. 2 and Boiler No. 4 are each subject to Title I conditions imposed at the time of modification (in the case of Boiler No. 2) and construction (in the case of Boiler No. 4) such that the modification/construction were not considered major modifications under PSD. This permit action includes synthetic minor limits on the amount of biomass authorized that will ensure that the proposed modification does not trigger PSD and that the entire facility remains as a non-major source under 40 CFR part 63.

2.2 Part 70 Permit Program

The facility is a major source under the Part 70 permit program.

2.3 New Source Performance Standards (NSPS)

Boiler No. 4 is subject to the Standards of Performance for Small Industrial-Commercial-Institutional Steam Generating Units (40 CFR 60, Subpart Dc). This permit action does not change anything about this emission unit.

2.4 National Emission Standards for Hazardous Air Pollutants (NESHAP)

There are no promulgated NESHAPs applicable to this facility. Coal usage limits and HAP coal content restrictions have been applied to prevent EU004 of this facility from being subject to the industrial boiler NESHAP (40 CFR 63, Subpart DDDDD).

2.5 Acid Rain Requirements (40 CFR 72)

The facility is not subject to Acid Rain requirements. None of the units is listed in tables 1, 2, or 3 of 40 CFR § 73.10 (40 CFR § 72.6(a)(1) and (2)); none of the units serves a generator with a nameplate capacity of 25 MW or greater (EU001 serves a generator of 4 MW, EU002 serves a generator of 7.5 MW, EU003 serves a generator of 17.8 MW, and EU004 does not serve a generator) (40 CFR § 72.6(a)(2) and (3)).

2.6 Minnesota State Rules

Several State Standards of Performance apply to portions of this facility. These include:

- Minn. R. 7011.0500 to 7011.0553 – New and Existing Indirect Heating Fossil Fuel Burning Equipment.
- Minn. R. 7011.0700 to 7011.0735 – Pre- and Post-1969 Industrial Process Equipment
- Minn. R. 7011.2300 – Stationary Internal Combustion Engines
- Minn. R. 7011.1110 – Existing Outstate Coal Handling Facilities

Table 4. Regulatory Overview of Units Affected by the Modification/Permit Amendment

EU, GP, or SV	Applicable Regulations	Comments:
EU003	Minn. R. 7007.0510	Standards of Performance for Existing Indirect Heating Equipment. Since does not need any physical or operational change for the short term trials it remains existing indirect heating equipment. In addition, the estimated PM emission factor for the proposed biomass is lower than the emission factor for coal.
EU003	Minn. R. 7009.0020	SO_2 limit set as a result of computer dispersion modeling completed at the time of construction of EU004 (which is not a major source of SO_2 itself). The estimated sulfur content of the biomass is lower than the sulfur content in coal and thus, this modification does not affect this limit.
EU003	Title I limit to avoid NESHAPs	The facility is limited to burning a maximum of 75,000 tpy of coal in order to stay minor source for HAPs .
EU003	Title I limit to avoid NESHAPS and NSR	The facility is limited to burning a maximum of 500 tons of accumulated biomass over the life of the permit amendment.
EU003	Title I limit to avoid NESHAPs	Annual fuel analysis of coal and Total Chlorine and Total Fluorine coal content trigger levels remains. Coal reports show chlorine levels well below the permit amendment trigger level in the permit. Limit on total Chlorine and total Fluorine content in biomass was not imposed because calculations show the facility will remain below thresholds with good margin even at the highest values of Cl and F found in databases for wood and other biofuels.
EU 003	Minn. R. 7007.0800, subp. 2, subp., subp. 5, Minn. R. 70.17.2030, subp. 1-4, 7017.2018, and Minn. R. 7017.2035, subp. 1-2	Biomass fuel testing pre-authorization for the purpose of generating emission factors. Required record keeping and reporting for trial burns, fuel analysis and emission testing to generate emission factors.

3.0 Technical Information

3.1 Calculations of Potential to Emit and Emissions Increase Analysis

Most calculations for fossil fuels were done using the emission factors from the most recent revision of AP-42 and FIRE. Some calculations for fossil fuels were done using information from a fuel analysis and AP-42 equations.

For a worst estimate of annual emissions from biomass, it is assumed that all 500 tons could be combusted in a single year. No other emissions data for corn cobs was found and thus surrogate emissions data from other biomass fuels, either corn-based (e.g., stover) or wood-based emission factors were consulted. An additional factor of 2.0 was applied to emission factors for criteria pollutants selected as representative of the proposed biomass.

The emission factors for PM, $PM_{2.5}$, SO_2 and CO were selected from AP-42, Chapter 1.6, Table 1.6-1 for "wet wood" with a mechanical collector control device because the proximate analysis of cobs indicate a moisture content range between 24 and 30% as received.

The emission factor for NO_x was selected from emissions testing conducted for combustion of DDGS because it is presumed to be more representative of cob combustion than wet wood.

The emission factors for VOCs and Lead were selected from AP-42, Chapter 1.6, "Wood Waste Combustion," Tables 1.6-3 and 1.6-4 respectively because wood waste is presumed to be more representative of corn cobs than coal.

In the case of HAPs, the applicant used AP-42 factors for Wood Combustion as a surrogate for firing of Corn Cobs in WMU's Boiler #3. WMU supplied the results of proximate and ultimate analysis of a sample of corn cobs. Because of the wide range in chlorine and fluorine content in wood, alternative calculations for HCl and HF emissions from burning biomass were included. These calculations were based on information in the permit No. 13900114-002 for Koda and in Table 4-2 of document titled Emission Factors for Priority Biofuels in Minnesota, Final Report, available at http://www.pca.state.mn.us/publications/aq1-33.pdf. An additional factor of 4.0 was applied to the HCl and HF factors selected as representative of the proposed biomass. According to the information provided with the permit application for Koda's permit No. 13900114-002, it shows corn stover with 0.266 %, by weight Cl. It shows corn cobs with ND. It shows pine saw dust with 0.07 %, by weight Cl. It shows pine with 0.03 %, by weight Cl. The factor of 4 to extrapolate from wood to corn cobs is justified.

Where a Title I emission limit or NSPS emission limit exists, they supersede the AP-42 emission factors. Potential emissions are based on operating limits imposed in the permit, and the most stringent short term applicable limits.

Attachment 1 contains detailed spreadsheets and supporting information prepared by the MPCA and the Permittee, as well as Form EC-02 prepared by the Permittee with specific source references for the emission factors used.

Attachment 2 to this TSD contains Facility Description and Compliance Demonstration Forms (CD-01).

3.2 Emissions Testing to Generate Emission Factors

Because of the limited emissions data available on the combustion of biomass on a co-fired mode; the permit includes conditions to ensure that during the trial burns when stack testing is done:

- Approved test plans include the pollutants of concern from the regulatory standpoint.
- Approved test plans include definition of operating conditions as well as sufficient records of these operating conditions.
- Approved test plans include sufficient fuel analysis to correlate fuel composition to emissions data from stack testing.
- Approved test plans define appropriate sampling and analysis methods

The applicant indicated that if the proposed biofuels trial burn show that this is a feasible alternative on the long term, permanent physical and operational changes would be implemented: the boiler would be upgraded (e.g. additional air ports, new steam soot blowers, a larger induced draft fan, etc.), a fabric filter would be added for enhanced control of fine particulate matter, and the fuel handling and ash load operations would be improved. The long term renewable energy project would require a permit amendment. The issue of testing for a wide range of HAPs was discussed. In light of the prospective upgrades to the boiler for the long term renewable energy project, MPCA agreed to limit the testing of HAPs during the trial burns authorized by this permit action. However, the current information on emission factor for HAPs shows a wide range in values for typical risk drivers and the MPCA would be looking at conservative values of all pollutants to estimate the emission increases due to a proposed long term renewable energy project.

The permit includes language that defines when stack test results constitute a "performance test" for the purpose of setting limits pursuant to Minn. R. 7017.2025, subp. 3.

3.3 Solid Waste and Air Quality Permitting Requirements for By-Product and Biomass Material in a Combustion Process.

Attachment 3 to this TSD includes the guidance that MPCA has prepared on the subject. None of the biomass authorized in this permit falls in the category of materials that could be considered solid waste. In light of this, it was not necessary to limit the biomass co-fired in trial burns to less than 30 % by mass or less pursuant to Minn. Rules 7011.055.

Some of the materials originally proposed (DDGS and corn kernels), with proper handling and management, are candidates for obtaining a Case Specific Beneficial Use Determination (CSBUD) from the MPCA. However, WMU opted to avoid any material that could be subject to a CSBUD.
The MPCA combustion biomass guidance does not alter the meaning of solid waste under federal regulations, and as such, this is still an uncertain matter until it is resolved at the federal level.

3.4 Compliance Assurance Monitoring

Boiler 3 (EU 003) is considered a "pollutant specific emissions unit" (PSEU) and is therefore subject to CAM rules. The control equipment applies only to PM reduction for the burning of solid fuels. The addition of biomass to EU003 does not change CAM requirements. The uncontrolled PTE is greater than the major source threshold and the limited PTE is less than the threshold, therefore the facility is considered an "other pollutant specific emissions unit". The CAM plan uses pressure drop in the Multiclone (CE 003) as the primary indicator of emission unit performance, and is required to be read manually once every eight hours. A Continuous Opacity Monitoring System (COMS) is used as a secondary indicator.

3.5 Modeling Limits

The technical support document for Permit No. 06700005-003 describes the basis for the modeling limits. The estimated sulfur content of the biomass is lower than the sulfur content in coal and thus, this modification does not affect this limit or any other compliance demonstration requirement.

3.6 Periodic Monitoring

In accordance with the Clean Air Act, it is the responsibility of the owner or operator of a facility to have sufficient knowledge of the facility to certify that the facility is in compliance with all applicable requirements.

In evaluating the monitoring included in the permit, the MPCA considers the following:

- The likelihood of violating the applicable requirements;
- Whether add-on controls are necessary to meet the emission limits;
- The variability of emissions over time;
- The type of monitoring, process, maintenance, or control equipment data already available for the emission unit;
- The technical and economic feasibility of possible periodic monitoring methods; and
- The kind of monitoring found on similar units elsewhere.

The technical support document for Permit No. 06700005-003 summarizes the periodic monitoring requirements for the total facility. Table 5 below includes only those conditions that were added or changed as a result of this permit action and for which the monitoring required by the applicable requirement is nonexistent or inadequate.

Table 5. Periodic Monitoring

Emission Unit or Group	Requirement (basis)	Additional Monitoring	Discussion
EU003	Biomass Usage Limit: (Minn. R. 7007.0800 subp 2; Minn R. 7017.2025, subp 3 and 3a)	Daily biomass usage record from solid fuel scales whenever biomass is being combusted	The facility is limited to burning a maximum of 500 tons of accumulated biomass in order to stay minor for HAPs and NSR.
EU003	Performance Testing for Generation of Emission Factors and Biomass Fuel Analysis	Approved Test Plan Requirements	Please *see the discussion* in part 3.2 above.
EU003	Definition of Authorized Biomass	Biomass Fuel Usage Records	Please see the discussion in part 3.3 above.

3.7 Insignificant Activities

Willmar Municipal Utilities has several operations which are classified as insignificant activities. These are listed in Appendix C* to the permit. This permit action does not change the list or requirements applicable to Insignificant Activities but it adds to the list the equipment to receive, handle and store biomass, as their associated emissions are expected to be no higher that the emissions associated with coal handling at the facility.

3.8 Public Comment and EPA Review

Public Notice Period: January 9 – February 9, 2009
Concurrent EPA 45-day Review Period: January 9 – February 24, 2009
No comments were received from the public.

4.0 Conclusion

Based on the information provided by Willmar Municipal Utilities, the MPCA has reasonable assurance that the proposed operation of the emission facility, as described in the Air Emission Permit No. 06700005-004 and this technical support document, will not cause or contribute to a violation of applicable federal regulations and Minnesota Rules.
Staff Members on Permit Team: Carolina Espejel-Schutt (permit writer/engineer)

Rachel Peters (enforcement)
Marc Severin (stack testing)
Bruce Braaten (peer reviewer)
Laurie O'Brien (administrative support)
Beckie Olson (administrative support)

AQ File No. 712A; DQ 2326 and 1968
The following files can be found in Appendix A*

1. PTE Summary and Emissions Increase Calculation Spreadsheets
2. Facility Description and CD-01 Forms
3. Solid Waste and Air Quality Permitting Requirements for By-Product and Biomass Material in a Combustion Process

* *Original document only*

C. Corn Cob Acquisition

<u>Harvest Equipment Selection</u>

During a harvest demonstration day put on by a nearby ethanol producer that was also researching the harvest of cobs – for use in a gasifier – FCI was able to evaluate the speed of harvest of two competing cob harvest systems, the Cob Caddy® prototype manufactured by Vermeer Corporation of Pella, IA, and the Stukenholtz Ceres Ag Residue Recovery System® manufactured by the Stukenholtz's in Nebraska City, NE. These two machines are the only equipment proven capable of harvesting cobs that are known to be currently available. In order to determine which was the most efficient and practical, the following aspects were evaluated:

a. Harvest time – *Cob collection could significantly slow the corn harvest compared to current non-cob-collecting harvest methods, leading to net corn yield reduction and higher per bushel harvest costs.*

The Cob Caddy system was able to achieve twice the harvest speed as the Residue Recovery System. The corn harvester was not slowed by the Cob Caddy but was required to stop to empty its 7,000 pound cob payload – requiring approximately two to three minutes.

b. Integration into existing machinery – *The ability to integrate the cob collection systems equipment with current, standard harvest equipment is important, based on time, effort and cost to adapt the machinery based on man hours and material costs.*

The Residue Recovery System was powered by and integrated into the corn harvester, requiring significant modification to the harvester. The Cob Caddy was self-powered and towed by the harvester, requiring the addition of only a tow hitch.

c. Effectiveness of cob collection – *The tonnage of cobs that remain uncollected compared to the tonnage collected, on a per-acre basis, as well as the tonnage of* *unwanted stover and trash collected with the cobs is important to the economical collection of cobs.*

Both machines appeared to collect nearly all of the cobs available, estimated at 80-90% based on cob residue remaining on the field. The Cob Caddy appeared to collect less than ten percent stover and trash, the Residue Recovery System about twenty percent.

d. Cob storage system – *The effectiveness of the means used to temporarily store and/or carry the cobs in the field will directly affect the efficiency of the collection system.*

The Residue Recovery System was self-contained – the harvester self-emptied the cobs "on the go" into a truck traveling alongside. The Cob Caddy also self-emptied into a truck alongside but was required to stop to do so.

e. Manpower – *Additional hours of labor required for the non-cob portion of the corn harvest will also impact the economics of the harvest.*

Additional labor was essentially equivalent for both systems and consisted of hauling the cobs away from the harvester and unloading at the point of storage.

Based on the above evaluation, the Vermeer Cob Caddy® was selected. Arrangements were made with the inventor of the machine, Mr. Vernon Flamme of North Bend, NE, to deliver a Vermeer prototype and harvest and haul the cobs. Figures 3 and 4 present photos of the equipment.

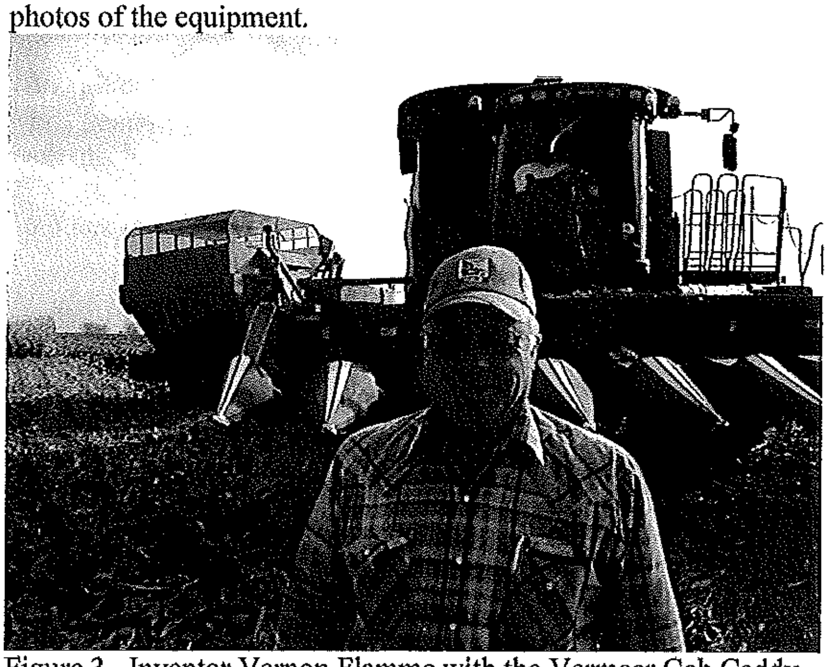


Figure 3. Inventor Vernon Flamme with the Vermeer Cob Caddy.

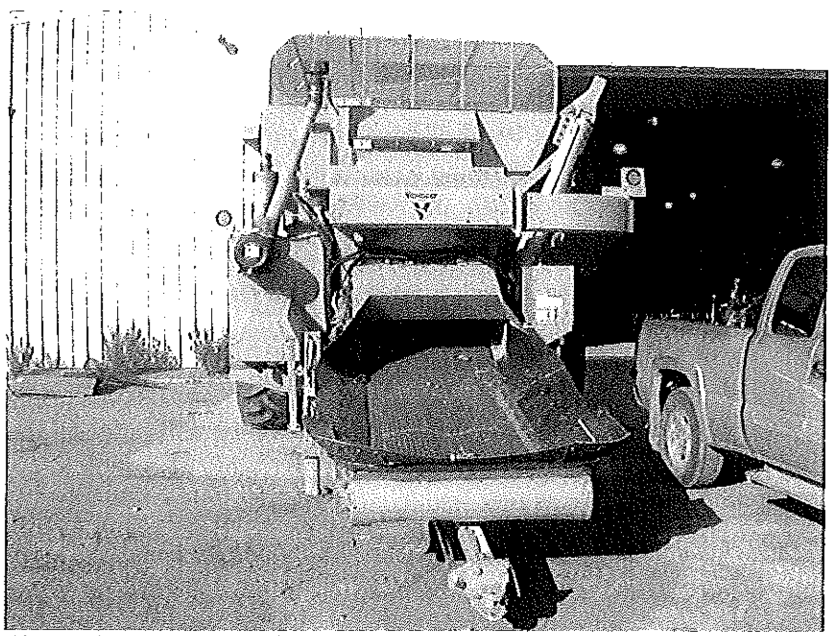


Figure 4. Vermeer Cob Harvester showing the cob and stover collection belt.

Producer Selection

Several corn producers were interviewed to gauge their interest and ability to harvest cobs for the WMU project. The names of potentially interested producers were suggested and introductions were provided by a local agricultural equipment dealer with good knowledge of area farmer capabilities. Fosso Farms of Pennock, Minnesota – approximately five miles from the WMU – was selected based on acres available for cob harvest, field locations, willingness to work with the selected cob harvest equipment and provider, and the ability to provide labor and equipment to haul the harvested cobs to the WMU cob storage site. A relatively informal agreement describing the cob harvest commitments was reached with the Fosso Farm owners, Ryan and Lonnie Fosso, and the cob harvester Vernon Flamme. A copy of the agreement is included in Appendix C.

Cob Harvest Sites

The cob harvest sites were selected by the producer based on field and crop conditions at the time of harvest. The producer had agreed verbally to provide approximately 400 to 600 tons of cobs. Figure 5 below shows the locations of the fields harvested.

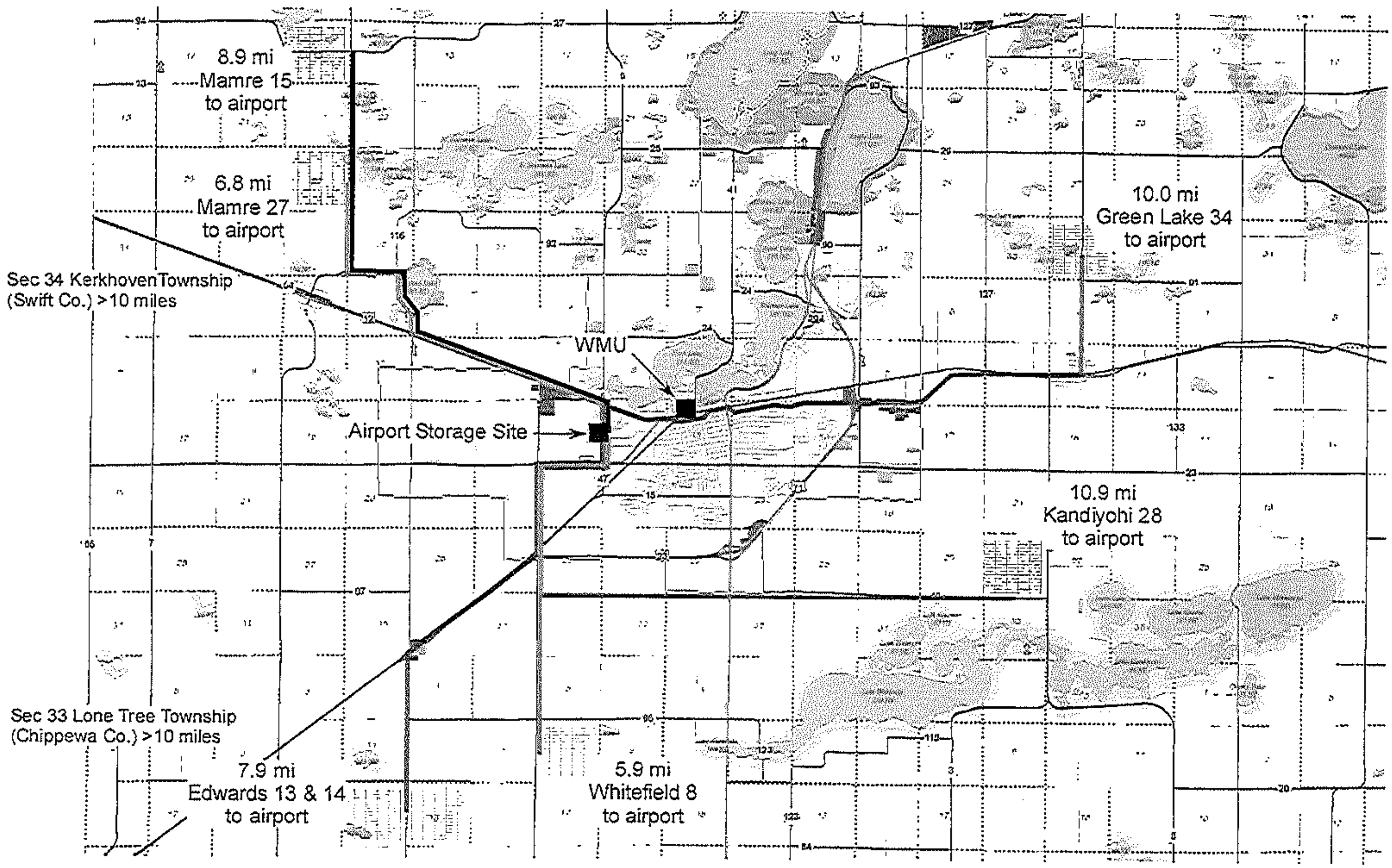


Figure 5. Kandiyohi County map showing cob harvest and storage sites.

Cob Storage Site

The length of time the harvested cobs would need to be stored was not certain. Therefore, storage on the ag fields was deemed inappropriate. Discussions with the City of Willmar resulted in permission to store the cobs on an unused portion of the former Willmar airport. Access was available and the distance to the WMU power plant was less than one mile. The fields where the cobs would be harvested were essentially clustered around the former airport site, and the City would provide the site at no charge. The decision was made to use the site. Figure 5 above shows the location of the storage site.

Cob Harvest Data Summary

Corn cobs were harvested for the Willmar Municipal Utilities by Vernon Flamme of North Bend, Nebraska, on the following dates in 2008:

October 30
October 31
November 1
November 3
November 4
November 12
November 13
November 14
November 15

The cobs were harvested from ten parcels of cropland owned and/or operated by Ryan and Lonnie Fosso of Pennock, Minnesota:

Kandiyohi County
Edwards Township
NW1/4, N1/2 SW1/4 Section 13
SE1/4 Section 14
Green Lake Township
S1/2, SE1/4 Section 27, and W1/2, NE1/4 Section 34
Kandiyohi Township
S1/2, SW1/4 Section 21, and E1/2, NW1/4 Section 28
Mamre Township
N1/2, NE1/4 Section 15
NW1/4, NW1/4 Section 27
Willmar Township
N1/2, NE1/4 Section 34
Whitefield Township
NW1/4 Section 8
Chippewa County
Lone Tree Township
SE1/4, SE1/4 Section 29, and S1/2, SW1/4 Section 28, and N1/2, NW1/4 Section 33
Swift County
Kerkhoven Township
E1/2 Section 34

Mr. Flamme harvested 631.1 acres for corn and cobs. The harvested cobs were hauled using both Flamme and Fosso equipment. The trucks were weighed full and empty as the cobs were delivered to the Willmar Airport storage site. The cobs delivered totaled 421.26 tons. The cob harvest averaged 0.67 tons per acre. The complete 2008 WMU Corn Cob Harvest Data Summary is included in Appendix C.

D. Engineering Design

Initial designs to provide a cob feed system that would allow temporary feeding of cobs into the WMU Boiler #3 were completed. The initial design was prepared to minimize interruption of daily work tasks at the WMU with least cost. The system was designed to evaluate the feasibility of injecting a volume of cobs into the furnace equivalent to 25% of the heat value currently provided by coal. Concerns about a temporary system having the ability to feed cobs that could supplant 25% of the heat input of the boiler arose due to the much lower bulk density of the cobs and the significantly higher moisture content when compared to coal. It was therefore decided to implement a short test burn prior to the longer duration test burns of cobs to evaluate the feeding potential. This short test burn is discussed in following sections of this report.

<u>Corn Cob Auger Feed System Design</u>

As discussed above, observation of the Pella, IA test burn indicated that fuel segregation problems would likely arise if the cobs were loaded into the coal silo with the coal. Therefore, a determination was made to inject the cob material separately through a view port near the rear of Boiler #3.

Figure 6 is a photo of the view port door through which the cobs were fed. Figure 7 illustrates the structural plan of the power plant in cross section with the view port on Boiler #3 that was determined to have the best potential to feed the cobs into the boiler. This view port is on the port side of the boiler (east) and at the rear of the firebox - the start of the traveling grate. If the cobs could be blown straight into the furnace through the view port, there was a good chance for relatively even distribution across the grate and the cobs placed on the grate at the rear of the furnace would travel to the front of the furnace similar to the combustion travel path of the coal.

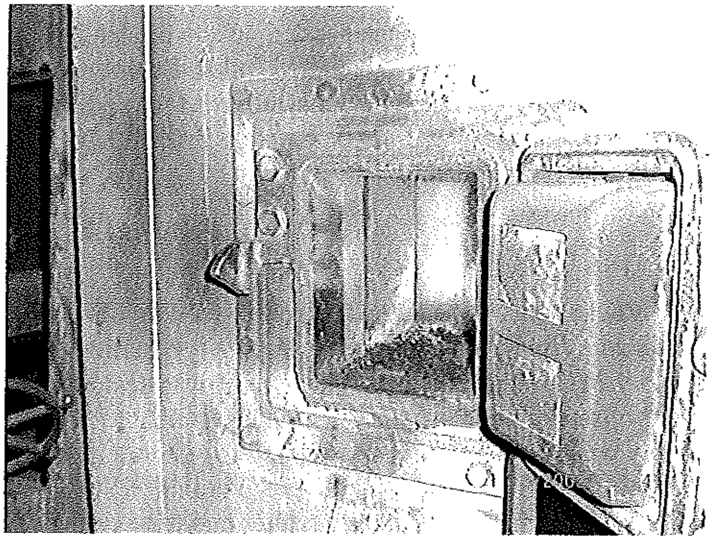


Figure 6. View port door through which the cobs were fed.

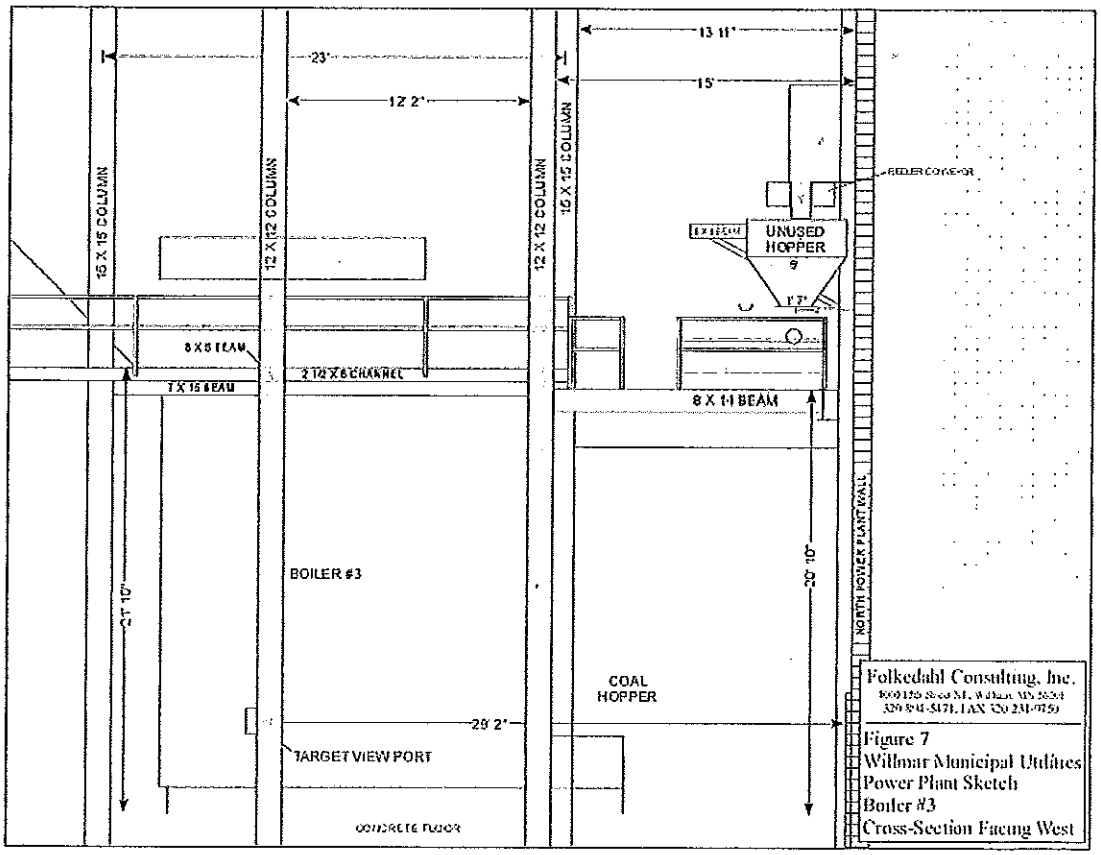


Figure 7. East elevation of Boiler #3 where Cob Injection System was installed.

Figures 8 and 9 are illustrations of the cob feed system in relation to the boiler and the hopper that was utilized to introduce the cobs to the furnace. The hopper is an existing coal hopper that is fed from a separate suspended shelf in the silo. This shelf is utilized as a reserve and for blending different secondary coals with the primary coal. The Redler coal conveyance system above the hopper was deemed inappropriate for feeding the cobs. The cobs were chopped to a 2" minus size and included many more fines than the lump coal that is currently fed to the boiler. This gave concerns about the ability of the Redler Conveyor system to satisfactorily convey the cobs to the furnace and feed the required amount to displace a significant portion of the heat content. Therefore, an agriculture based handling system was designed from the hopper to the view port door for introduction into the furnace, as illustrated in Figures 8 and 9 below.

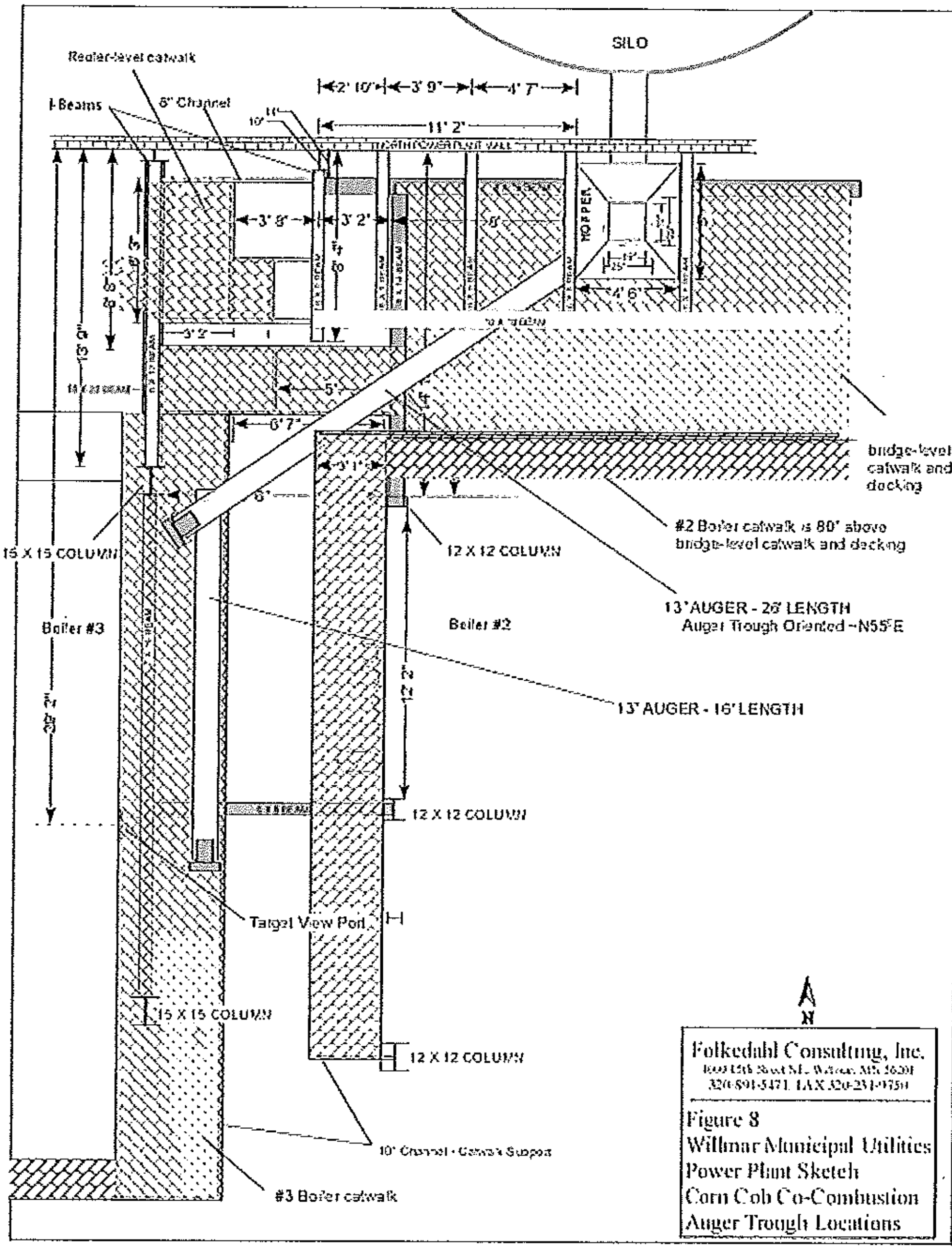


Figure 8. Structural plan view of the boiler and the cob feed auger system.

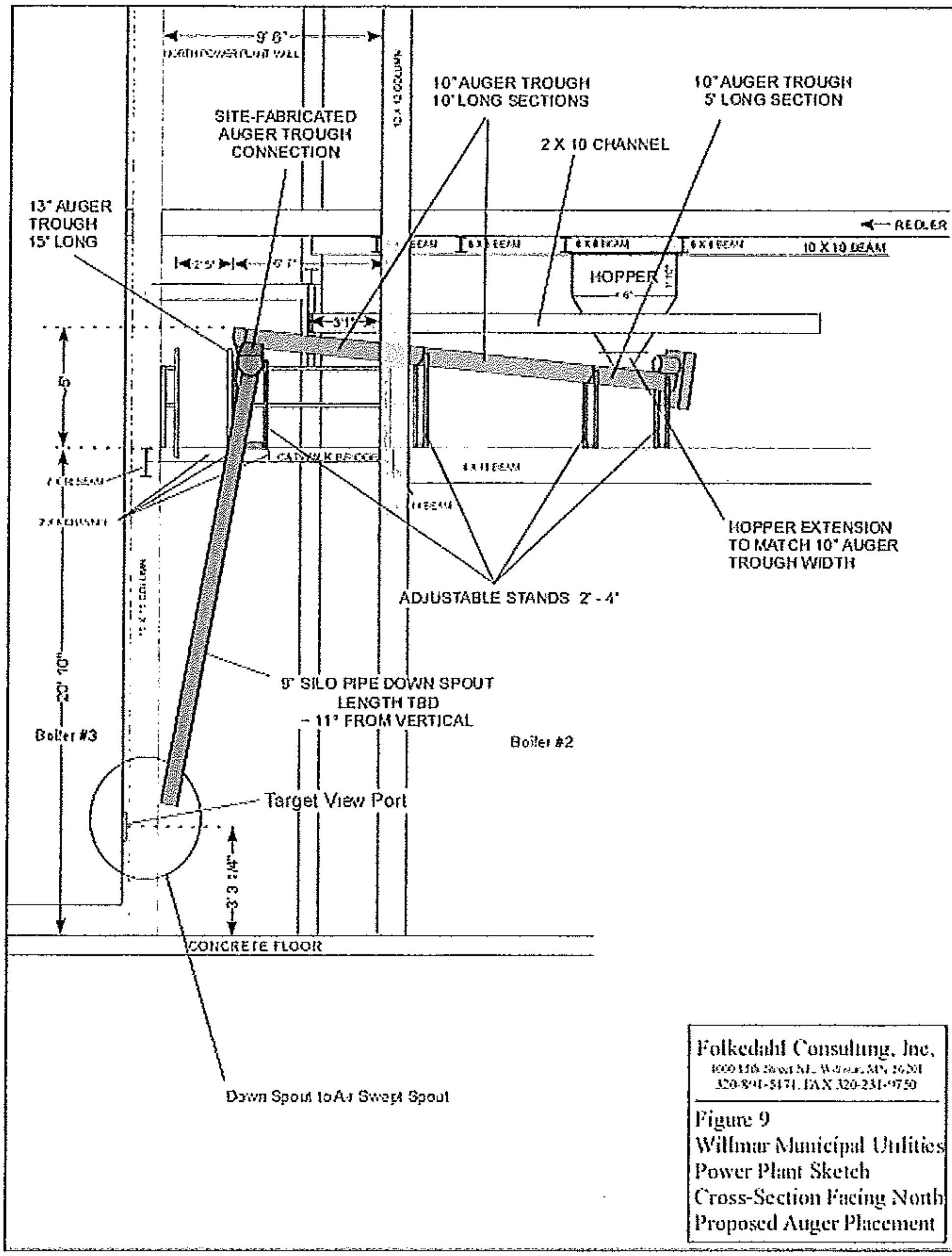


Figure 9 North facing view of the cob feed auger system.

A concern arose, due to the relatively small size of the view port opening (see Figure 10 below), that whole cobs would bridge across the view port opening and prevent injection into the firebox. Therefore a decision was made to grind the cobs prior to injection. Several industrial grinders were observed and demonstrated including: a small 40 hp Vermeer brush chipper used by the City of Willmar Parks and Recreation Department, a large 1,000 hp Vermeer tub grinder used to grind logs at the City brush dump, a 600 hp Vermeer horizontal grinder used at the brush dump, and a 475 hp RotoChopper horizontal grinder brought to Willmar by the manufacturer to demonstrate the grinder. The RotoChopper was selected based on performance and availability, and a contractor, RW Farms of Chanhassen, Minnesota was retained to grind the 421 tons of cobs stored on the former Willmar airport runway.

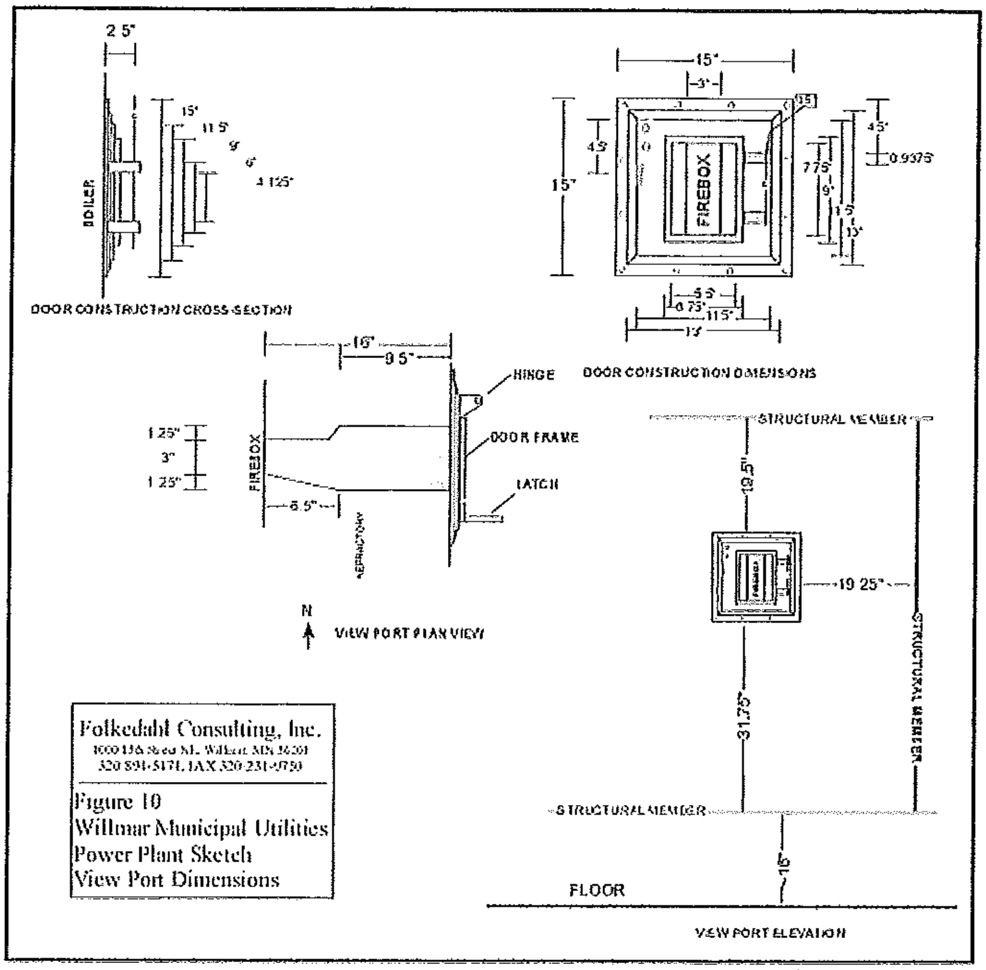


Figure 10 View port dimensions

Grind sizes ranging from ½ inch minus to 3 inch minus were produced for evaluation, with a size of 2 inch minus selected for the initial test burn.

A custom engineered air swept cob injector was developed by PCi Engineering of Schaumberg, IL, with input from the Detroit Stoker Company of Detroit, MI. The injector accepts cob material from above and injects the cobs using an air input at the rear of the injector. The air supply was ducted from an unused over-fire air fan, throttled to provide a pressure equal to approximately 19 inches of water. The device, christened "The Cob Rocket", and designed to attach directly to the view port assembly, was fabricated on site by WMU personnel and was supported by a framework also fabricated on site.

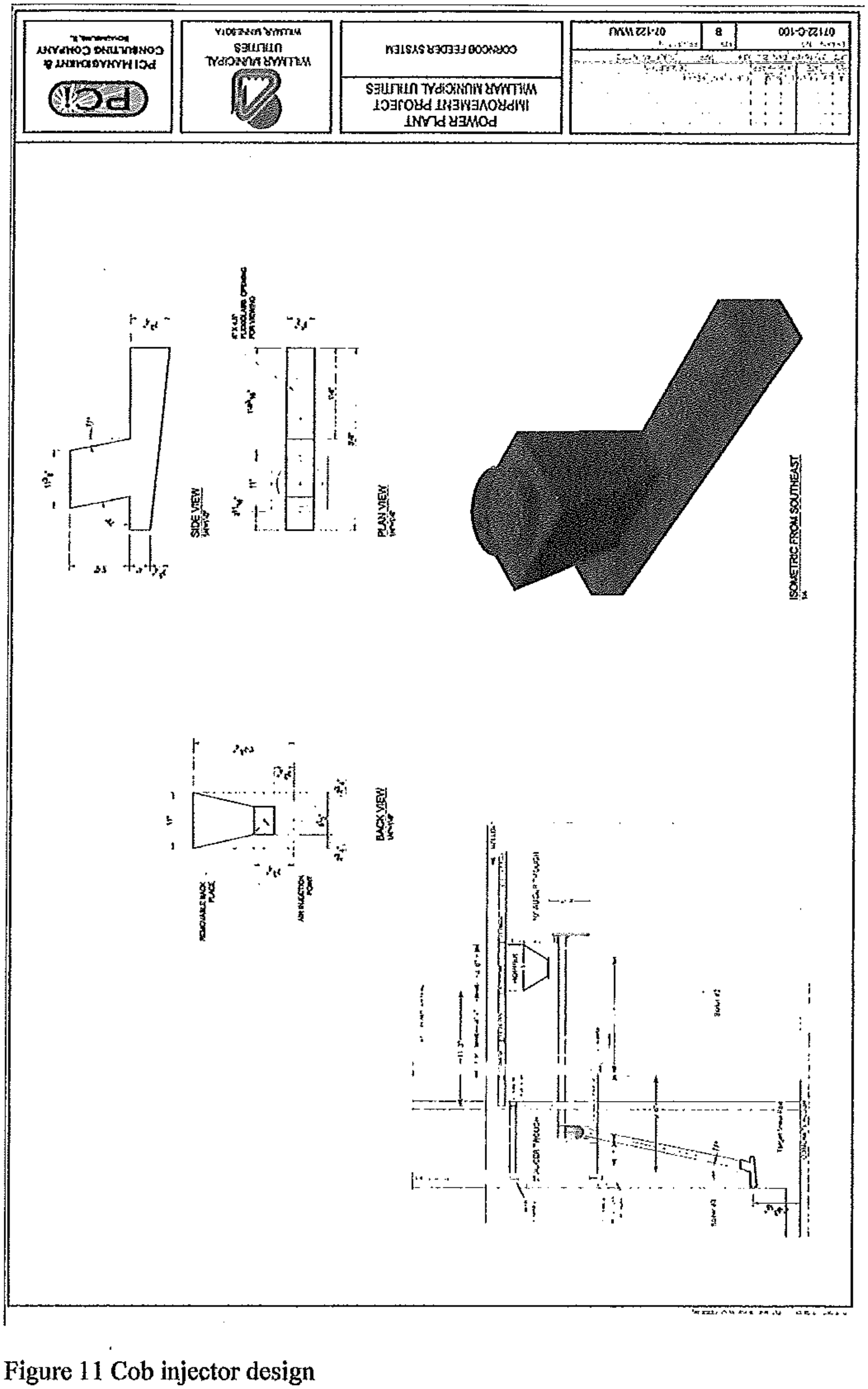


Figure 11 Cob injector design

E. Test Burn Plan

The operating specification developed prior to co-combusting the cobs and coal is reproduced below.

TEST BURN OPERATING SPECIFICATION
Temporary Cob Injection System
Willmar Utilities Corn Cob-Coal Co-Combustion Project
May 31, 2009

DISTRIBUTION:
B. Folkedahl
J. Folkedahl
B. Gomm
W. Hompe
K. Nash
C. Tyburk
W. Miller

Introduction

The primary objective of the test burns is two fold; 1) to put a representative amount of corn cobs on the grate over a significant period of time such that combustion characteristics, fouling and slagging tendency and stoker grate ash formation issues can be assessed to determine the feasibility of co-combusting corn cobs on a regular basis to generate heat and power at Willmar Municipal Utilities, 2) to provide stack emissions testing data that can be used to evaluate the feasibility of co-combusting corn cobs for issues relevant to the Minnesota Pollution Control Agency (MPCA). The test burn will be implemented in two stages with the first stage to evaluate combustion feasibility and the second stage to provide emissions data for the MPCA.

Due to the nature of the temporary cob injection system (CIS), it will be necessary to spend the first portion of the test period tuning the CIS to ensure that the required amount of cobs can be placed onto the grate in an acceptable fashion. This will include adjusting the air flow and auger speeds to place a representative amount of cobs, up to 25% of the total heat input of the furnace, onto the grate. It will be determined during this portion of the test burn whether the cobs can be evenly distributed across the grate or if a smaller fraction of the heat input will need to be placed on the grate at a singular location such as the center of the grate. Additionally, due to the nature of the inorganic fraction of the cobs, it will also be important to monitor the tube banks of the furnace for increased fouling or slagging due to vaporization of inorganic materials and impingement on tube surfaces of ash formed and entrained in the flue gas. This will be done by visually inspecting and documenting the condition of the tube banks through images obtained through the view ports. A data sheet will also be used to record the visual inspections that will take place throughout the test period.

Once the operational characteristics of the CIS have been established and stabilized, initial combustion testing will continue until sufficient data have been collected, up to a maximum of approximately 100 tons of cobs. The remaining cobs will be held in reserve to provide the fuel input required for the stack testing to establish emissions data for the MPCA, as well as for any additional desired test burns.

Order of Operation

1) Chop ~100 tons of cobs to 2" minus size.

2) Haul chopped cobs to power plant to fill and maintain east coal silo reserve shelf with cobs.

3) Set initial blower air speed to maximum flow rate. (Observe cob distribution pattern on traveling grate and adjust air flow to achieve optimum distribution for each cob feed rate.)

4) Set bottom auger speed at maximum speed. Bottom auger should be started first to avoid potential plugging problems.

5) Set initial upper auger speed, refer to table below (Measure the actual cob feed rate using 55 gallon drums and a scale - see Figure 1.0 – and calibrate control setting accordingly.)

AUGER SPEED SETTINGS TABLE

13" Screw Diameter, 30% Trough Loading

Desired Cob Percentage (Btu)	Required Cob Feed Rate (TPH)	Auger Output* Per RPM (TPH)	Required Auger Speed (RPM)	Auger RPM per (Hz)	Required Control Setting (Hz)
5%	0.52	0.10	5.2	0.034	0.18
10%	1.04	0.10	10.4	0.034	0.35
15%	1.55	0.10	15.5	0.034	0.53
20%	2.07	0.10	20.7	0.034	0.71
25%	2.59	0.10	25.9	0.034	0.89

*(Auger data determined from Martin specifications - see Attachment)

6) Open the slide gate from the east silo reserve shelf to initiate cob injection into furnace. Make necessary operational changes and stabilize system operation before initiating the sampling plan.

7) Once the parametric test plan and sampling plan have been completed, initiate an orderly shutdown. This will be performed by reversing the order of start up procedures

listed above. Close slide gate on silo, run the upper auger until empty, run lower auger until empty, shut off upper auger, shut off lower auger, shut off blower air, etc.

A data sheet to record speed adjustments and settings of the feed system components will be supplied by FCI and placed at the speed controller location for the upper auger, at the east silo chute to track the slide position and at the blower control to record the value of the air speed/flow rate to blow cobs into the furnace. Initial settings and all adjustments are to be recorded on these data sheets at the time of setting.

Test Procedures and Parameters

The primary objective of this test series is to document the performance of the combustion system when co-firing corn cobs and coal. The performance objective is to inject cob material into the boiler furnace at varying rates that will equal up to 25% of the combined cob/coal heat input. The rates shown in the table below are calculations based on laboratory-derived fuel analyses.

Desired Cob % by Btu	Cob Btu/lb	Coal Btu/lb	Required Cob % by weight	Coal Only Combustion: Rate - Tons/Hr	Coal Only Combustion: Rate -Btu/Hr
5%	5100	8800	8.6%	6	105,600,000
10%	5100	8800	17.3%	6	105,600,000
15%	5100	8800	25.9%	6	105,600,000
20%	5100	8800	34.5%	6	105,600,000
25%	5100	8800	43.1%	6	105,600,000

Combined Combustion: Coal Rate -Btu/Hr	Combined Combustion: Cob Rate -Btu/Hr	Combined Combustion: Coal Rate -Tons/Hr	Combined Combustion: Cob Rate -Tons/Hr
100,320,000	5,280,000	5.7	0.5
95,040,000	10,560,000	5.4	1.0
89,760,000	15,840,000	5.1	1.6
84,480,000	21,120,000	4.8	2.1
79,200,000	26,400,000	4.5	2.6

Visual inspection through the view ports listed on the data sheet should be made and the condition of the tube banks in the furnace documented on the data sheet provided. Note initial baseline and any subsequent changes in flame characteristics, as well as changes in sparklers or other indications of ongoing combustion in the upper furnace area.

The data sheets to be used during this run will be supplied by FCI. Printouts of the control, flue gas, and pressure screens should be made during each test run over the multi-day test period. Data historians for the computer data acquisition system are to be turned on at the start of the test run as appropriate.

In order to establish a baseline reference for the effect of adding overfire air through the view port, air only should be injected through the view port prior to injecting cob material, for a minimum time period of four hours and while recording data as described above.

Flue Gas Sampling Plan

The concentration values from all of the instruments will be recorded continuously on a data-logging system. In addition, visual inspection data will be manually recorded at set time intervals.
The following flue gas constituents will be measured during the test series:

CO[1]
NOx
O2
SO2
VOCs[1]
Particulates

Fuel & Ash Sampling and Analysis Requirements

Coal samples will be taken at the start of each day of the test burns. One composite coal sample will be submitted for analysis following completion of the test series.

Ash samples will be taken from the grate prior to the beginning of the test series. This sample is to be taken from the center of the discharge end of the grate. Approximately a two gallon sample of ash should be taken, allowed to cool and placed into a container which will be supplied by FCI. A calculation using the grate speed and time of the test will be performed to determine when to sample the ash from the grate for corn cob ash. Both samples will be submitted for standard ash analysis as listed below.

Ash samples are to be taken from the furnace heat transfer surfaces prior to the start of the test burns. The exact location of the samples will be determined after discussion with WMU operational personnel. An example location would be sample point 3 utilizing a metal cup attached to a metal rod of sufficient length to reach the tube surfaces and scrape ash from the surface for analysis. This is to be repeated once per day or test burn event during the Stage 1 test burns and samples archived appropriately in containers to be supplied by FCI.

Analyses required are as follows:

Composite Coal Sample:
1. Proximate
2. Sulfur

3. CHN
4. Heating Value (Btu)

Ash samples
1. Ash chemistry
2. Unburned carbon content (CHN)
3. Scanning electron microscopy (SEM) analysis (for agglomeration potential)

Visual and Image Analysis

A sample data sheet will be supplied by FCI to document ash buildup on heat transfer surfaces inside the furnace that may be exacerbated by the introduction of the corn cobs to the combustion system. Visual analysis and data recording of the ash layer on the heat transfer surfaces will begin prior to the Stage 1 test burn to provide the baseline for comparison and will continue for the entire test burn. Visual inspection and recording of the ash layer in the furnace should be performed at the beginning of each test burn event and once per hour thereafter. (The schedule of documentation and locations of visual inspection will be finalized after consultation with operational personnel at WMU.)

Additional visual analysis during the Stage 2 test burn should be performed through use of a high temperature combustion camera system that will record combustion characteristics of the furnace and ash buildup in the furnace. A high temperature camera system will be made available on a monthly lease basis.

General Sampling Locations

Sample Point 1 - Furnace grate exit – Boiler 3 (representative section at the end of the grate)
Sample Point 2 - View port southeast corner of Boiler 3 (1st Floor)
Sample Point 3 - View port center of North side Boiler 3 (2nd Floor)
Sample Point 4 - View port center of East side Boiler 3 (1st Floor)

Sample Storage

Samples not submitted for immediate analysis will be stored appropriately. When samples are taken they will be dated, the time of the sample noted, and the location of the sample listed and initialed.

F. Cost Projections

Costs To Date

A summary of costs expended through May 31, 2009 for Task 2.0 activities was prepared and is presented in Table 6 below. Subtask 2.1 was completed previously; Subtask 2.2 was completed with this Implementation Plan/Report.

Table 6 Subtask 2.0 Expenditures through May 31, 2009

Description	Date	Amount
DOE/NETL Grant Application	4/24/2008	$2,840.50
Application Postage	4/30/2008	$43.44
Subtask 2.1 Feasibility Analysis	5/31/2008	$13,340.80
Subtask 2.1 Feasibility Analysis	10/31/2008	$19,199.64
Subtask 2.1 Feasibility Analysis	10/31/2008	$14,986.58
WMU In-Kind	3/25/2009	$5,955.89
		$56,366.85
Subtask 2.2 Permitting	11/30/2008	$4,861.62
Subtask 2.2 MPCA Permitting Fees	12/1/2008	$1,679.10
Subtask 2.2 MPCA Permitting Fees	12/10/2008	$559.70
Subtask 2.2 Engineering Design	12/31/2008	$9,635.95
Subtask 2.2 Permitting	12/31/2008	$9,158.86
Subtask 2.2 Permitting - Newspaper Notice	1/22/2009	$428.40
Subtask 2.2 Engineering Design	2/19/2009	$7,017.14
Subtask 2.2 Permitting Fees	1/31/2009	$307.99
Subtask 2.2 Corn Cob Acquisition	2/28/2009	$7,184.92
Subtask 2.2 Permitting	2/28/2009	$669.60
WMU In-Kind	4/8/2009	$5,192.43
Subtask 2.2 Permitting	3/31/2009	$2,462.20
		$49,157.91
Subtask 2.3 Acquisition	3/5/2009	$100.23
Subtask 2.3 Acquisition	3/19/2009	$704.31
Subtask 2.3 Acquisition	3/19/2009	$928.59
Subtask 2.3 Acquisition	3/19/2009	$32.71
Subtask 2.3 Acquisition	3/19/2009	$132.82
Subtask 2.3 Acquisition	3/19/2009	$49.43
Subtask 2.3 Acquisition	3/19/2009	$834.96
Subtask 2.3 Acquisition	3/19/2009	$8,216.82
Subtask 2.3 Acquisition	4/9/2009	$1,887.36
Subtask 2.3 Acquisition	3/31/2009	$20,850.07
Subtask 2.3 Acquisition	3/31/2009	$259.70
Subtask 2.3 Acquisition	4/23/2009	$128.64
Subtask 2.3 Acquisition	4/23/2009	$2,860.00
Subtask 2.3 Acquisition	4/23/2009	$246.85
		$37,232.49
TOTAL		$142,757.25

Anticipated Additional Expenditures

Anticipated additional expenditures included those costs incurred but not reported as of May 31, 2009 for Subtasks 2.2, 2.3, and 2.4, as well as costs for Subtask 2.5 Test Burn and Analysis. Those anticipated expenditures are outlined below.

Subtask 2.1	Feasibility Study	$ 0.00
Subtask 2.2	Implementation Plan	$ 5,000.00
Subtask 2.3	Acquisition	$ 55,000.00
Subtask 2.4	Construction	$ 10,000.00
Subtask 2.5	Test Burn and Analysis	$ 60,000.00

Cob Harvest Costs Comparison – Projected vs. Actual

The table below presents the initial projected costs to purchase and harvest the cobs, haul the cobs to storage, and hire Mr. Vernon Flamme to harvest the cobs, compared to the final actual costs.

Three smaller farmers who were contacted concurrently with the Fossos had agreed to participate in the study. They agreed to sell their cobs for $27.50 per ton. However, even though their per-day haul rates were lower, because their harvesting and hauling equipment was smaller and slower, their haul costs were projected to be considerably higher than those projected for the Fosso farm. This resulted in an overall projected cost that was virtually the same as for the Fosso cobs. Because a single source was judged more easily managed for the purposes of this study, the Fosso's Church Lake Farm was selected to provide cobs for the WMU.

The Fossos agreed to sell the cobs for $40/ton, and haul the cobs for $750/day per truck. At the projected 100 acres/day harvest rate, and 0.75 tons/acre, haul costs were predicted at $10/ton. Actual haul costs were considerably higher, principally due to harvester equipment problems which idled the trucks for long periods.

As can be observed, the projected total cob cost based on the above costs plus $35/acre for Mr. Flamme's services, was $96/ton,. The actual cost came to more than 50% higher, at $148.87/ton. The increase was due not just to the higher haul costs, but also to a lower than projected cob yield – 0.67 tons/acre versus the projected 0.75 tons/acre.

The all-in cost of the electricity produced from the cobs during the test burns was projected to equal $128/ MW-hr, based on a cob Btu value equal to 75% of coal. The as-tested Btu value of the cobs was actually just 47% of the coal, due to the high cob moisture content, which returned an estimated electricity cost of $317/MW-hr. Using the same 47% moisture value, but substituting a $45 delivered cob cost, the projected cost of electricity from cobs would still have equaled an estimated $96/MW-hr.

Cob Harvest Costs Comparison -Projected vs. Actual

Farmer Name	Acres	Harvest Rate (ac/d)*	Haul Truck $/Day**	Total Tons	Chase Wagon Tractor Provided?	Farmer Cob Price/Ton	Cob Hauling Cost/Ton**	Flamme Cost/Ton***	TOTALS
Dan Tepfer	135	30	650	101.25	Y	$27.50	$28.89	$46.67	$10,434.38
Donovan Monson	146	45	650	109.5	Y	$27.50	$19.26	$46.67	$10,230.14
Ed Arndorfer	200	45	650	150	Y	$27.50	$19.26	$46.67	$14,013.89
	481			360.75		$27.50	$22.47	$46.67	$34,861.37
(3) Farmers	$9,920.63	total	$20.63	per acre					
Hauler	$8,105.74	total	$16.85	per acre					
Flamme	$16,835.00	total	$35.00	per acre					
Total Cost	$34,861.37		$72.48	per acre					
Total $/Ton	$96.64								

*harvest rates provided by producer

**Flamme quoted price

***contract rate $35/acre, harvesting 0.75 tons cobs /acre

Farmer Name	Acres	14 days Harvest Rate (ac/d)	13 days Haul Truck Ave/$/Day	Tons	Chase Wagon Tractor Provided?	Fosso Farmer Cob Price/Ton	Fosso+Flamme Cob Hauling Cost/Ton	Flamme Cost/Ton*** Cost/Ton	TOTALS
Fosso+Flamme	650	100	750	487.5	Y	$40.00	$10.00	$46.67	$47,125.00
Fosso+Flamme	631	45	1827	421	Y	$40	$56	$52	$62,676.00
Fosso Cobs	$19,500.00	total	$30.90	per acre	$16,840.00	total	$26.69	per acre	
Hauler Total	$4,875.00	total	$7.73	per acre	$23,751.00	total	$37.64	per acre	
Flamme Harvest	$22,750.00	total	$36.05	per acre	$22,085.00	total	$35.00	per acre	
Total Cost	$47,125.00		$74.68	per acre	$62,676.00	total	$87.40	per acre	
Total Tons	487.5				421	total tons			
Total $/Ton	$96.67				$148.87	per ton			
Tons Cobs Harvested				360.75	487.5	421	(measured)		
MWh produced				271	366	198	(estimated)		
Incremental Cost per MWh*				$128.85	$128.89	$316.75	(calculated)*		
Projected Electricity Cost per MWh @ $45 ton cobs net cost delivered, 47% moisture cobs*						$95.74			
Projected Electricity Cost per MWh @ $45 ton cobs net cost delivered, 12% moisture cobs**						$57.15			

ASSUMPTIONS

*1 ton coal to produce 1 MWh;

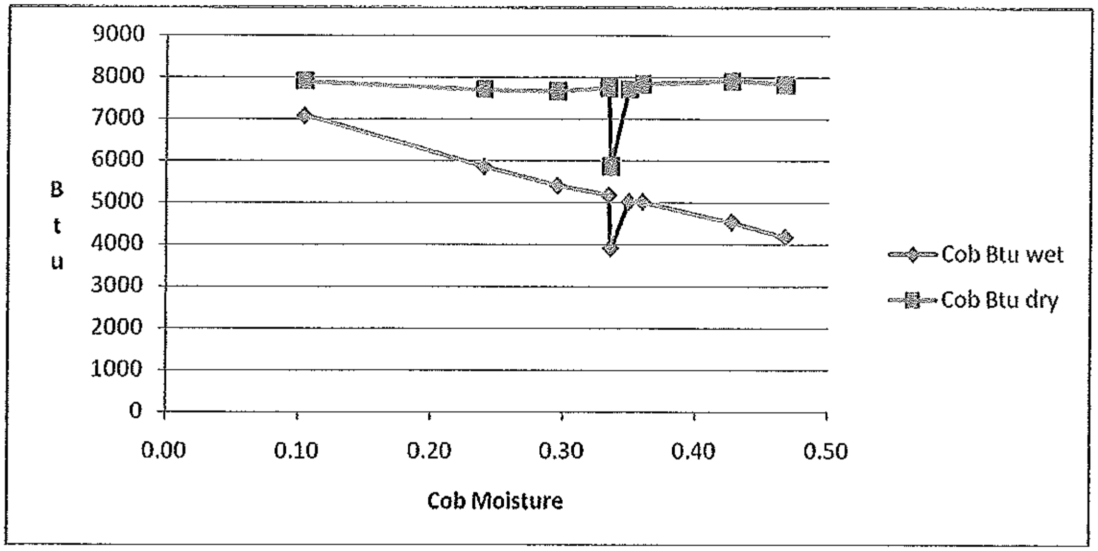
*1 /0.75 (coal/cob Btu ratio)

*8785/4167 coal/cob Btu ratio, 2.11 tons cobs/MW-hr

*actual Test Burn Btu Ratio: 1/0.47 (coal/cob)

**8785/6900 coal/cob Btu ratio, 1.27 tons cobs/MW-hr

The following graph shows the relationship between cob moisture and cob Btu value, as determined from laboratory analyses. The spreadsheet used to calculate the values and create the chart is included in Appendix D.



As can be observed there is a nearly linear relationship between moisture and Btu value. (The values at roughly 35% cob moisture are considered inaccurate and were removed from the calculation.) The Btu/lb value for the cobs falls at a rate of about 75 Btu per 1% decline in moisture. Therefore, cobs at 12% moisture would be expected to provide about 6900 Btu/lb. At 6900 Btu and at $45(net)/ton delivered, the projected costs of electricity from cobs would equal approximately $57/MW-hr.

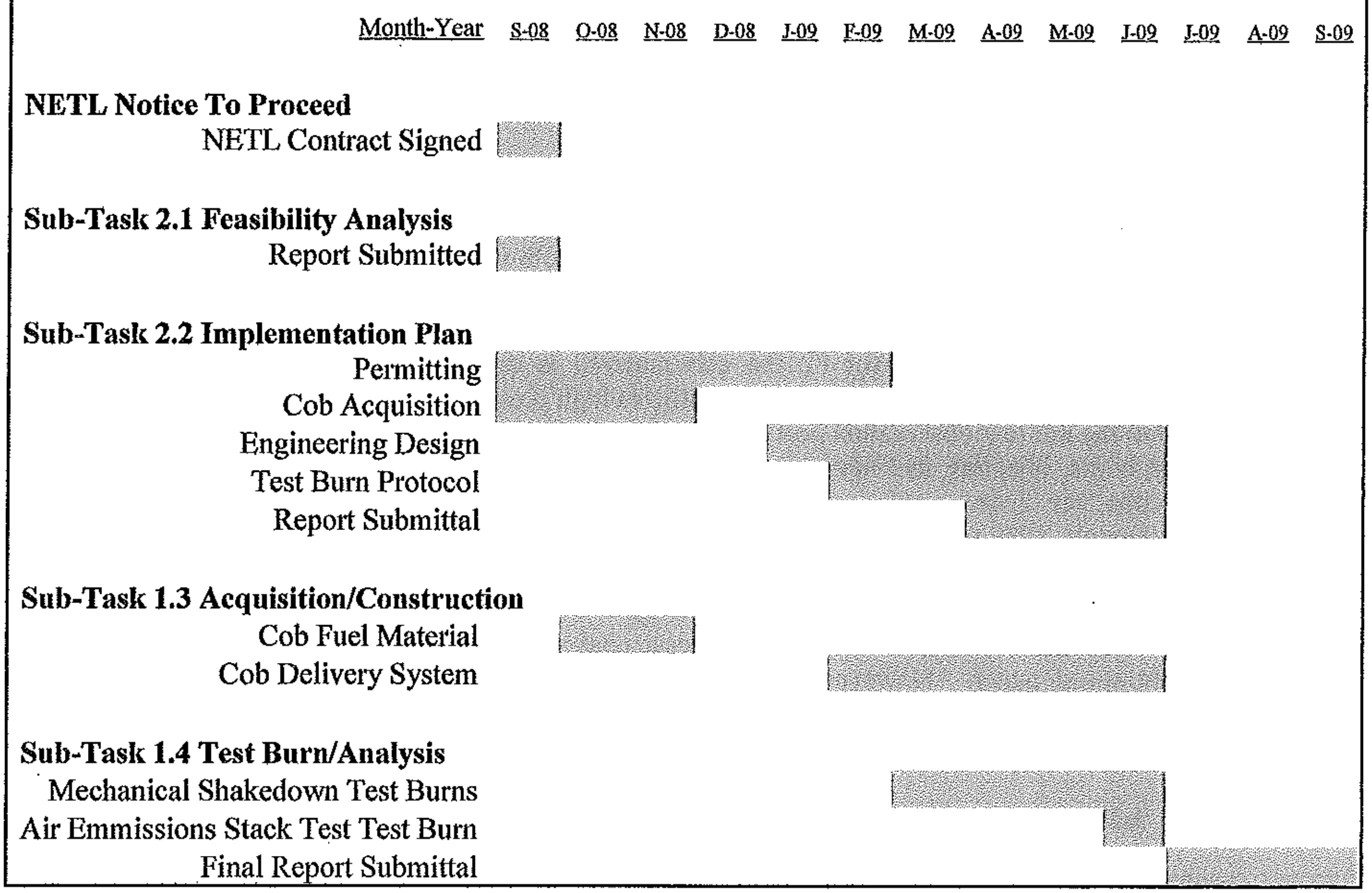
G. Project Schedule

A Project Schedule for Subtask 2.0 was prepared and is presented in the Table below. Fuel delivery design, engineering, and installation were essentially complete but additional design changes and associated construction were anticipated as the test burns moved forward. Mechanical shakedown test burns were conducted on March 31 and April 1 prior to the air emissions stack tests. The stack testing began June 17th and continued through the 19th. Following completion of the stack testing and receipt of the test measurements and laboratory analysis results, a final report was prepared by the stack testing company.

WILLMAR MUNICIPAL UTILITIES POWER GENERATION STUDY

TASK 2.0 CORN COB/COAL CO-COMBUSTION STUDY

PROJECT SCHEDULE



SECTION III

Sub-Task 2.5 Test Burn and Analysis

Initial test firing of corn cobs was conducted at Willmar Municipal Utilities ("WMU"), in boiler No. 3 on Tuesday, March 31, 2009 and Wednesday, April 1, 2009. The purpose of this test was to 1) demonstrate that corn cobs could: a) be introduced into the boiler furnace at a rate sufficient to satisfy WMU renewable fuel requirements, and b) be successfully combusted with coal, 2) make preliminary observations of the impact on boiler performance including stack emissions, and 3) make recommendations with respect to test procedure modifications for future test burns.

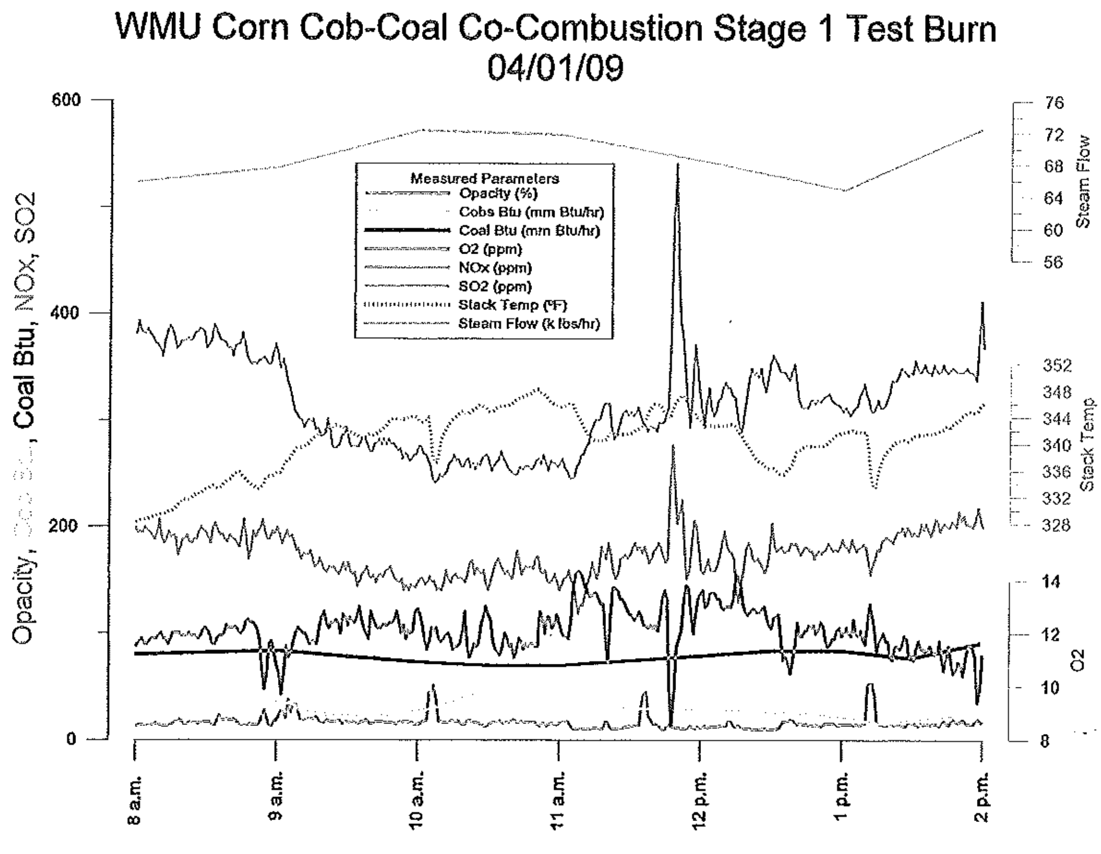
A. Cob Injection System Equipment

A design was developed and Willmar plant staff installed a temporary corn cob conveying and injection system. The system includes both variable speed (auger #1) and fixed speed (auger #2) agricultural auger conveyors that convey chopped corn cobs (2" minus) from the power plant east coal storage silo, to a drop pipe on the left hand side of boiler No. 3. From conveyor #2 the cob material is dropped to an injection box, fabricated by plant staff. The injection box utilizes high pressure over-fire air to blow the cobs into the left rear observation port of boiler No. 3. This system was successful during the test burns, injecting fuel material at rates varying from one to five tons of chopped corn cobs per hour. This corresponded on the test dates, on a BTU basis, to approximately 10% to 40% of the total corn cob/coal mixture being fired. The feed system worked very well but required continuous operator attention at the inlet of the variable speed auger, which serves as a metering conveyor. It was difficult to feed the cob material at a consistent rate from the east coal silo live shelf to the inlet of the variable speed auger. However, after some experience was gained, plant staff was successful in maintaining a relatively continuous and uniform flow of cob material to the auger. Photographs of the equipment are included in Appendix E.

B. Initial Firing of Corn Cobs

Initial co-combustion of corn cobs and PRB coal commenced on March 31, 2009 at 9:00 a.m. Corn cobs were fed into the boiler with the feed rate gradually increased to approximately 10% of the boiler's heat input. For this test, the coal feed was placed on "hand control" and left in a fixed position. As corn cobs were added, steam output increased with a corresponding increase in electrical generation.

On the following day, April 1, 2009, the corn cob firing rate was increased to range between approximately 20% and 40% of the #3 boiler heat input. The average cob firing rate was approximately 30% on a calculated heat input basis. This rate was held for approximately four hours. During this period of time, emissions monitoring revealed the results of cob injection shown on the graph presented below.



As can be observed on the graph, following the addition of cobs the emission monitor indicated a distinct reduction in SO_2 and NO_X with very little increase in opacity. Nitrogen oxide levels likely decreased because of the higher moisture content in the corn cobs reducing peak flame temperature; sulfur dioxide levels decreased because the corn cobs are lower in sulfur than the PRB coal. Opacity increased slightly perhaps because of fly ash carry over due to a higher portion of fines in the corn cob ash, as well as lower density of the cob material resulting in more combustion occurring above the bed.

Flue gas temperature corresponded qualitatively to the additional Btu's added via the corn cobs, as did steam flow. However, the increases did not entirely match the expected increase due to firing of corn cobs. This can be explained by the higher moisture content to Btu ratio of the corn cobs, compared to PRB coal. The higher moisture content produces more water vapor in the flue gas when compared to just firing coal. Water vapor has a higher heat capacity than the other two main constituents of flue gas, CO_2 and nitrogen. A higher heat input is required to vaporize the additional water which will be reflected in a reduction in boiler efficiency.

The spikes on the opacity graph represent soot blowing events. The spikes on the oxygen, NO_X, and SO_2 lines represent a cob injection plugging event. The cob air injection system normally added significant amounts of O_2 to the firebox. When the cob injector plugged, O_2 and moisture input plummeted, with a corresponding temporary increase in NO_X and SO_2.

C. Visual Observations

Visual observations were made of furnace conditions by looking into all accessible observation ports. Observations on both days indicated that combustion appeared to be only slightly changed from conditions previously observed when firing 100% PRB coal. Photographs of the firebox conditions are included in Appendix E.

D. Material Samples

Sample Collection

During the test burn, approximately 4 tons of corn cobs were burned on March 31 at a Btu-based cob firing rate of approximately 10% of total fuel input, with another 10 tons burned on April 1 at cob firing rates up to 40%. Samples of the coal and corn cob fuels were taken on April 1 for laboratory proximate/ultimate analyses. Copies of the laboratory reports are included in Appendix F.

Ash samples including bottom ash and mechanical collector fly ash were taken on both test dates, during PRB coal firing only as well as during firing of PRB coal plus corn cobs. Visual examination of the ash samples indicated no discernible differences. Laboratory analyses of composites of the samples were performed to determine any changes in ash composition, characteristics and properties as a result of corn cob firing. Copies of the laboratory reports are included in Appendix F.

Sample Analysis Results

The results of the April 1 cob and coal Proximate/Ultimate analyses are presented on Tables 1 and 2 in Section II above.

The corn cobs collected during the test burn were also analyzed for moisture content and were found to contain approximately 47% moisture, apparently due to recent rain and snow that had accumulated on the outdoor pile of corn cobs.

A comparison of the ash analyses of the pre-test and during-test cyclone and bottom ash is presented in Table 7 below.

Table 7. Comparison of Co-Combustion Coal Ash and Coal-Cob Ash Analyses Pre-Test Burn (Coal Only) and During-Test Burn (Coal and Cob Combined)

Ash Analysis (wt%)	Cyclone Ash Pre-Test Burn 3/31/09	Cyclone Ash During-Test Burn 4/1/09	Bottom Ash Pre-Test Burn 3/31/09	Bottom Ash During-Test Burn 4/1/09
Silicon Oxide	51.44	54.19	54.52	53.31
Aluminum Oxide	19.34	19.91	18.81	19.42
Titanium Oxide	0.83	0.83	0.95	0.87
Iron Oxide	3.20	2.34	8.06	7.43
Calcium Oxide	13.51	12.21	10.78	10.71
Magnesium Oxide	4.91	4.61	3.53	3.54
Potassium Oxide	0.88	1.74	0.59	0.65
Sodium Oxide	1.05	0.39	0.24	0.31
SO_3	2.65	1.48	0.83	0.92
P_2O_5	0.70	0.69	0.53	0.56
Strontium Oxide	0.23	0.22	0.17	0.16
Barium Oxide	0.86	0.60	0.86	0.81
Mangenese Oxide	0.16	0.15	0.35	0.13
Moisture	0.09	0.09	0.04	0.03
LOI	3.73	5.45	0.40	1.49
Mercury (ug/g)	<0.02	0.024	<0.02	<0.02

Only relatively small differences can be observed between the pre and during test burn ash sample analyses results. It should be noted that the lab analysis reporting limit for Hg was 0.02 ug/g. No Hg was detected in the test burn cob composite sample. The Hg level in the test burn coal sample was 0.079 ug/g. Thus it would appear that the addition of cobs to the fuel mix lowered the mercury content of the co-combustion ash. Also notable is that the decrease in SO_3 percentage in the during test cyclone ash is greater than the corresponding increase in the during test bottom ash. This net decrease in SO_3 is most likely due to the lower percentage of sulfur in the cobs compared to the coal. This decrease also correlates with the decrease in SO_2 in the flue gas when combusting cobs, as shown on the emission monitor graph above.

E. Initial Test Burn Completion

At the completion of the initial test firing on April 1, 2009 the remaining corn cobs in the storage silo were burned and firing returned to normal conditions on 100% PRB coal. The boiler was shut down over the April 4-5 weekend in preparation for the annual spring outage, during which time necessary inspections and related repair and maintenance work were accomplished.

F. Emission Compliance Testing

Emission compliance testing while corn cobs were co-combusted with coal was performed on the WMU Boiler #3 on June 17, 18, and 19, 2009. FCI monitored and assisted the co-combustion test burns, recorded fuel feed rate data, and collected cob and coal fuel samples for laboratory analysis.

The rate of cob injection was measured and is compared to the coal feed rates in the tables below. Table 8 presents the percent of cobs by Btu projected on the day of the tests based on Btu analyses of samples collected previously. Table 9 shows the percent of cobs by Btu results based on analyses of the fuel samples collected on the day of the tests.

Table 8. WMU AQ Emissions Testing Fuel Feed Rates (est. Btu)

TEST 1			Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	% Cobs
6/17	Clock Time	Minutes	Total LB	TPH	Btu/Hr	Total LB	TPH	Btu/Hr	TPH	Mm Btu/hr	By Btu
Run 1	9:40 to 11:30	110	18076	4.93	86.45	10100	2.75	28.10	35.85%	114.55	24.53%
Run 2	12:15 to 14:00	105	17350	4.96	86.93	9330	2.67	27.19	34.97%	114.12	23.83%
Run 3	14:50 to 16:51	121	20024	4.96	87.06	9280	2.30	23.47	31.67%	110.53	21.23%
										Average =	**23.20%**
TEST 2		Minutes	Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	Cobs %
Run 1	7:35 to 9:17	102	18009	5.30	92.88	4784	1.41	14.35	20.99%	107.24	13.38%
Run 2	9:45 to 11:27	102	17120	5.04	88.30	5904	1.74	17.71	25.64%	106.01	16.71%
Run 3	12:00 to 13:28	88	15197	5.18	90.85	4266	1.45	14.83	21.92%	105.68	14.04%
										Average =	**14.71%**
TEST 3		Minutes	Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	Cobs %
Run 1	7:20 to 9:00	100	17922	5.38	94.28	2309	0.69	7.07	11.41%	101.35	6.97%
Run 2	9:30 to 11:05	95	18077	5.71	100.10	2800	0.88	9.02	13.41%	109.12	8.26%
Run 3	11:35 to 13:10	95	18604	5.87	103.02	2060	0.65	6.64	9.97%	109.66	6.05%
										Average =	**7.10%**

Estimated Fuel BTU/lb	
Coal	Cob
8768	5100

Table 9. WMU AQ Emmissions Testing Fuel Feed Rates (actual Btu)

TEST 1			Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	% Cobs
6/17	Clock Time	Minutes	Total LB	TPH	Btu/Hr	Total LB	TPH	Btu/Hr	TPH	mmBtu/hr	By Btu
Run 1	9:40 to 11:30	110	18530	5.05	89.28	10100	2.75	35.28%	21.49	89.63	19.40%
Run 2	12:15 to 14:00	105	16975	4.85	85.68	9330	2.67	35.47%	20.80	86.03	19.53%
Run 3	14:50 to 16:51	121	19199	4.76	84.09	9280	2.30	32.59%	17.95	84.42	17.59%
										Average =	**18.84%**
TEST 2			Coal Fired			Cobs Fired		% Cobs			% Cobs
6/18	Clock Time	Minutes	Total LB	TPH	mm Btu/Hr	Total LB	TPH	TPH	mm Btu/Hr	Total	Btu/hr
Run 1	7:35 to 9:17	102	18009	5.30	93.65	4784	1.41	20.99%	14.12	93.86	13.10%
Run 2	9:45 to 11:27	102	17120	5.04	89.02	5904	1.74	25.64%	17.42	89.28	16.37%
Run 3	12:00 to 13:28	88	15197	5.18	91.60	4266	1.45	21.92%	14.59	91.82	13.74%
										Average =	**14.40%**
TEST 3			Coal Fired			Cobs Fired		% Cobs			% Cobs
6/19	Clock Time	Minutes	Total LB	TPH	mm Btu/Hr	Total LB	TPH	TPH	mm Btu/Hr	Total	Btu/hr
Run 1	7:20 to 9:00	100	17922	5.38	93.37	2309	0.69	11.41%	7.48	93.48	7.42%
Run 2	9:30 to 11:05	95	18077	5.71	99.13	2800	0.88	13.41%	9.55	99.27	8.79%
Run 3	11:35 to 13:10	95	18604	5.87	102.02	2060	0.65	9.97%	7.03	102.12	6.44%
										Average =	**7.55%**

Actual Fuel BTU/lb		
Coal	Cob	
8833	3901*	25% test
8840	5017	15% test
8683	5400	5% test

*This result is believed to be anomalous – see Moisture/Cost Chart on Page 48 above and in Appendix D

As can be observed, laboratory analyses of the cob and coal samples revealed that the actual Btu values of the cobs on the day of the tests were lower than projected. Thus the actual % Cobs by Btu values varied from true values more than would be desired, but remained within an acceptable range.

Table 10. Emission Test Cob Composite Proximate/Ultimate Analysis Results

ANALYTE		6/17 Test 1 Cob Composite	6/18 Test 2 Cob Composite	6/19 Test 3 Cob Composite
Moisture	%	33.52	34.19	29.52
Ash	%	18.89	6.48	3.77
Volatile Matter	%	41.92	47.29	53.29
Fixed Carbon	%	5.68	11.32	13.42
BTU/lb		3901	5017	5400
Total Sulfur	%	0.06	0.06	0.04
Carbon	%	23.36	28.67	30.86
Hydrogen	%	6.52	7.35	7.21
Nitrogen	%	0.33	0.53	0.47
Oxygen	%	0.06	56.91	57.65
Chlorine	ug/g	1550	1780	1860
Fluorine	ug/g	<70	<70	<70
Mercury	ug/g	0.026	0.022	0.022

Table 11. Emission Test Coal Composite Proximate/Ultimate Analysis Results

ANALYTE		6/17 Test 1 Coal Composite	6/18 Test 2 Coal Composite	6/19 Test 3 Coal Composite
Moisture	%	24.61	24.88	24.07
Ash	%	8.88	8.71	10.08
Volatile Matter	%	28.26	28.30	28.41
Fixed Carbon	%	38.25	38.11	37.44
BTU/lb		8833	8840	8663
Total Sulfur	%	0.73	0.59	0.79
Carbon	%	50.66	50.92	50.92
Hydrogen	%	6.39	6.44	6.26
Nitrogen	%	0.82	0.78	0.81
Oxygen	%	32.52	32.56	31.14
Chlorine	ug/g	<20	<20	<20
Fluorine	ug/g	<70	<70	<70
Mercury	ug/g	0.060	0.077	0.057

Tables 10 and 11 above present the results of laboratory analyses of the coal and cob composite samples collected during the emission compliance testing. The samples were collected directly from the fuel flowing into the coal hoppers and the "Cob Rocket".

The above comparison between coal and cobs is instructive in understanding the real source of heating value in fuels. Correcting for moisture content (~75 Btu/1% moisture in cobs), the ratio between Btu's and carbon content in both fuels is almost identical (~0.6).

A significant difference between the two fuels is noted in the mercury analysis results. The average Hg level in the emission test cob samples was 0.023 ug/g. The average Hg level in the emission test coal samples was 0.065 ug/g. As discussed above, the lower Hg levels in the cobs likely lowered the Hg level in the co-combustion emission test ash.

Another, less positive difference between the two fuels is noted in the chlorine analysis results. No chlorine was detected in the coal samples, but the cobs contained an average 1,730 ug/g. Chlorine levels as high as these may affect the co-combustion permitting process.

The emission compliance testing was performed by Interpoll Laboratories, Inc. of Circle Pines, Minnesota. Complete review of the MPCA-required stack testing results is beyond the scope of this report. However, partial results were made available for the purposes of this co-combustion report. The table following presents a summary of the emission test data that was made available, with CEM data collected by WMU equipment, and cob feed rate data recorded by FCI.

The WMU CEM data correspond very well with the Interpoll emission test data. The NOx and CO values varied by no more than about 3% from one data set to the other. NOx and CO levels decreased with the addition of cobs to the combustion process. However, HCL increased to a level above what is allowable under Minnesota and Federal pollution control rules. These relatively high hydrochloric acid levels in the exhaust gas reflect the relatively high chlorine levels in the cob fuel.

Post combustion treatment may be required to remove the HCL from the exhaust gas stream. However, planned power plant upgrades include a dry scrubber system that will likely resolve this issue. No other air pollutant issues are anticipated.

Table 12. Emission Testing Results Summary

Emission Testing CEM Results*					Emission Testing Flue Gas Results**						
Test 1 06/17/09	**NOx***	**O_2***	**CO ***	**Cobs *****	**PM****	**PM10****	**Nox****	**CO****	**VOC****	**HCL****	**HF****
	ppm,d	%	ppm,d	%	lb/mmBtu	lb/mmBtu	ppm,d	ppm,d	ppm,d	ppm, 7%O2	ppm, 7%O2
Run 1 Averages	203.556	12.060	104.982	19.40%							
Run 2 Averages	191.370	11.898	113.884	19.53%							
Run 3 Averages	186.742	11.384	106.896	17.59%							
Test 1 Averages	**193.890**	**11.781**	**108.588**	**18.84%**	**0.356**	**0.298**	**200.32**	**108.30**	**2.03**	**44.37**	**3.47**
Test 2 06/18/09	NOx ppm	% O_2	CO ppm	% Cobs							
Run 1 Averages	235.956	12.598	163.575	13.10%							
Run 2 Averages	235.956	12.598	163.575	16.37%							
Run 3 Averages	212.899	12.816	142.040	13.74%							
Test 2 Averages	**228.270**	**12.671**	**156.397**	**14.40%**	**0.376**	**0.306**	**225.42**	**159.77**	**0.99**	**31.41**	**3.45**
Test 3 06/19/09	NOx ppm	% O_2	CO ppm	% Cobs							
Run 1 Averages	224.462	13.197	105.389	7.42%							
Run 2 Averages	231.254	13.009	126.522	8.79%							
Run 3 Averages	222.110	13.238	112.359	6.44%							
Test 3 Averages	**225.942**	**13.148**	**114.757**	**7.55%**	**0.439**	**0.273**	**227.05**	**112.99**	**1.12**	**15.43**	**3.83**

* WMU data table included in Appendix G
**Interpoll Labs data table included in Appendix G
***FCI data table included in Appendix G

SECTION IV

Summary and Recommendations

Feasibility Analysis Conclusions

The purpose of the feasibility study was to identify the issues – problematic or otherwise - involved in corn cob co-combustion with coal. No "show stoppers" were identified and many positive aspects were associated with the corn cob co-combustion with coal. Laboratory analyses of the corn cob fuel indicated that no boiler depositional issues, ash volume, or other pollutant issues should be expected. Based on preliminary conversations with the MPCA it was expected that the WMU would have little problem in obtaining permitting for co-combustion of corn cobs. Similarly, there appeared to be no major fuel delivery obstacles to performing the corn cob co-combustion study and it was recommended that the project continue as proposed. Some of the positive aspects associated with corn cob co-combustion are presented below:

- The timing is right for the WMU – design and installation of the final cob fuel delivery system can be coordinated with planned boiler upgrades.
- The upgraded fuel delivery system will be designed to accept multiple fuels.
- The fuel delivery system will be designed to allow continued 100% coal use.
- A biofuels capability, whether used or not, will add energy security.
- The design capability will make the Minnesota Renewable Portfolio Standard achievable.
- WMU's ash disposal issues will likely improve if corn cobs are burned.
- Future carbon trading may be possible via reduced fossil CO_2 emissions.
- Environmental benefits will accrue, such as reduced Hg and reduced CO_2 emissions.
- Corn cobs will be purchased locally and create a significant positive effect on the local economy.
- Success will focus positive attention on WMU and the City of Willmar.

Feasibility Analysis Recommendations

It was recommended that the WMU move forward with Phase 1.2 (Sub-Task 2.2) of the Corn Cob Co-Combustion Feasibility Study as proposed.

Recommendations were made to 1) complete an agreement with a local producer to harvest cobs from approximately 700 acres 2) complete an agreement with Mr. Vernon Flamme of North Bend, Nebraska to conduct the pilot project cob harvest, 3) make arrangements with the City of Willmar to store cobs at the former Municipal Airport, and 4) reduce the size of the harvested cobs in order to allow injection through a small view port on the boiler firebox wall.

Permitting, Cob Acquisition, Engineering Design, and Construction Planning Results

Preparations for the co-combustion test burns included: application for an Air Quality Permit from the Minnesota Pollution Control Agency to conduct the co-combustion test burns; review of the existing WMU Power Plant configuration; identification of and a site visit to a similar facility in Iowa; cob fuel analyses; review of cob grinding machines; and agreements with a corn grower, a cob harvester, and the City of Willmar to procure, harvest, and store cobs.

The WMU facility is a major source under 40 CFR Section 52.21 (Prevention of Significant Deterioration), a synthetic minor for HAPs, and considered a major source under the federal operation permits program (40 CFR pt. 70). Numerous meetings and discussions with the MPCA resulted in an agreement with the MPCA whereby the WMU would be granted an amendment to their existing Air Emission Permit to combust up to 500 tons of Allowable Biomass on a test burn basis, over a defined time period, to allow the collection of air quality data on which to base any later permanent use permits. Wenck Associates, Inc., of Woodbury, Minnesota prepared the permit application.

A power plant in Pella, IA that uses stoker boilers similar to those at the WMU was observed during a corn cob-coal co-combustion test burn of approximately 5% corn cobs by weight. The Pella plant mixed ground cobs with coal at the origin of the conveyor belt that feeds their boilers, roughly 300 feet from the boiler. The density difference between the two fuels resulted in fuel segregation on the belt and in the hopper and ultimately, actual cob supply to only one of their three boilers.

Pre-test burn laboratory analyses found that on a Btu comparison basis, cob ash production equals only ~13% of coal ash production. Therefore, no significant slagging or fouling from co-combustion was anticipated. However, moisture measurements found that the stored cobs' moisture level was higher than desired. The cob moisture content increased during the storage period prior to the test burns, from 28% at harvest to 47% at the time of co-combustion.

Four grinders to size the cobs for air injection into the firebox were evaluated at the airport storage site. RW Farms of Chanhassen, Minnesota was retained to grind the 421 tons of cobs stored on the former Willmar airport runway, to a 2-inch and minus size.

Agreements were reached to procure, harvest, and store cobs: with a local corn grower – Fosso Farms of Pennock, Minnesota; with a cob harvester – Vernon Flamme of North Bend, Nebraska; and with the City of Willmar, Minnesota, respectively. Between October 30 and November 15, 2008, 421 tons of cobs were harvested from 631 acres in Kandiyohi, Chippewa and Swift Counties. The cobs were hauled and stored on the former Willmar airport runway.

Cost projections were prepared that predicted the delivered cost of cobs for the Power Plant Study would equal $96/ton. Actual costs were driven higher by lower than projected cob yields and by corn harvester breakdowns that resulted in much higher trucking costs. The actual final cost of the cobs as delivered to the Willmar airport amounted to \$149/ton. The associated cost for the electricity generated by combusting the cobs equaled approximately \$317/MW-hr. However, projections derived from the study results indicate that if the cobs can be dried to 12% moisture, and the cobs can be delivered to the power plant for a net price of \$45/ton, the associated electricity cost for future generation should equal approximately \$57/MW-hr.

Test Burn Conclusions

The corn cob-coal co-combustion test burns were deemed to be successful. They demonstrated that:

a. Corn cobs can be burned in Boiler No. 3 on the existing Detroit Stoker traveling grate stoker in quantities exceeding 40% of the boilers heat input.
b. Boiler operating parameters did not appear to be adversely affected during the initial tests. Longer term testing was recommended to assure reliable and consistent fuel injection on a continuous burn basis and to establish and measure air quality emission data.

Test Burn Recommendations

Longer term co-combustion test firing was recommended to determine the following:

- slagging or fouling tendencies, determined through sample collection and analysis, and by visual observation of the furnace and super heater area during operation,
- stack compliance and emission monitoring, and
- Potential changes in boiler performance.

The above characteristics were evaluated during the June 2009 emission compliance testing. No increase in slagging was observed. A decrease in NOx and CO levels was observed in the exhaust gases in addition to decreased Hg in the ash. HCL emissions increased during co-combustion to potentially problematic levels. However, planned upgrades to the power plant will likely remediate any future increases in HCL emissions.

Study Results and Recommendations

From the Co-Combustion Study results, and from the emission compliance testing data, the WMU was able to make the decision to proceed with the steps necessary to include in planned permanent power modifications, additional modifications to allow a corn cob-coal co-combustion system, including:

a. application for necessary MPCA Air Quality permit modifications,
b. modification of the existing boiler fuel feed systems, and
c. establishing corn cob sources and availability.

Both the permit application and preparations for plant modifications that will allow the use of biofuels are underway.

The opportunity to establish corn cob supply sources exists via a newly established USDA Farm Service Agency program, known as the Biomass Crop Assistance Program (BCAP). The BCAP program provides financial assistance to producers of biomass material for use as heat, power, or biofuels. Participation in the program requires that a participating entity such as the Willmar Municipal Utilities obtain designation as a Qualified Biomass Conversion Facility. Once a facility is so designated - by simply completing an application for FSA review and approval - the FSA will enter into contracts with area producers who will provide biomass to the facility. The FSA will pay the producers up to 50% of the cost of the delivered biomass, up to $45 per ton. The facility will accept the delivery of the biomass and pay the remainder of the contract price to the producer. The program has established two year contracts initially, with plans to expand to five year contracts subsequently (beginning in 2011).

As a first step toward establishing the near-term capability of the WMU to produce electricity economically from renewable biomass fuels, FCI recommends that the WMU obtain designation as a Biomass Conversion Facility.

Since cob harvest can only occur in the fall, but co-combustion must occur year-around, the WMU will need to store cobs. The cobs stored for the co-combustion study were observed to absorb significant amounts of moisture over the winter months while exposed on the former Willmar airport runway. The added moisture significantly reduced the heating value and thus the economic value of the cobs. Therefore, it would appear that for future cob storage, some sort of covered storage will be desirable. FCI recommends that an additional study be completed to evaluate the cost-effectiveness of potential types of covered cob storage.

This report was prepared by:

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APPENDICES

APPENDIX A

Feasibility Report References

APPENDIX A: Feasibility Analysis

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APPENDIX B

Pella, IA Site Visit Notes

MEETING NOTES

Date: **Wednesday, December 3, 2008**

Project: **Willmar Municipal Utilities Power Plant Improvement Project ("Power Plant")**

Location: **Pella, Iowa**

Subject: **Inspection and Observations, Test Firing of Coal and Corn Cob Fuel Mixture at Pella, Iowa Municipal Utility Power Plant**

Reference: **Project Number 07-122 WMU**

Attendees: **Willmar Municipal Utilities ("WMU")**

Bruce Gomm, General Manager - WMU
Ken Nash, Superintendent Power Production - WMU
Jon Folkedahl – Folkedahl Consulting, Inc.

City of Pella

Ben McBride, Asst. Electric Director
Mike Norman, Instrument Control Technician

University of Missouri

Gregg Coffin, P.E., Superintendent- MU Power Plant

PCI Management & Consulting Company ("PCI")

Wayne Miller, Senior Mechanical Engineer
Chuck Tyburk, Project Manager

The City of Pella, Iowa ("Pella") owns and operates a coal fired power plant. The coal fired power plant includes two (2) Erie City stoker fired boilers equipped with Detroit Stokers. The boilers were originally designed for Illinois Basin Coal and some time ago a fuel conversion was made to screened PRB Coal.

The Pella has decided to embark on a program to identify and test fire a wide range biomass renewable fuels including:

a. Waste wood.

b. TDF.
c. Corn cobs.
d. Waste corn.
e. Other agricultural waste products.

This is being done to:

a. Reduce fuel costs.
b. Reduce sulfur emissions.
c. Otherwise improve the "Green" aspects of the plant.

Willmar Municipal Utilities ("WMU") is contemplating a conversion of its stoker fired boiler to allow firing up to 20-25% of chopped corn cobs available in the Willmar area. WMU plans to test fire corn cobs in early 2009, and depending on the test results embark on a program to add the necessary permanent equipment, facilities and systems to allow the burning a mixture of coal and corn cobs.

Pella had received a load of corn cobs and was test firing a mixture of coal and corn cobs on the date of the inspection. In summary the firing of a mixture of corn cobs and PRB coal (the same coal burned by Willmar) in a stoker fired boiler appears to be successful.

The following are significant items of note from this meeting and inspection:

1. The Pella Municipal Power Plant includes among another equipment two (2) Erie City stoker fired boilers of approximate capacity of 150 thousand pounds per hour each. The two (2) boilers supply steam on a steam header system at 900 psig 900 °F to two (2) steam turbine generators with a total electric capacity of approximately 34 MW. The boilers are equipped with Detroit Stokers. The original mechanical drive coal feeders have been replaced with Detroit's newer Ultrafeed Coal Distributors, each independently operated with electric motor drives.

   The boilers are typical of Midwest styled stoker boilers designed to operate on Midwest high sulfur coal. Sometime ago a fuel conversion to PRB coal was made to lower sulfur emissions. The utility purchases PRB coal from an Alliant Energy power plant nearby where it is screened and then is delivered by truck to the plant.

Plant & Facilities

2. The plant is operated as a peaking plant, operating maximum hours during the summer and minimal time during the winter. During the winter months typically only one (1) boiler is operated at minimum load (approximately 6-7 MW output) to provide heat for the power plant building.

   The plant is generally in good condition and it is typical of a small municipal power plant.

The utility desires to reduce sulfur emissions and respond to future anticipated carbon dioxide emission reductions by utilizing biomass or other bio-renewable fuels which have zero carbon emissions. Recently the plant has embarked on a program to identify, secure, and test fire a range of bio-renewable fuels including:

a. Waste wood.
b. Construction and demolition debris ("C&D").
c. Reclaimed wood from landfills.
d. Corn cobs.
e. Waste seed corn.
f. Other agricultural waste products.
g. Tire derived fuel (TDF).

Of particular interest are the corn cobs as Willmar Municipal Utilities plans to test fire and ultimately modify its stoker fired boiler to burn corn cobs which are abundantly available in the Willmar, Minnesota area.

3. The existing fuel delivery system includes a system of bucket elevators and belt conveyors, typical for a stoker fired boiler. A bucket elevator elevates coal to a horizontal in feed conveyor, which, through a plow feeder, supplies coal to the two (2) coal bunkers serving each stoker fired boiler. This system is well suited for receiving, unloading, and feeding coal to the coal bunkers. The bunkers discharge into a non segregating chute, which supplies coal to the individual feeders which feed coal to the grate. This system works very well on coal, but is not an ideal system for feeding irregular size fuel such as waste wood, C&D, and corn cobs. Blended fuel tends to segregate and is distributed unevenly on the grate.

4. The utility staff reported that waste wood and TDF were burned successfully only in limited quantities because of fuel handling system problems, particularly with the TDF fuel. The utility recently procured approximately 400 tons of corn cobs, which were harvested in the local area this fall.

5. The corn cobs were collected from combine operations in a specially designed trailer that was attached to the combine. This device was manufactured by the Pella, Iowa based Vermeer Manufacturing Company and included a wagon type trailer with a feed conveyor and mechanism for eliminating much of the non corn cob material harvested from the field including corn husks. The corn cobs were collected and delivered to the plant site. An initial test firing of the corn cobs was made without any chopping or grinding. Utility staff reported that in the limited quantities the whole cobs were able to be fed with the coal, the corn cobs appear to be able to be burned successfully. Pella staff reported that corn cob coal mixture was estimated to be approximately 5-10% corn cobs by weight. The second test, which was conducted on the day of the visit, included the chopping of the corn cobs to an approximate size of two inch (2) by zero (0). To accomplish this Pella acquired a tub grinder on a rental basis and ground the existing pile of corn cobs to the two (2) by zero (0) size. This material was fed by front end loader to the existing coal hopper where the cobs were mixed with coal. The mix was elevated by

bucket elevator and distributed to the coal bunker by feed conveyor. Observations indicated that a mixture of maybe 5-10% corn cobs was being fed with the coal into the stoker fired boilers.

Observations

6. Observations were made of the test firing of corn cobs and PRB coal. These observations indicated, based on visual inspections made through the furnace observation ports, that the corn cobs appear to be distributed evenly over the grate and were burned in a manner similar to the PRB coal. An inspection of ash coming off the grate indicated complete burnout of both the corn cobs and the coal. Likewise samples of fly ash from the precipitator indicated complete burnout with little or no unburned carbon in the fly ash.

Summary of Observations

7. In summary chopped corn cobs appears to be a suitable, bio-renewable fuel for stoker firing. Suggestions for the Willmar Plant include:

    a. Replacing the existing Detroit mechanical drive feeders with the new individual controlled under throw feeders.
    b. Replacing the six (6) feeders with four (4) new feeders.
    c. Adding air swept spouts between the new feeders for introduction of corn cobs.
    d. Adding a new metering bin and conveyor to allow separate feeding of corn cobs from the coal.
    e. Adding control modifications to allow base load firing on PRB coal with the fuel demand signal split allowing coal or corn cob firing as conditions require.

Test Firing

8. PCI will work closely with Willmar staff to develop a temporary system for feeding chopped corn cobs into the Willmar boiler number #3, in early 2009, to allow test firing of the cobs.

Corn Cob Harvesting

9. The corn cobs being collected and burned at the Pella, Iowa plant appeared to contain a lot of attached corn husks. This stringy leaf like material may cause plugage and jamming of chutes, therefore it is important to minimize the husks that are harvested with the corn cobs. According to John Folkedahl combine adjustments can be made to minimize the husks that are harvested with the corn cobs. To the extent this is possible this should be done. Further it is recommended that chopped corn cobs be utilized as fuel in a size range approximately two (2) inches by zero (0). Attempting to handle whole corn cobs will have the potential for causing plugage and jamming of various conveyors, feed chutes, and feeders.

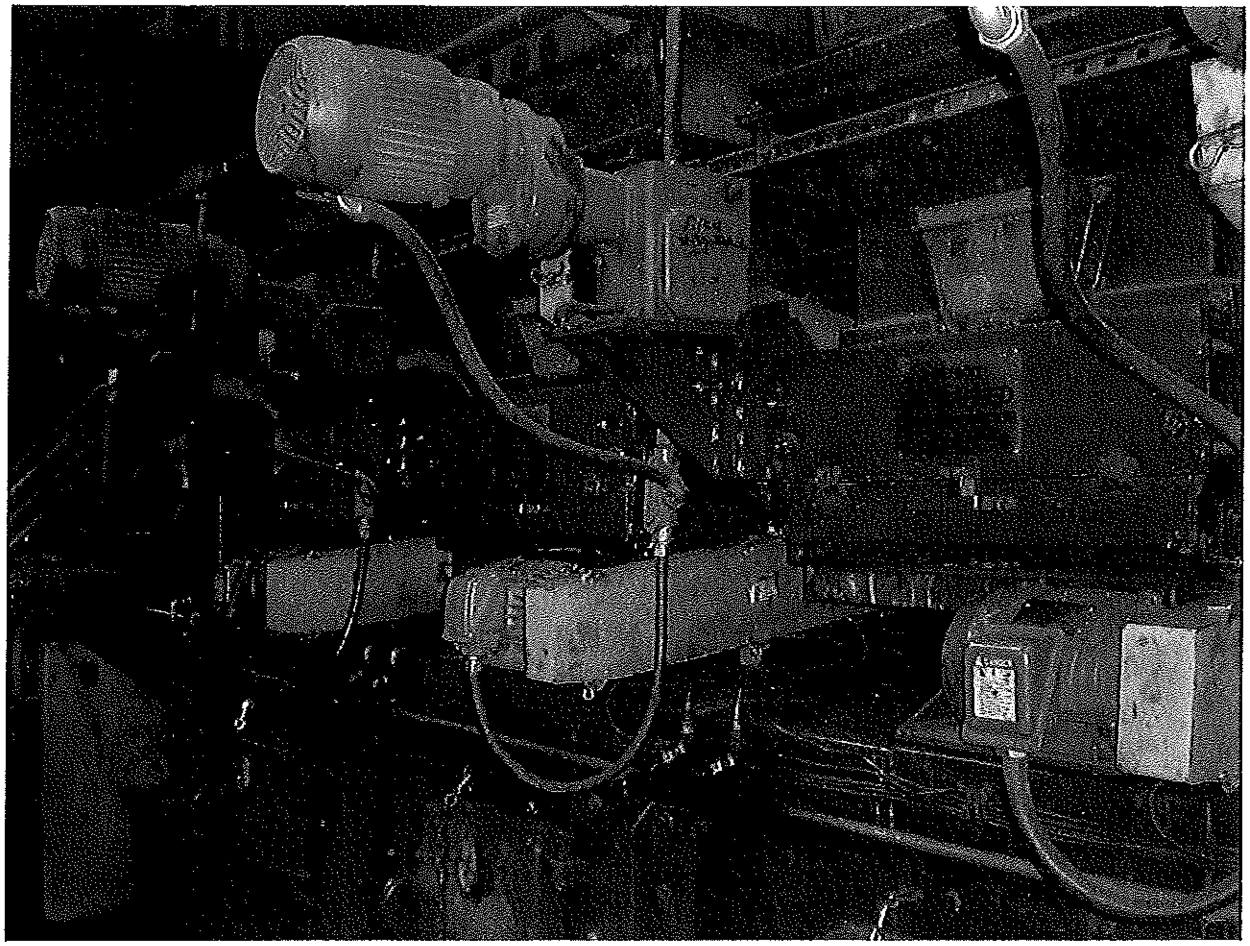
Summary and Conclusions

10. As stated in the above, chopped corn cobs appear to be an ideal bio-renewable fuel. Its heating value and moisture characteristics are very similar to PRB coal which Willmar currently is firing. Because of the irregular size and the potential for a lot of husk material to be included with the corn cobs consideration must be given to a corn cob feed system that will allow the unloading, storage, handling, and feeding of this material without bridging and plugage.

Photographs

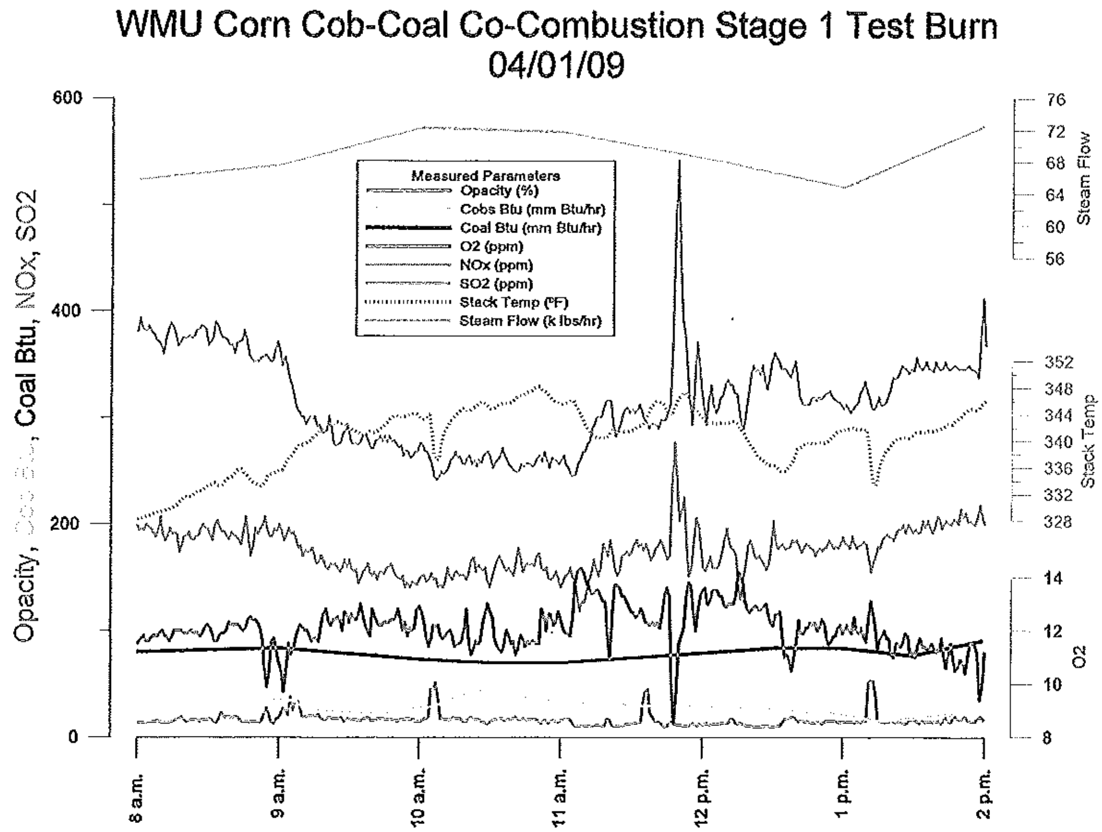
Attached to this report are photographs at the Pella, Iowa Municipal Utility Power Plant when burning the corn cobs under test.

Bunker Fill Conveyor-PRB Coal & Chopped Corn Cobs



Stoker Feeders (Detroit Stoker Co. - Over/Through Feeder)

Mixture of PRB Coal and Chopped Corn Cobs Entering Feeder



As can be observed on the graph, following the addition of cobs the emission monitor indicated a distinct reduction in SO_2 and NO_X with very little increase in opacity. Nitrogen oxide levels likely decreased because of the higher moisture content in the corn cobs reducing peak flame temperature; sulfur dioxide levels decreased because the corn cobs are lower in sulfur than the PRB coal. Opacity increased slightly perhaps because of fly ash carry over due to a higher portion of fines in the corn cob ash, as well as lower density of the cob material resulting in more combustion occurring above the bed.

Flue gas temperature corresponded qualitatively to the additional Btu's added via the corn cobs, as did steam flow. However, the increases did not entirely match the expected increase due to firing of corn cobs. This can be explained by the higher moisture content to Btu ratio of the corn cobs, compared to PRB coal. The higher moisture content produces more water vapor in the flue gas when compared to just firing coal. Water vapor has a higher heat capacity than the other two main constituents of flue gas, CO_2 and nitrogen. A higher heat input is required to vaporize the additional water which will be reflected in a reduction in boiler efficiency.

The spikes on the opacity graph represent soot blowing events. The spikes on the oxygen, NO_X, and SO_2 lines represent a cob injection plugging event. The cob air injection system normally added significant amounts of O_2 to the firebox. When the cob injector plugged, O_2 and moisture input plummeted, with a corresponding temporary increase in NO_X and SO_2.

C. Visual Observations

Visual observations were made of furnace conditions by looking into all accessible observation ports. Observations on both days indicated that combustion appeared to be only slightly changed from conditions previously observed when firing 100% PRB coal. Photographs of the firebox conditions are included in Appendix E.

D. Material Samples

Sample Collection

During the test burn, approximately 4 tons of corn cobs were burned on March 31 at a Btu-based cob firing rate of approximately 10% of total fuel input, with another 10 tons burned on April 1 at cob firing rates up to 40%. Samples of the coal and corn cob fuels were taken on April 1 for laboratory proximate/ultimate analyses. Copies of the laboratory reports are included in Appendix F.

Ash samples including bottom ash and mechanical collector fly ash were taken on both test dates, during PRB coal firing only as well as during firing of PRB coal plus corn cobs. Visual examination of the ash samples indicated no discernible differences. Laboratory analyses of composites of the samples were performed to determine any changes in ash composition, characteristics and properties as a result of corn cob firing. Copies of the laboratory reports are included in Appendix F.

Sample Analysis Results

The results of the April 1 cob and coal Proximate/Ultimate analyses are presented on Tables 1 and 2 in Section II above.

The corn cobs collected during the test burn were also analyzed for moisture content and were found to contain approximately 47% moisture, apparently due to recent rain and snow that had accumulated on the outdoor pile of corn cobs.

A comparison of the ash analyses of the pre-test and during-test cyclone and bottom ash is presented in Table 7 below.

Table 7. Comparison of Co-Combustion Coal Ash and Coal-Cob Ash Analyses Pre-Test Burn (Coal Only) and During-Test Burn (Coal and Cob Combined)

Ash Analysis (wt%)	Cyclone Ash Pre-Test Burn 3/31/09	Cyclone Ash During-Test Burn 4/1/09	Bottom Ash Pre-Test Burn 3/31/09	Bottom Ash During-Test Burn 4/1/09
Silicon Oxide	51.44	54.19	54.52	53.31
Aluminum Oxide	19.34	19.91	18.81	19.42
Titanium Oxide	0.83	0.83	0.95	0.87
Iron Oxide	3.20	2.34	8.06	7.43
Calcium Oxide	13.51	12.21	10.78	10.71
Magnesium Oxide	4.91	4.61	3.53	3.54
Potassium Oxide	0.88	1.74	0.59	0.65
Sodium Oxide	1.05	0.39	0.24	0.31
SO_3	2.65	1.48	0.83	0.92
P_2O_5	0.70	0.69	0.53	0.56
Strontium Oxide	0.23	0.22	0.17	0.16
Barium Oxide	0.86	0.60	0.86	0.81
Mangenese Oxide	0.16	0.15	0.35	0.13
Moisture	0.09	0.09	0.04	0.03
LOI	3.73	5.45	0.40	1.49
Mercury (ug/g)	<0.02	0.024	<0.02	<0.02

Only relatively small differences can be observed between the pre and during test burn ash sample analyses results. It should be noted that the lab analysis reporting limit for Hg was 0.02 ug/g. No Hg was detected in the test burn cob composite sample. The Hg level in the test burn coal sample was 0.079 ug/g. Thus it would appear that the addition of cobs to the fuel mix lowered the mercury content of the co-combustion ash. Also notable is that the decrease in SO_3 percentage in the during test cyclone ash is greater than the corresponding increase in the during test bottom ash. This net decrease in SO_3 is most likely due to the lower percentage of sulfur in the cobs compared to the coal. This decrease also correlates with the decrease in SO_2 in the flue gas when combusting cobs, as shown on the emission monitor graph above.

E. Initial Test Burn Completion

At the completion of the initial test firing on April 1, 2009 the remaining corn cobs in the storage silo were burned and firing returned to normal conditions on 100% PRB coal. The boiler was shut down over the April 4-5 weekend in preparation for the annual spring outage, during which time necessary inspections and related repair and maintenance work were accomplished.

F. Emission Compliance Testing

Emission compliance testing while corn cobs were co-combusted with coal was performed on the WMU Boiler #3 on June 17, 18, and 19, 2009. FCI monitored and assisted the co-combustion test burns, recorded fuel feed rate data, and collected cob and coal fuel samples for laboratory analysis.

The rate of cob injection was measured and is compared to the coal feed rates in the tables below. Table 8 presents the percent of cobs by Btu projected on the day of the tests based on Btu analyses of samples collected previously. Table 9 shows the percent of cobs by Btu results based on analyses of the fuel samples collected on the day of the tests.

Table 8. WMU AQ Emissions Testing Fuel Feed Rates (est. Btu)

TEST 1			Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	% Cobs
6/17	Clock Time	Minutes	Total LB	TPH	Btu/Hr	Total LB	TPH	Btu/Hr	TPH	Mm Btu/hr	By Btu
Run 1	9:40 to 11:30	110	18076	4.93	86.45	10100	2.75	28.10	35.85%	114.55	24.53%
Run 2	12:15 to 14:00	105	17350	4.96	86.93	9330	2.67	27.19	34.97%	114.12	23.83%
Run 3	14:50 to 16:51	121	20024	4.96	87.06	9280	2.30	23.47	31.67%	110.53	21.23%
										Average =	**23.20%**
TEST 2		Minutes	Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	Cobs %
Run 1	7:35 to 9:17	102	18009	5.30	92.88	4784	1.41	14.35	20.99%	107.24	13.38%
Run 2	9:45 to 11:27	102	17120	5.04	88.30	5904	1.74	17.71	25.64%	106.01	16.71%
Run 3	12:00 to 13:28	88	15197	5.18	90.85	4266	1.45	14.83	21.92%	105.68	14.04%
										Average =	**14.71%**
TEST 3		Minutes	Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	Cobs %
Run 1	7:20 to 9:00	100	17922	5.38	94.28	2309	0.69	7.07	11.41%	101.35	6.97%
Run 2	9:30 to 11:05	95	18077	5.71	100.10	2800	0.88	9.02	13.41%	109.12	8.26%
Run 3	11:35 to 13:10	95	18604	5.87	103.02	2060	0.65	6.64	9.97%	109.66	6.05%
										Average =	**7.10%**

Estimated Fuel BTU/lb	
Coal	Cob
8768	5100

Table 9. WMU AQ Emmissions Testing Fuel Feed Rates (actual Btu)

TEST 1			Coal Fired		mm	Cobs Fired		mm	% Cobs	Total	% Cobs
6/17	Clock Time	Minutes	Total LB	TPH	Btu/Hr	Total LB	TPH	Btu/Hr	TPH	mmBtu/hr	By Btu
Run 1	9:40 to 11:30	110	18530	5.05	89.28	10100	2.75	35.28%	21.49	89.63	19.40%
Run 2	12:15 to 14:00	105	16975	4.85	85.68	9330	2.67	35.47%	20.80	86.03	19.53%
Run 3	14:50 to 16:51	121	19199	4.76	84.09	9280	2.30	32.59%	17.95	84.42	17.59%
										Average =	**18.84%**
TEST 2			Coal Fired			Cobs Fired		% Cobs			% Cobs
6/18	Clock Time	Minutes	Total LB	TPH	mm Btu/Hr	Total LB	TPH	TPH	mm Btu/Hr	Total	Btu/hr
Run 1	7:35 to 9:17	102	18009	5.30	93.65	4784	1.41	20.99%	14.12	93.86	13.10%
Run 2	9:45 to 11:27	102	17120	5.04	89.02	5904	1.74	25.64%	17.42	89.28	16.37%
Run 3	12:00 to 13:28	88	15197	5.18	91.60	4266	1.45	21.92%	14.59	91.82	13.74%
										Average =	**14.40%**
TEST 3			Coal Fired			Cobs Fired		% Cobs			% Cobs
6/19	Clock Time	Minutes	Total LB	TPH	mm Btu/Hr	Total LB	TPH	TPH	mm Btu/Hr	Total	Btu/hr
Run 1	7:20 to 9:00	100	17922	5.38	93.37	2309	0.69	11.41%	7.48	93.48	7.42%
Run 2	9:30 to 11:05	95	18077	5.71	99.13	2800	0.88	13.41%	9.55	99.27	8.79%
Run 3	11:35 to 13:10	95	18604	5.87	102.02	2060	0.65	9.97%	7.03	102.12	6.44%
										Average =	**7.55%**

Actual Fuel BTU/lb		
Coal	Cob	
8833	3901*	25% test
8840	5017	15% test
8683	5400	5% test

*This result is believed to be anomalous – see Moisture/Cost Chart on Page 48 above and in Appendix D

As can be observed, laboratory analyses of the cob and coal samples revealed that the actual Btu values of the cobs on the day of the tests were lower than projected. Thus the actual % Cobs by Btu values varied from true values more than would be desired, but remained within an acceptable range.

Table 10. Emission Test Cob Composite Proximate/Ultimate Analysis Results

ANALYTE		6/17 Test 1 Cob Composite	6/18 Test 2 Cob Composite	6/19 Test 3 Cob Composite
Moisture	%	33.52	34.19	29.52
Ash	%	18.89	6.48	3.77
Volatile Matter	%	41.92	47.29	53.29
Fixed Carbon	%	5.68	11.32	13.42
BTU/lb		3901	5017	5400
Total Sulfur	%	0.06	0.06	0.04
Carbon	%	23.36	28.67	30.86
Hydrogen	%	6.52	7.35	7.21
Nitrogen	%	0.33	0.53	0.47
Oxygen	%	0.06	56.91	57.65
Chlorine	ug/g	1550	1780	1860
Fluorine	ug/g	<70	<70	<70
Mercury	ug/g	0.026	0.022	0.022

Table 11. Emission Test Coal Composite Proximate/Ultimate Analysis Results

ANALYTE		6/17 Test 1 Coal Composite	6/18 Test 2 Coal Composite	6/19 Test 3 Coal Composite
Moisture	%	24.61	24.88	24.07
Ash	%	8.88	8.71	10.08
Volatile Matter	%	28.26	28.30	28.41
Fixed Carbon	%	38.25	38.11	37.44
BTU/lb		8833	8840	8663
Total Sulfur	%	0.73	0.59	0.79
Carbon	%	50.66	50.92	50.92
Hydrogen	%	6.39	6.44	6.26
Nitrogen	%	0.82	0.78	0.81
Oxygen	%	32.52	32.56	31.14
Chlorine	ug/g	<20	<20	<20
Fluorine	ug/g	<70	<70	<70
Mercury	ug/g	0.060	0.077	0.057

Tables 10 and 11 above present the results of laboratory analyses of the coal and cob composite samples collected during the emission compliance testing. The samples were collected directly from the fuel flowing into the coal hoppers and the "Cob Rocket".

The above comparison between coal and cobs is instructive in understanding the real source of heating value in fuels. Correcting for moisture content (~75 Btu/1% moisture in cobs), the ratio between Btu's and carbon content in both fuels is almost identical (~0.6).

A significant difference between the two fuels is noted in the mercury analysis results. The average Hg level in the emission test cob samples was 0.023 ug/g. The average Hg level in the emission test coal samples was 0.065 ug/g. As discussed above, the lower Hg levels in the cobs likely lowered the Hg level in the co-combustion emission test ash.

Another, less positive difference between the two fuels is noted in the chlorine analysis results. No chlorine was detected in the coal samples, but the cobs contained an average 1,730 ug/g. Chlorine levels as high as these may affect the co-combustion permitting process.

The emission compliance testing was performed by Interpoll Laboratories, Inc. of Circle Pines, Minnesota. Complete review of the MPCA-required stack testing results is beyond the scope of this report. However, partial results were made available for the purposes of this co-combustion report. The table following presents a summary of the emission test data that was made available, with CEM data collected by WMU equipment, and cob feed rate data recorded by FCI.

The WMU CEM data correspond very well with the Interpoll emission test data. The NOx and CO values varied by no more than about 3% from one data set to the other. NOx and CO levels decreased with the addition of cobs to the combustion process. However, HCL increased to a level above what is allowable under Minnesota and Federal pollution control rules. These relatively high hydrochloric acid levels in the exhaust gas reflect the relatively high chlorine levels in the cob fuel.

Post combustion treatment may be required to remove the HCL from the exhaust gas stream. However, planned power plant upgrades include a dry scrubber system that will likely resolve this issue. No other air pollutant issues are anticipated.

Table 12. Emission Testing Results Summary

Emission Testing CEM Results*					Emission Testing Flue Gas Results**						
Test 1 06/17/09	**NOx***	**O_2 ***	**CO ***	**Cobs *****	**PM****	**PM10****	**Nox****	**CO****	**VOC****	**HCL****	**HF****
	ppm,d	%	ppm,d	%	lb/mmBtu	lb/mmBtu	ppm,d	ppm,d	ppm,d	ppm, 7%O2	ppm, 7%O2
Run 1 Averages	203.556	12.060	104.982	19.40%							
Run 2 Averages	191.370	11.898	113.884	19.53%							
Run 3 Averages	186.742	11.384	106.896	17.59%							
Test 1 Averages	**193.890**	**11.781**	**108.588**	**18.84%**	**0.356**	**0.298**	**200.32**	**108.30**	**2.03**	**44.37**	**3.47**
Test 2 06/18/09	NOx ppm	% O_2	CO ppm	% Cobs							
Run 1 Averages	235.956	12.598	163.575	13.10%							
Run 2 Averages	235.956	12.598	163.575	16.37%							
Run 3 Averages	212.899	12.816	142.040	13.74%							
Test 2 Averages	**228.270**	**12.671**	**156.397**	**14.40%**	**0.376**	**0.306**	**225.42**	**159.77**	**0.99**	**31.41**	**3.45**
Test 3 06/19/09	NOx ppm	% O_2	CO ppm	% Cobs							
Run 1 Averages	224.462	13.197	105.389	7.42%							
Run 2 Averages	231.254	13.009	126.522	8.79%							
Run 3 Averages	222.110	13.238	112.359	6.44%							
Test 3 Averages	**225.942**	**13.148**	**114.757**	**7.55%**	**0.439**	**0.273**	**227.05**	**112.99**	**1.12**	**15.43**	**3.83**

* WMU data table included in Appendix G
**Interpoll Labs data table included in Appendix G
***FCI data table included in Appendix G

SECTION IV

Summary and Recommendations

Feasibility Analysis Conclusions

The purpose of the feasibility study was to identify the issues – problematic or otherwise - involved in corn cob co-combustion with coal. No "show stoppers" were identified and many positive aspects were associated with the corn cob co-combustion with coal. Laboratory analyses of the corn cob fuel indicated that no boiler depositional issues, ash volume, or other pollutant issues should be expected. Based on preliminary conversations with the MPCA it was expected that the WMU would have little problem in obtaining permitting for co-combustion of corn cobs. Similarly, there appeared to be no major fuel delivery obstacles to performing the corn cob co-combustion study and it was recommended that the project continue as proposed. Some of the positive aspects associated with corn cob co-combustion are presented below:

- The timing is right for the WMU – design and installation of the final cob fuel delivery system can be coordinated with planned boiler upgrades.
- The upgraded fuel delivery system will be designed to accept multiple fuels.
- The fuel delivery system will be designed to allow continued 100% coal use.
- A biofuels capability, whether used or not, will add energy security.
- The design capability will make the Minnesota Renewable Portfolio Standard achievable.
- WMU's ash disposal issues will likely improve if corn cobs are burned.
- Future carbon trading may be possible via reduced fossil CO_2 emissions.
- Environmental benefits will accrue, such as reduced Hg and reduced CO_2 emissions.
- Corn cobs will be purchased locally and create a significant positive effect on the local economy.
- Success will focus positive attention on WMU and the City of Willmar.

Feasibility Analysis Recommendations

It was recommended that the WMU move forward with Phase 1.2 (Sub-Task 2.2) of the Corn Cob Co-Combustion Feasibility Study as proposed.

Recommendations were made to 1) complete an agreement with a local producer to harvest cobs from approximately 700 acres 2) complete an agreement with Mr. Vernon Flamme of North Bend, Nebraska to conduct the pilot project cob harvest, 3) make arrangements with the City of Willmar to store cobs at the former Municipal Airport, and 4) reduce the size of the harvested cobs in order to allow injection through a small view port on the boiler firebox wall.

Permitting, Cob Acquisition, Engineering Design, and Construction Planning Results

Preparations for the co-combustion test burns included: application for an Air Quality Permit from the Minnesota Pollution Control Agency to conduct the co-combustion test burns; review of the existing WMU Power Plant configuration; identification of and a site visit to a similar facility in Iowa; cob fuel analyses; review of cob grinding machines; and agreements with a corn grower, a cob harvester, and the City of Willmar to procure, harvest, and store cobs.

The WMU facility is a major source under 40 CFR Section 52.21 (Prevention of Significant Deterioration), a synthetic minor for HAPs, and considered a major source under the federal operation permits program (40 CFR pt. 70). Numerous meetings and discussions with the MPCA resulted in an agreement with the MPCA whereby the WMU would be granted an amendment to their existing Air Emission Permit to combust up to 500 tons of Allowable Biomass on a test burn basis, over a defined time period, to allow the collection of air quality data on which to base any later permanent use permits. Wenck Associates, Inc., of Woodbury, Minnesota prepared the permit application.

A power plant in Pella, IA that uses stoker boilers similar to those at the WMU was observed during a corn cob-coal co-combustion test burn of approximately 5% corn cobs by weight. The Pella plant mixed ground cobs with coal at the origin of the conveyor belt that feeds their boilers, roughly 300 feet from the boiler. The density difference between the two fuels resulted in fuel segregation on the belt and in the hopper and ultimately, actual cob supply to only one of their three boilers.

Pre-test burn laboratory analyses found that on a Btu comparison basis, cob ash production equals only ~13% of coal ash production. Therefore, no significant slagging or fouling from co-combustion was anticipated. However, moisture measurements found that the stored cobs' moisture level was higher than desired. The cob moisture content increased during the storage period prior to the test burns, from 28% at harvest to 47% at the time of co-combustion.

Four grinders to size the cobs for air injection into the firebox were evaluated at the airport storage site. RW Farms of Chanhassen, Minnesota was retained to grind the 421 tons of cobs stored on the former Willmar airport runway, to a 2-inch and minus size.

Agreements were reached to procure, harvest, and store cobs: with a local corn grower – Fosso Farms of Pennock, Minnesota; with a cob harvester – Vernon Flamme of North Bend, Nebraska; and with the City of Willmar, Minnesota, respectively. Between October 30 and November 15, 2008, 421 tons of cobs were harvested from 631 acres in Kandiyohi, Chippewa and Swift Counties. The cobs were hauled and stored on the former Willmar airport runway.

Cost projections were prepared that predicted the delivered cost of cobs for the Power Plant Study would equal $96/ton. Actual costs were driven higher by lower than projected cob yields and by corn harvester breakdowns that resulted in much higher trucking costs. The actual final cost of the cobs as delivered to the Willmar airport amounted to $149/ton. The associated cost for the electricity generated by combusting the cobs equaled approximately $317/MW-hr. However, projections derived from the study results indicate that if the cobs can be dried to 12% moisture, and the cobs can be delivered to the power plant for a net price of $45/ton, the associated electricity cost for future generation should equal approximately $57/MW-hr.

Test Burn Conclusions

The corn cob-coal co-combustion test burns were deemed to be successful. They demonstrated that:

a. Corn cobs can be burned in Boiler No. 3 on the existing Detroit Stoker traveling grate stoker in quantities exceeding 40% of the boilers heat input.
b. Boiler operating parameters did not appear to be adversely affected during the initial tests. Longer term testing was recommended to assure reliable and consistent fuel injection on a continuous burn basis and to establish and measure air quality emission data.

Test Burn Recommendations

Longer term co-combustion test firing was recommended to determine the following:

- slagging or fouling tendencies, determined through sample collection and analysis, and by visual observation of the furnace and super heater area during operation,
- stack compliance and emission monitoring, and
- Potential changes in boiler performance.

The above characteristics were evaluated during the June 2009 emission compliance testing. No increase in slagging was observed. A decrease in NOx and CO levels was observed in the exhaust gases in addition to decreased Hg in the ash. HCL emissions increased during co-combustion to potentially problematic levels. However, planned upgrades to the power plant will likely remediate any future increases in HCL emissions.

Study Results and Recommendations

From the Co-Combustion Study results, and from the emission compliance testing data, the WMU was able to make the decision to proceed with the steps necessary to include in planned permanent power modifications, additional modifications to allow a corn cob-coal co-combustion system, including:

a. application for necessary MPCA Air Quality permit modifications,
b. modification of the existing boiler fuel feed systems, and
c. establishing corn cob sources and availability.

Both the permit application and preparations for plant modifications that will allow the use of biofuels are underway.

The opportunity to establish corn cob supply sources exists via a newly established USDA Farm Service Agency program, known as the Biomass Crop Assistance Program (BCAP). The BCAP program provides financial assistance to producers of biomass material for use as heat, power, or biofuels. Participation in the program requires that a participating entity such as the Willmar Municipal Utilities obtain designation as a Qualified Biomass Conversion Facility. Once a facility is so designated - by simply completing an application for FSA review and approval - the FSA will enter into contracts with area producers who will provide biomass to the facility. The FSA will pay the producers up to 50% of the cost of the delivered biomass, up to $45 per ton. The facility will accept the delivery of the biomass and pay the remainder of the contract price to the producer. The program has established two year contracts initially, with plans to expand to five year contracts subsequently (beginning in 2011).

As a first step toward establishing the near-term capability of the WMU to produce electricity economically from renewable biomass fuels, FCI recommends that the WMU obtain designation as a Biomass Conversion Facility.

Since cob harvest can only occur in the fall, but co-combustion must occur year-around, the WMU will need to store cobs. The cobs stored for the co-combustion study were observed to absorb significant amounts of moisture over the winter months while exposed on the former Willmar airport runway. The added moisture significantly reduced the heating value and thus the economic value of the cobs. Therefore, it would appear that for future cob storage, some sort of covered storage will be desirable. FCI recommends that an additional study be completed to evaluate the cost-effectiveness of potential types of covered cob storage.

This report was prepared by:

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Jon Folkedahl
President

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Bruce Folkedahl, Ph.D.
Principal Investigator

APPENDICES

APPENDIX A

Feasibility Report References

APPENDIX A: Feasibility Analysis

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APPENDIX B

Pella, IA Site Visit Notes

MEETING NOTES

Date: **Wednesday, December 3, 2008**

Project: **Willmar Municipal Utilities Power Plant Improvement Project ("Power Plant")**

Location: **Pella, Iowa**

Subject: **Inspection and Observations, Test Firing of Coal and Corn Cob Fuel Mixture at Pella, Iowa Municipal Utility Power Plant**

Reference: **Project Number 07-122 WMU**

Attendees: **Willmar Municipal Utilities ("WMU")**

Bruce Gomm, General Manager - WMU
Ken Nash, Superintendent Power Production - WMU
Jon Folkedahl – Folkedahl Consulting, Inc.

City of Pella

Ben McBride, Asst. Electric Director
Mike Norman, Instrument Control Technician

University of Missouri

Gregg Coffin, P.E., Superintendent- MU Power Plant

PCI Management & Consulting Company ("PCI")

Wayne Miller, Senior Mechanical Engineer
Chuck Tyburk, Project Manager

The City of Pella, Iowa ("Pella") owns and operates a coal fired power plant. The coal fired power plant includes two (2) Erie City stoker fired boilers equipped with Detroit Stokers. The boilers were originally designed for Illinois Basin Coal and some time ago a fuel conversion was made to screened PRB Coal.

The Pella has decided to embark on a program to identify and test fire a wide range biomass renewable fuels including:

a. Waste wood.

b. TDF.
c. Corn cobs.
d. Waste corn.
e. Other agricultural waste products.

This is being done to:

a. Reduce fuel costs.
b. Reduce sulfur emissions.
c. Otherwise improve the "Green" aspects of the plant.

Willmar Municipal Utilities ("WMU") is contemplating a conversion of its stoker fired boiler to allow firing up to 20-25% of chopped corn cobs available in the Willmar area. WMU plans to test fire corn cobs in early 2009, and depending on the test results embark on a program to add the necessary permanent equipment, facilities and systems to allow the burning a mixture of coal and corn cobs.

Pella had received a load of corn cobs and was test firing a mixture of coal and corn cobs on the date of the inspection. In summary the firing of a mixture of corn cobs and PRB coal (the same coal burned by Willmar) in a stoker fired boiler appears to be successful.

The following are significant items of note from this meeting and inspection:

1. The Pella Municipal Power Plant includes among another equipment two (2) Erie City stoker fired boilers of approximate capacity of 150 thousand pounds per hour each. The two (2) boilers supply steam on a steam header system at 900 psig 900 ^{o}F to two (2) steam turbine generators with a total electric capacity of approximately 34 MW. The boilers are equipped with Detroit Stokers. The original mechanical drive coal feeders have been replaced with Detroit's newer Ultrafeed Coal Distributors, each independently operated with electric motor drives.

   The boilers are typical of Midwest styled stoker boilers designed to operate on Midwest high sulfur coal. Sometime ago a fuel conversion to PRB coal was made to lower sulfur emissions. The utility purchases PRB coal from an Alliant Energy power plant nearby where it is screened and then is delivered by truck to the plant.

Plant & Facilities

2. The plant is operated as a peaking plant, operating maximum hours during the summer and minimal time during the winter. During the winter months typically only one (1) boiler is operated at minimum load (approximately 6-7 MW output) to provide heat for the power plant building.

   The plant is generally in good condition and it is typical of a small municipal power plant.

The utility desires to reduce sulfur emissions and respond to future anticipated carbon dioxide emission reductions by utilizing biomass or other bio-renewable fuels which have zero carbon emissions. Recently the plant has embarked on a program to identify, secure, and test fire a range of bio-renewable fuels including:

a. Waste wood.
b. Construction and demolition debris ("C&D").
c. Reclaimed wood from landfills.
d. Corn cobs.
e. Waste seed corn.
f. Other agricultural waste products.
g. Tire derived fuel (TDF).

Of particular interest are the corn cobs as Willmar Municipal Utilities plans to test fire and ultimately modify its stoker fired boiler to burn corn cobs which are abundantly available in the Willmar, Minnesota area.

3. The existing fuel delivery system includes a system of bucket elevators and belt conveyors, typical for a stoker fired boiler. A bucket elevator elevates coal to a horizontal in feed conveyor, which, through a plow feeder, supplies coal to the two (2) coal bunkers serving each stoker fired boiler. This system is well suited for receiving, unloading, and feeding coal to the coal bunkers. The bunkers discharge into a non segregating chute, which supplies coal to the individual feeders which feed coal to the grate. This system works very well on coal, but is not an ideal system for feeding irregular size fuel such as waste wood, C&D, and corn cobs. Blended fuel tends to segregate and is distributed unevenly on the grate.

4. The utility staff reported that waste wood and TDF were burned successfully only in limited quantities because of fuel handling system problems, particularly with the TDF fuel. The utility recently procured approximately 400 tons of corn cobs, which were harvested in the local area this fall.

5. The corn cobs were collected from combine operations in a specially designed trailer that was attached to the combine. This device was manufactured by the Pella, Iowa based Vermeer Manufacturing Company and included a wagon type trailer with a feed conveyor and mechanism for eliminating much of the non corn cob material harvested from the field including corn husks. The corn cobs were collected and delivered to the plant site. An initial test firing of the corn cobs was made without any chopping or grinding. Utility staff reported that in the limited quantities the whole cobs were able to be fed with the coal, the corn cobs appear to be able to be burned successfully. Pella staff reported that corn cob coal mixture was estimated to be approximately 5-10% corn cobs by weight. The second test, which was conducted on the day of the visit, included the chopping of the corn cobs to an approximate size of two inch (2) by zero (0). To accomplish this Pella acquired a tub grinder on a rental basis and ground the existing pile of corn cobs to the two (2) by zero (0) size. This material was fed by front end loader to the existing coal hopper where the cobs were mixed with coal. The mix was elevated by

bucket elevator and distributed to the coal bunker by feed conveyor. Observations indicated that a mixture of maybe 5-10% corn cobs was being fed with the coal into the stoker fired boilers.

Observations

6. Observations were made of the test firing of corn cobs and PRB coal. These observations indicated, based on visual inspections made through the furnace observation ports, that the corn cobs appear to be distributed evenly over the grate and were burned in a manner similar to the PRB coal. An inspection of ash coming off the grate indicated complete burnout of both the corn cobs and the coal. Likewise samples of fly ash from the precipitator indicated complete burnout with little or no unburned carbon in the fly ash.

Summary of Observations

7. In summary chopped corn cobs appears to be a suitable, bio-renewable fuel for stoker firing. Suggestions for the Willmar Plant include:

    a. Replacing the existing Detroit mechanical drive feeders with the new individual controlled under throw feeders.
    b. Replacing the six (6) feeders with four (4) new feeders.
    c. Adding air swept spouts between the new feeders for introduction of corn cobs.
    d. Adding a new metering bin and conveyor to allow separate feeding of corn cobs from the coal.
    e. Adding control modifications to allow base load firing on PRB coal with the fuel demand signal split allowing coal or corn cob firing as conditions require.

Test Firing

8. PCI will work closely with Willmar staff to develop a temporary system for feeding chopped corn cobs into the Willmar boiler number #3, in early 2009, to allow test firing of the cobs.

Corn Cob Harvesting

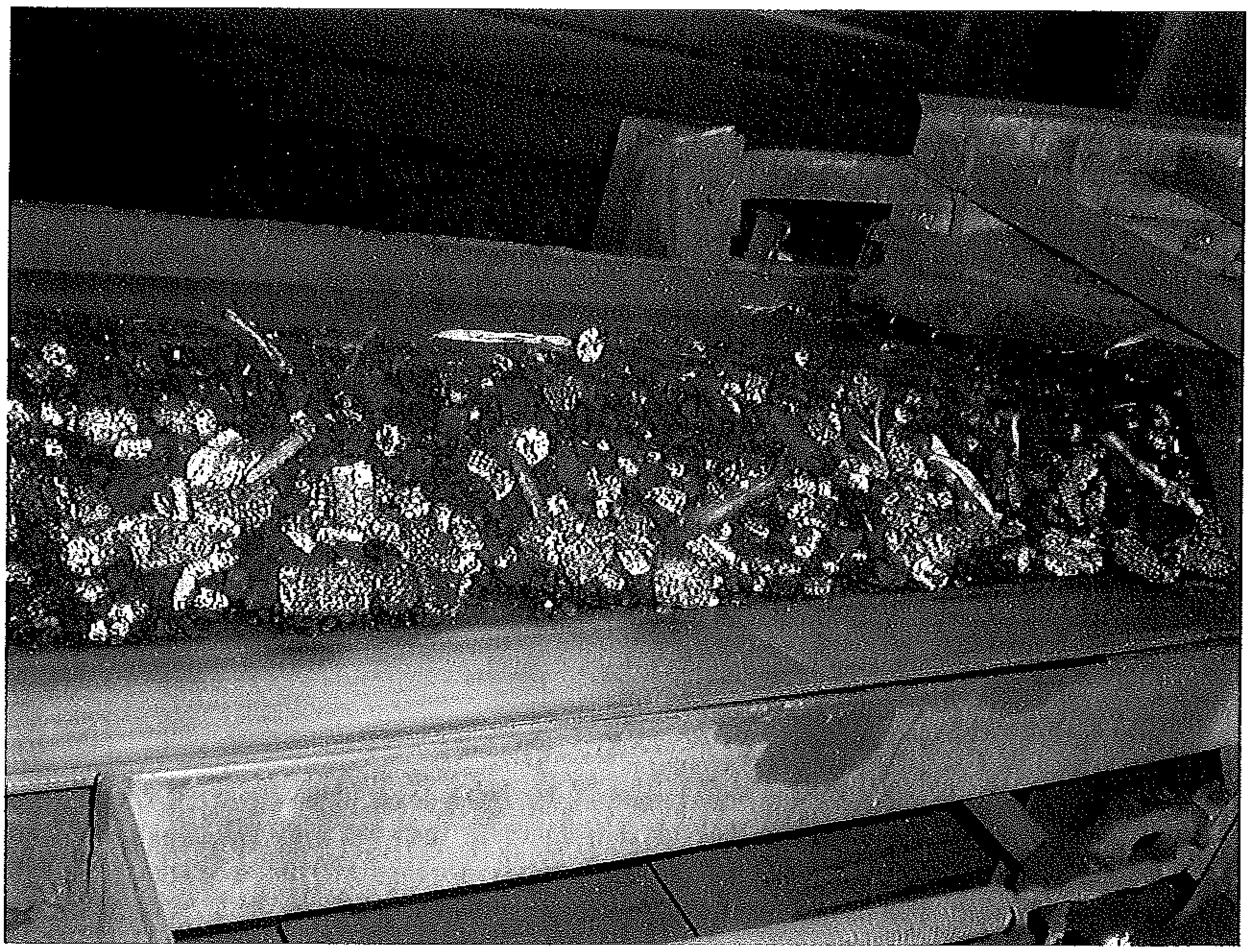
9. The corn cobs being collected and burned at the Pella, Iowa plant appeared to contain a lot of attached corn husks. This stringy leaf like material may cause plugage and jamming of chutes, therefore it is important to minimize the husks that are harvested with the corn cobs. According to John Folkedahl combine adjustments can be made to minimize the husks that are harvested with the corn cobs. To the extent this is possible this should be done. Further it is recommended that chopped corn cobs be utilized as fuel in a size range approximately two (2) inches by zero (0). Attempting to handle whole corn cobs will have the potential for causing plugage and jamming of various conveyors, feed chutes, and feeders.

Summary and Conclusions

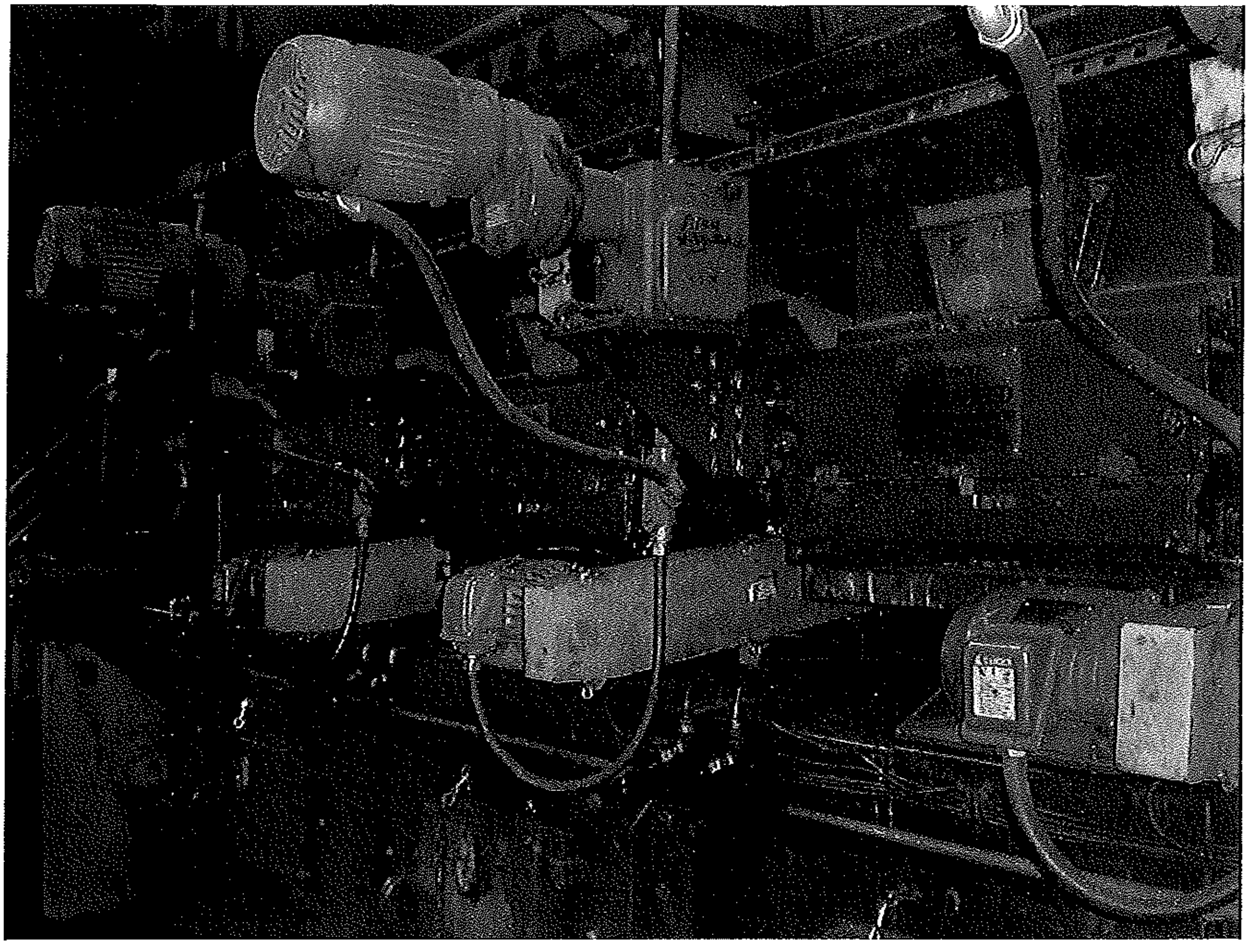
10. As stated in the above, chopped corn cobs appear to be an ideal bio-renewable fuel. Its heating value and moisture characteristics are very similar to PRB coal which Willmar currently is firing. Because of the irregular size and the potential for a lot of husk material to be included with the corn cobs consideration must be given to a corn cob feed system that will allow the unloading, storage, handling, and feeding of this material without bridging and plugage.

Photographs

Attached to this report are photographs at the Pella, Iowa Municipal Utility Power Plant when burning the corn cobs under test.



Bunker Fill Conveyor-PRB Coal & Chopped Corn Cobs



Stoker Feeders (Detroit Stoker Co. - Over/Through Feeder)


Mixture of PRB Coal and Chopped Corn Cobs Entering Feeder

APPENDIX C

Cob Harvest Data Summary

2008 WMU CORN COB HARVEST DATA SUMMARY

Corn cobs were harvested for the Willmar Municipal Utilities by Vernon Flamme of North Bend, Nebraska, on the following dates in 2008:

October 30
October 31
November 1
November 3
November 4
November 12
November 13
November 14
November 15

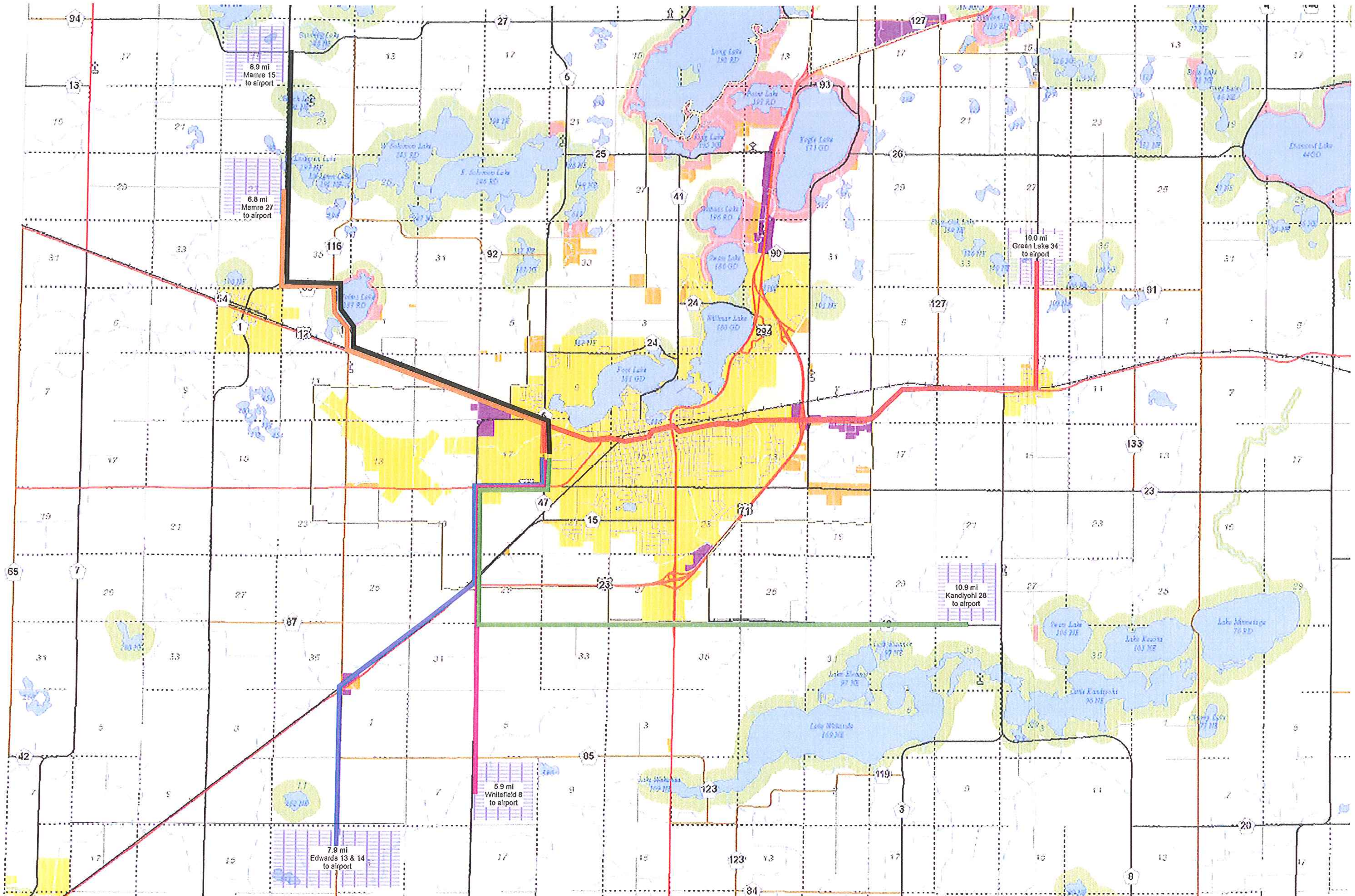
The cobs were harvested from ten parcels of cropland owned and/or operated by Ryan and Lonnie Fosso of Pennock, Minnesota:

Kandiyohi County
- Edwards Township
  - NW1/4, N1/2 SW1/4 Section 13
  - SE1/4 Section 14
- Green Lake Township
  - S1/2, SE1/4 Section 27, and W1/2, NE1/4 Section 34
- Kandiyohi Township
  - S1/2, SW1/4 Section 21, and E1/2, NW1/4 Section 28
- Mamre Township
  - N1/2, NE1/4 Section 15
  - NW1/4, NW1/4 Section 27
- Willmar Township
  - N1/2, NE1/4 Section 34
- Whitefield Township
  - NW1/4 Section 8

Chippewa County
- Lone Tree Township
  - SE1/4, SE1/4 Section 29, and S1/2, SW1/4 Section 28, and N1/2, NW1/4 Section 33

Swift County
- Kerkhoven Township
  - E1/2 Section 34

Mr. Flamme harvested 631.1 acres for corn and cobs. The harvested cobs were hauled using both Flamme and Fosso equipment. The trucks were weighed full and empty as the cobs were delivered to the Willmar Airport storage site. The cobs delivered totaled 421.26 tons. The cob harvest averaged 0.67 tons per acre.


8.9 mi
Mamre 15
to airport
6.8 mi
Mamre 27
to airport
10.0 mi
Green Lake 34
to airport
10.9 mi
Kandiyohi 28
to airport
5.9 mi
Whitefield 8
to airport
7.9 mi
Edwards 13 & 14
to airport

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2008
Grain Harvest
Corn - CORN
Harvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
22.23 ‡	20.51 ‡	223,565 ‡	3,755.7 ‡	168.92 ‡	N/A	N/A	10/30/2008
0.247 ‡	20.92 ‡	2,861.4 ‡	47.82 ‡	193.80 ‡	2,905.0 ‡	-1.501 % ‡	10/31/2008
0.241 ‡	21.14 ‡	2,956.2 ‡	49.27 ‡	204.67 ‡	2,925.1 ‡	1.064 % ‡	10/31/2008
122.01 ‡	21.95 ‡	1,301,846 ‡	21,473 ‡	176.00 ‡	N/A	N/A	10/31/2008
44.73 ‡	**21.72 ‡** Average	**1,531,229 ‡**	**25,326 ‡**	**174.99 ‡** Average			**10/30/2008 - 10/31/2008**

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rain Harvest
orn - CORN
arvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
94.40 ‡	23.69 ‡	1,091,778 ‡	17,606 ‡	186.51 ‡	N/A	N/A	11/1/2008
94.40 ‡	**23.69 ‡** Average	**1,091,778 ‡**	**17,606 ‡**	**186.51 ‡** Average	**N/A**	**N/A**	**11/1/2008**

Field Summary Report

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arvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
81.82 ‡	21.92 ‡	861,209 ‡	14,210 ‡	173.68 ‡	N/A	N/A	11/3/2008
81.82 ‡	**21.92 ‡**	**861,209 ‡**	**14,210 ‡**	**173.68 ‡**	**N/A**	**N/A**	**11/3/2008**
	Average			Average			

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arvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
80.83 ‡	22.00 ‡	782,993 ‡	12,906 ‡	159.67 ‡	N/A	N/A	11/4/2008
80.83 ‡	**22.00 ‡**	**782,993 ‡**	**12,906 ‡**	**159.67 ‡**	**N/A**	**N/A**	**11/4/2008**
	Average			Average			

Fi S ma K rt

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rain Harvest
orn - CORN
arvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
6.553 ‡	21.11 ‡	73,300 ‡	1,222.1 ‡	186.50 ‡	N/A	N/A	11/5/2008
4.192 ‡	21.06 ‡	50,451 ‡	841.62 ‡	200.76 ‡	N/A	N/A	11/12/2008
10.74 ‡	**21.09 ‡** Average	**123,751 ‡**	**2,063.7 ‡**	**192.06 ‡** Average			**11/5/2008 - 11/12/2008**

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arvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
21.95 ‡	21.02 ‡	231,955 ‡	3,871.5 ‡	176.41 ‡	N/A	N/A	11/13/2008
21.95 ‡	**21.02 ‡** Average	**231,955 ‡**	**3,871.5 ‡**	**176.41 ‡** Average	**N/A**	**N/A**	**11/13/2008**

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Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
84.73 ‡	21.24 ‡	819,561 ‡	13,640 ‡	160.99 ‡	N/A	N/A	11/13/2008
34.73 ‡	**21.24 ‡**	**819,561 ‡**	**13,640 ‡**	**160.99 ‡**	**N/A**	**N/A**	**11/13/2008**
	Average			Average			

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008
rain Harvest
orn - CORN
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Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
30.76 ‡	21.69 ‡	213,202 ‡	3,528.2 ‡	114.72 ‡	N/A	N/A	11/14/2008
0.00 †	N/A	N/A	N/A	N/A	N/A	N/A	11/14/2008
30.76 *	**21.69 ‡**	**213,202 ‡**	**3,528.2 ‡**	**114.72 ‡**			**11/14/2008 - 11/14/2008**
	Average			Average			

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2008
Grain Harvest
Corn - CORN
Harvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
36.47 ‡	22.34 ‡	361,044 ‡	5,925.5 ‡	162.46 ‡	N/A	N/A	11/14/2008
36.47 ‡	**22.34 ‡**	**361,044 ‡**	**5,925.5 ‡**	**162.46 ‡**	**N/A**	**N/A**	**11/14/2008**
	Average			Average			

I
2008
Grain Harvest
Corn - CORN
Harvest - 1

Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Actual Weight (Wet) lb	Error %	Date Logged
78.56 ‡	20.20 ‡	775,751 ‡	13,082 ‡	166.52 ‡	N/A	N/A	11/15/2008
78.56 ‡	**20.20 ‡**	**775,751 ‡**	**13,082 ‡**	**166.52 ‡**	**N/A**	**N/A**	**11/15/2008**
	Average			Average			

Condensed Farm Report

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AFS

Field	Load / Region(s)	Area ac	Average Moisture %	Estimated Weight (Wet) lb	Estimated Volume (Dry) bu	Average Yield (Dry) bu/ac	Cal. Loads
1	4	144.73	21.72	1,531,229	25,326	174.99	2
AA	1	94.40	23.69	1,091,778	17,606	186.51	0
BB	1	81.82	21.92	861,209	14,210	173.68	0
CC	1	80.83	22.00	782,993	12,906	159.67	0
DD	2	10.74	21.09	123,751	2,063.7	192.06	0
EE	1	21.95	21.02	231,955	3,871.5	176.41	0
FFGG	1	84.73	21.24	819,561	13,640	160.99	0
GG	2	30.76	21.69	213,202	3,528.2	114.72	0
HH	1	36.47	22.34	361,044	5,925.5	162.46	0
II	1	78.56	20.20	775,751	13,082	166.52	0
Totals	**15**	**665.00**	**21.82** (Average)	**6,792,472**	**112,160**	**168.66** (Average)	**2**

Field Name

1	(156.3 ac)	Latham
AA	(100.7 ac)	Hanson
BB	(90.1 ac)	DeVries
CC	(118.1 ac)	Harts
DD	(7.1 ac)	Woltjer 40E
EE	(24.1 ac)	Brandt
FFGG	(78.4 ac)	Wolth
GG	(32.7 ac)	Arnolds
HH	(37.9 ac)	Sloefe
II	(78.3 ac)	Hanson

631.1 acres harvested for CODS

34 Kerkhoven (Swift)
>10 miles
78 acres
11/15

Sloefe Sec 15 Mamre
± 10 miles
38 acres
11/14

Woltjer 40E Sec 27 Mamre
<10 miles
7 acres
11/5 (4 acres)
11/2 (3 acres)

Wolth N Sec 34 Green Lake
>10 mi
78 acres
11/13

Brandt Sec 28 Kandiyohi
>10 mi
24 acres
11/13

Arnolds Sec 34 Willmar
<10 miles
33 acres
11/14

DeVries Sec 8 Whitfield
<10 miles
90 acres
11/3

Latham Sec 13 Edwards
<10 miles
156 acres
10/30
10/31

Sec 14 Edwards Hanson
<10 miles
100 acres
11/1

N

CASE IH AFS Software

2008 WMU COB HARVEST

Haul Log Summary

Truck	Odom Out	Odom Return	Trip Miles	Gross #	Tare #	Net #	Net Tons
T-600	724040	724060	20	-	-	42000	21.00
3OCATS	-	-	-	-	-	19000	9.50
T-600	724060	724066	6	-	-	42000	21.00
T-600	724066	724084	18	75460	33960	41500	20.75
3OCATS	-	-	-	-	-	19000	9.50
3OCATS	948654	948669	15	52940	34640	18300	9.15
T-600	724084	724099	15	90280	34060	56220	28.11
3OCATS	948669	948684	15	53900	34600	19300	9.65
T-600	724099	724130	31	94040	33960	60080	30.04
3OCATS	948684	948702	18	55280	34580	20700	10.35
T-600	724130	724137	7	88980	33900	55080	27.54
T-600	924137	924150	13	79780	33840	45940	22.97
T-600	924150	924182	32	61380	33760	27620	13.81
OCATS	948702	948733	31	50420	34550	15870	7.94
OCATS	948733	-	-	52620	34440	18180	9.09
T-600	724182	-	-	86200	33480	52720	26.36
OCATS	-	-	-	52800	34300	18500	9.25
				FLAMME SUBTOTAL		572010	**286.01**

2008 WMU COB HARVEST

Haul Log Summary

Fosso	48260	34820	13440	6.72
Fosso	48640	34960	13680	6.84
Fosso	49760	34920	14840	7.42
Fosso	50780	34880	15900	7.95
Fosso	52460	34840	17620	8.81
Fosso	46700	33620	13080	6.54
Fosso	46440	33580	12860	6.43
Fosso	46560	33540	13020	6.51
Fosso	50900	33500	17400	8.70
Fosso	47260	33440	13820	6.91
Fosso	51340	38500	12840	6.42
Fosso	54040	38600	15440	7.72
Fosso	52760	38540	14220	7.11
Fosso	52760	38500	14260	7.13
Fosso	45020	33580	11440	5.72
Fosso	44600	33780	10820	5.41
Fosso	45380	33760	11620	5.81
Fosso	44300	33740	10560	5.28
Fosso	46120	33720	12400	6.20
Mack	43040	31800	11240	5.62
	FOSSO SUBTOTAL		270500	**135.25**
	TOTAL			**421.26**

Farm to Neutral Site

DATE: 10.31.08 ODOMETER START:

DRIVER: ODOMETER FINISH:

FROM: Fosso's

TO: TIME AT FARM:

TRUCKS USED: T-600 TIME LEAVE FARM:

	LOAD	ODOMETER	TIME		
10/31/08	1	724.040	2:00		20 ton
	2	724.060	8:00		20 ton
11/1/08	3	724.066	6:00	75,460 33,960	20.75 ton
11.2.08	4	724.084	3:00	90,280 34,060	28.11 ton
11.3.08	5	724 099	9:50	94040 33960	30.04 ton
11.3.08	6	724 120	3:30	88980 33900	27.54 ton
11.4.08	7	724 137	7:00	79780 33840	22.97 ton (171.41)
11.4.08	8	724, 150	1:30	61380 33760	
11.4.08	9	724, 182	9:30	86,200 33,480	
11-17-08	10				19.5 ton (estimated)
	11				
	12				
	13				
	14				
	15				

Farm to Neutral Site

DATE: ______ ODOMETER START: ______

DRIVER: GARY ODOMETER FINISH: ______

FROM: FOSSO'S COBS

TO: ______ TIME AT FARM: ______

TRUCKS USED: BOCATS TIME LEAVE FARM: ______

	LOAD ODOMETER	TIME	GROSS	TARE	
	1 — —	10·31·08 UNWEIGHED			9
	2 — —	11·1·08 UNWEIGHED			9
	3 948654	11·2·08 12:00	52,940 #	34,640 #	9
	4 948 669	11·3·08 8:00	53,900 #	34,600 #	9
47.45 ton	5 948684	11·3·08 12:00	55280	34580	10
	6 948702	11·4·08 2:03	50420	34,550	
	7 948733	11·4·08 4:06	52620	34,440	
LOADED w/ RAYMOND	8	11·5·08 10:00	52,800	34,300	
	9				
	10				
	11				
	12				
	13				
	14				
	15				

Farm to Neutral Site

DATE: 11-20-08 ODOMETER START: 532420

DRIVER: Jake ODOMETER FINISH:

FROM: Shop - Corn Cobs

TO: Airport TIME AT FARM:

TRUCKS USED: Mack TIME LEAVE FARM:

LOAD	ODOMETER	TIME	net	
1	43040	31800	11,240	5.62 T
2	Full	Empty		
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

62.42 T

135.03 T from home

Load 1	Full ~~[illegible]~~ 45020	Empty 33580	5.72
Load 2	Full 44600	Empty 33780	5.41
Load 3	Full 45380	Empty 33760	5.81
Load 4	Full 44300	Empty 33740	5.28
Load 5	Full 46120	Empty 33720	6.20

Farm to Neutral Site

DATE: ______ ODOMETER START: ______

DRIVER: ______ ODOMETER FINISH: ______

FROM: ______

TO: ______ TIME AT FARM: ______

TRUCKS USED: ______ TIME LEAVE FARM: ______

LOAD	ODOMETER		TIME net	
1	51,340 - 38,500	→	12,840	6.42 T
2	54,040 - 38,600		15,440	7.72 T
3	52,760 - 38,540		14,220	7.11 T
4	52,760 - 38,500		14,260	7.13 T
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Farm to Neutral Site

DATE: ODOMETER START:

DRIVER: CO ODOMETER FINISH:

FROM:

TO: TIME AT FARM:

TRUCKS USED: TIME LEAVE FARM:

LOAD	ODOMETER	TIME
1	48,260/34,820	6.72
2	48,640/34,960	6.82
3	49,760/34,920	7.42
4	50,780/34,880	7.95
5	52,460/34,840	8.81
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

1320 231 9750

1) Latham NW1/4, N1/2 SW1/4 Sec 13 Edwards Kandiyohi

2) Hanson SE 1/4 Sec 14 Edwards Kandiyohi

3) DeVries NW1/4 Sec 8 Whitefield Kandiyohi

4) Haaks SE1/4 SE1/4 Sec 29, S1/2 SW1/4 Sec 28, N1/2 NW1/4 Sec 33
Lone Tree Chippewa

5) Woltjer-40E NW1/4 NW1/4 Sec 27 Mamre

6) Brandt S1/2 SW1/4 Sec 21, E1/2 NW1/4 Sec 28 Kandiyohi Kandiyohi

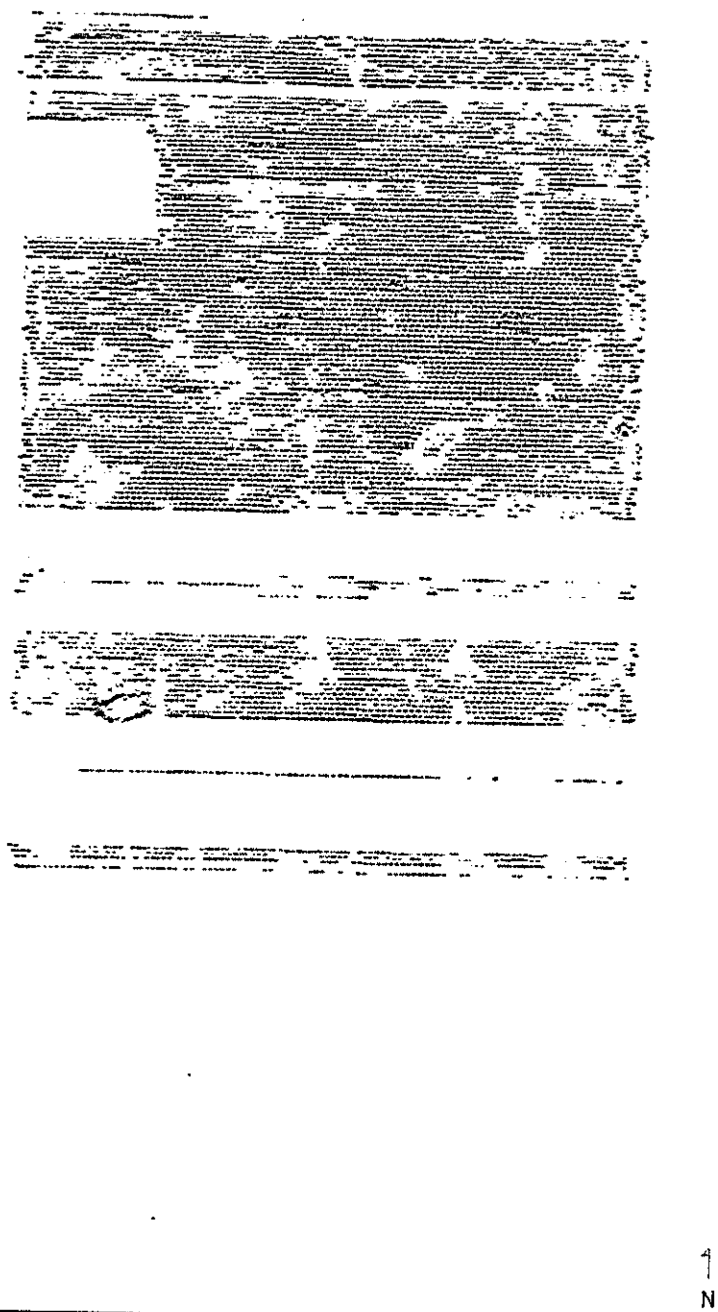
7) Welch S1/2 SE1/4 Sec 27, W1/2 NE1/4 Sec 34 Green Lake Kandiyohi

8) Arnolds N1/2 NE1/4 Sec 34 Willmar Kandiyohi

9) Skoglie N1/2 NE1/4 Sec 15 Mamre Kandiyohi

10) Monson E1/2 Sec 34 Kerkhoven Swift

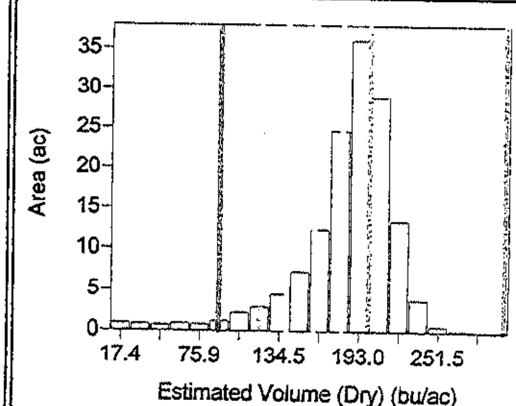
Grain Harvest 2008 - 1(CORN)



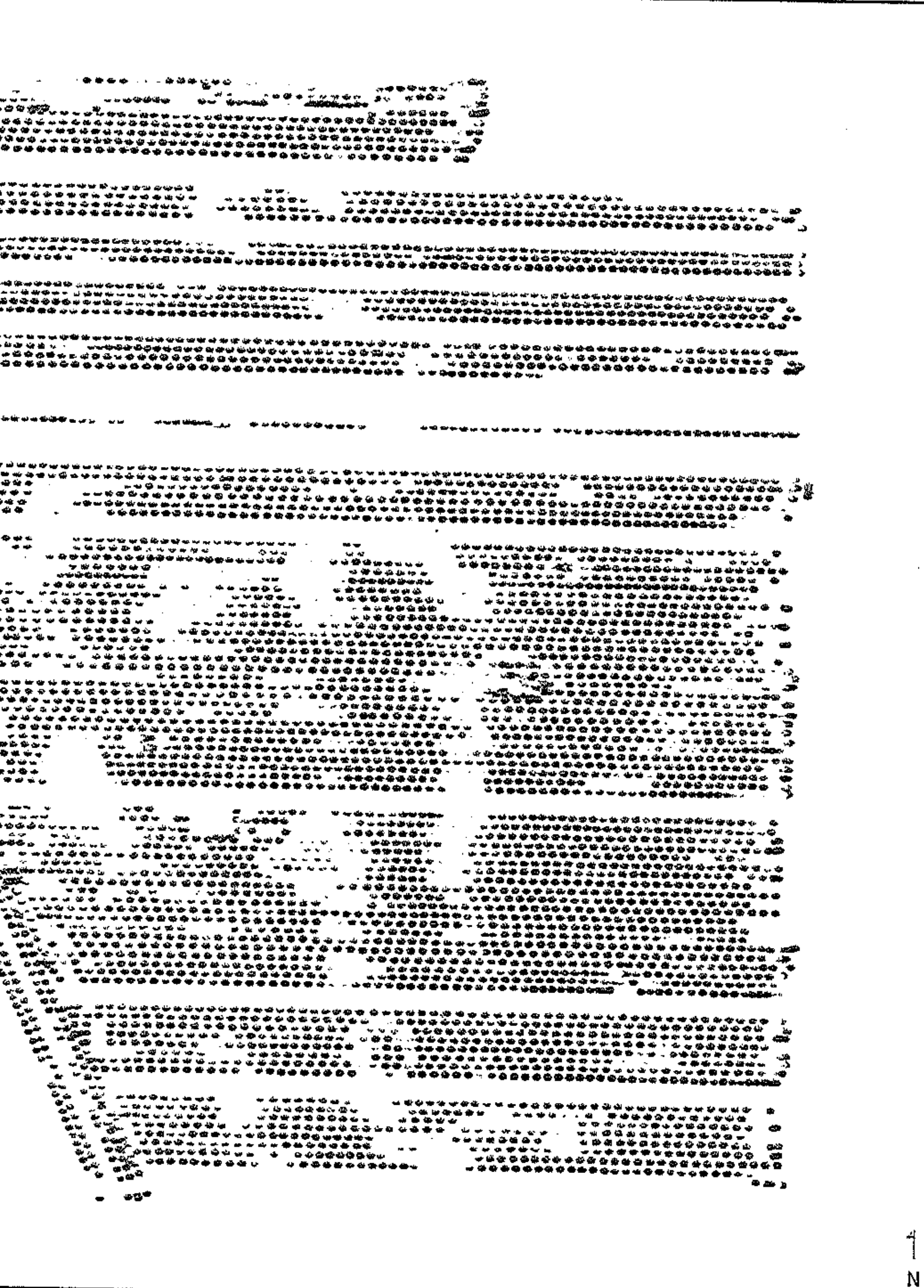
Grower : Folkedahl Consulting
Farm : FOSSO
Field : 1
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 142.01 ac
Avg. Yield : 174.99 bu/ac
Avg. Moisture : 21.72 %

Estimated Volume (Dry)
(bu/ac)

200.00 - 300.00	(47.69 ac)
180.00 - 200.00	(46.87 ac)
160.00 - 180.00	(23.20 ac)
140.00 - 160.00	(10.23 ac)
120.00 - 140.00	(5.39 ac)
90.00 - 120.00	(4.31 ac)
10.00 - 90.00	(4.29 ac)



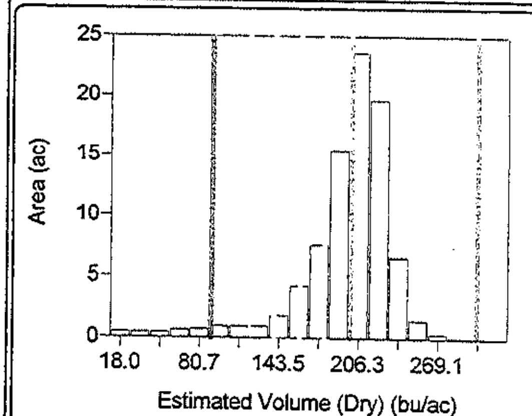
Grain Harvest 2008 - AA(CORN)



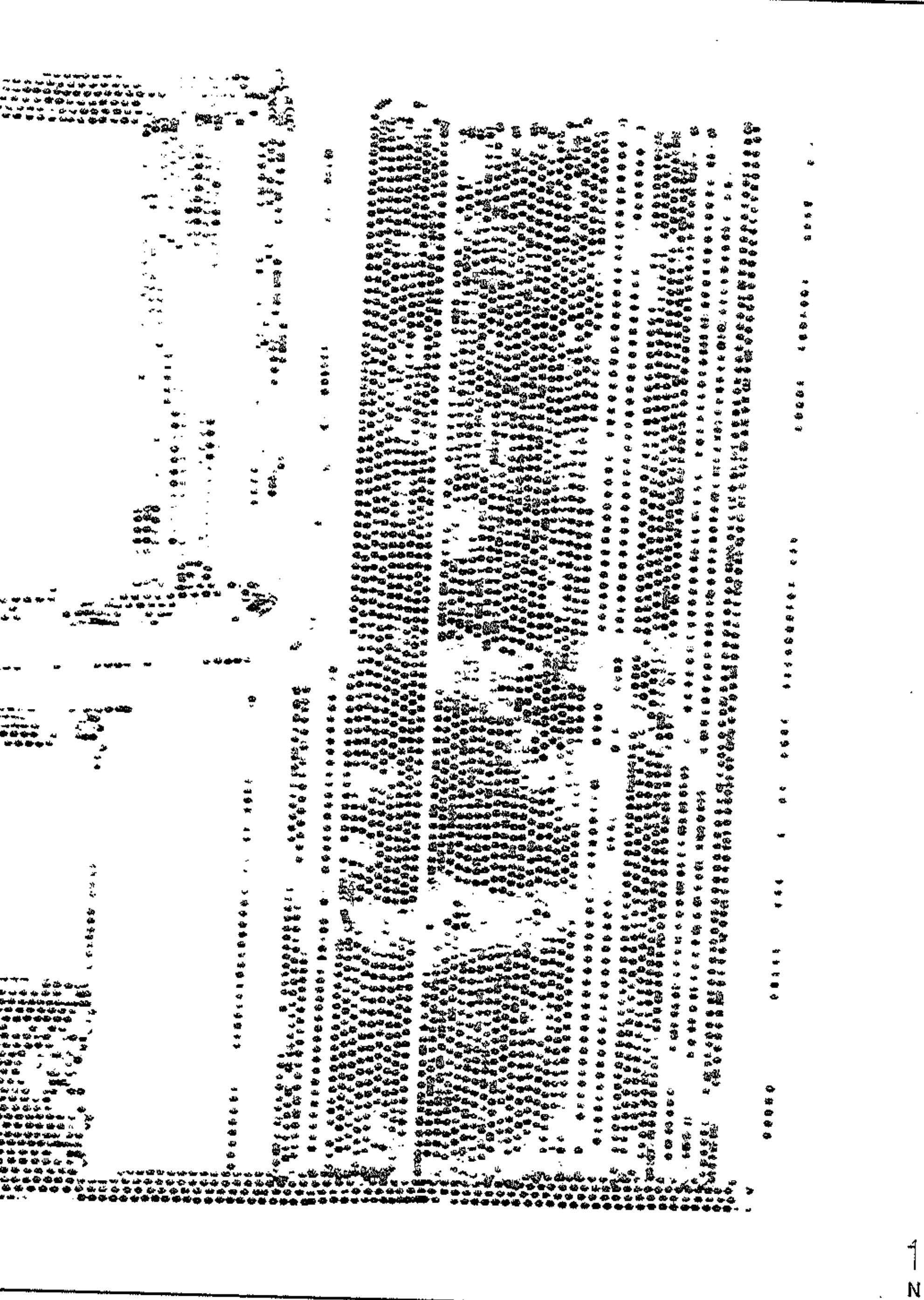
Grower : Folkedahl Consulting
Farm : FOSSO
Field : AA
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 85.93 ac
Avg. Yield : 186.51 bu/ac
Avg. Moisture : 23.69 %

Estimated Volume (Dry) (bu/ac)

200.00	300.00	(49.64 ac)
180.00	200.00	(19.02 ac)
160.00	180.00	(8.26 ac)
140.00	160.00	(3.36 ac)
120.00	140.00	(1.17 ac)
90.00	120.00	(1.77 ac)
10.00	90.00	(2.71 ac)



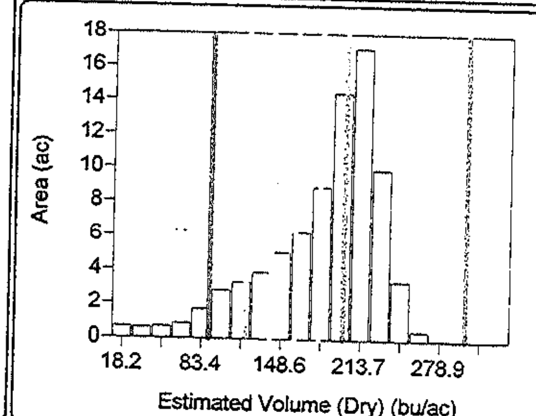
Grain Harvest 2008 - BB(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : BB
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 80.14 ac
Avg. Yield : 173.68 bu/ac
Avg. Moisture : 21.92 %

Estimated Volume (Dry) (bu/ac)

200.00 - 300.00	(36.46 ac)
180.00 - 200.00	(14.71 ac)
160.00 - 180.00	(8.35 ac)
140.00 - 160.00	(6.38 ac)
120.00 - 140.00	(4.59 ac)
90.00 - 120.00	(5.61 ac)
10.00 - 90.00	(4.01 ac)



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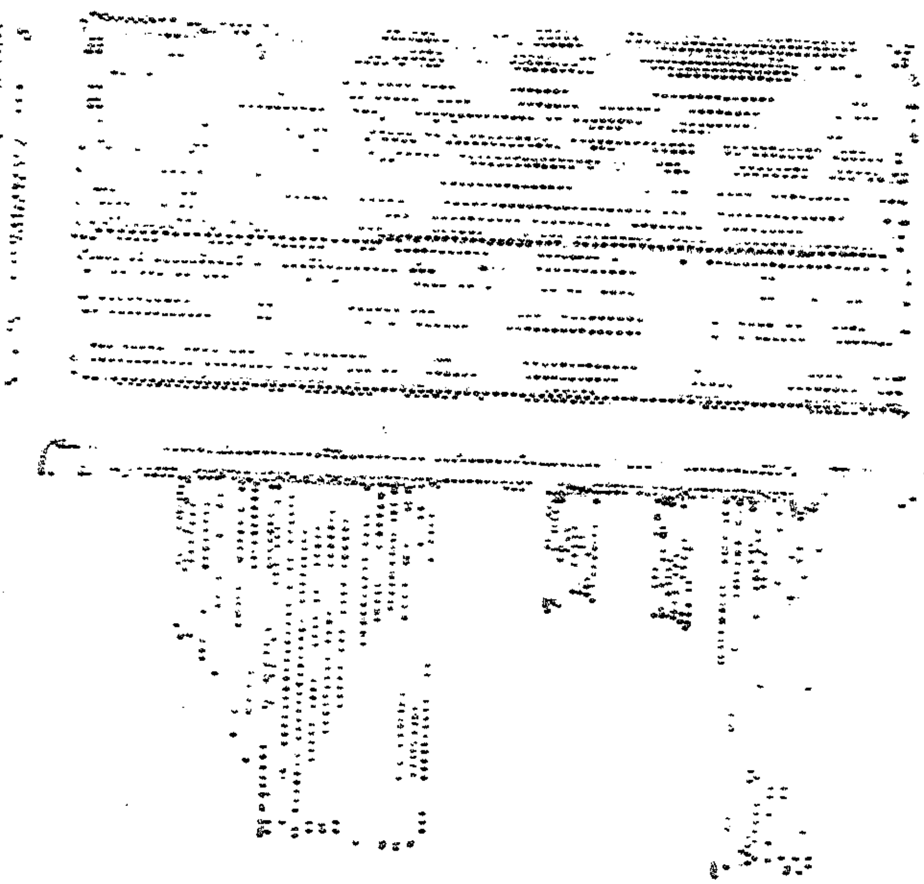
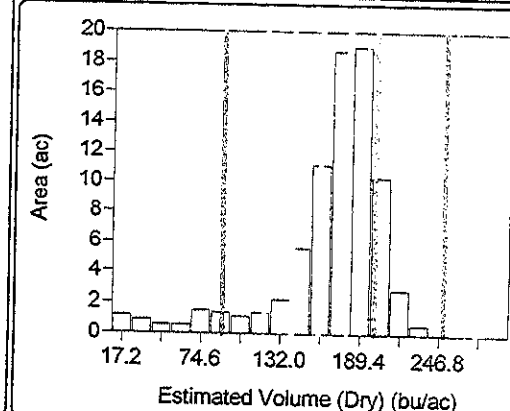
Grain Harvest 2008 - CC(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : CC
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 79.19 ac
Avg. Yield : 159.67 bu/ac
Avg. Moisture : 22.00 %

Estimated Volume (Dry) (bu/ac)

200.00	250.00	(10.52 ac)
180.00	200.00	(25.69 ac)
160.00	180.00	(22.04 ac)
140.00	160.00	(9.70 ac)
120.00	140.00	(3.05 ac)
90.00	120.00	(2.49 ac)
10.00	90.00	(5.68 ac)



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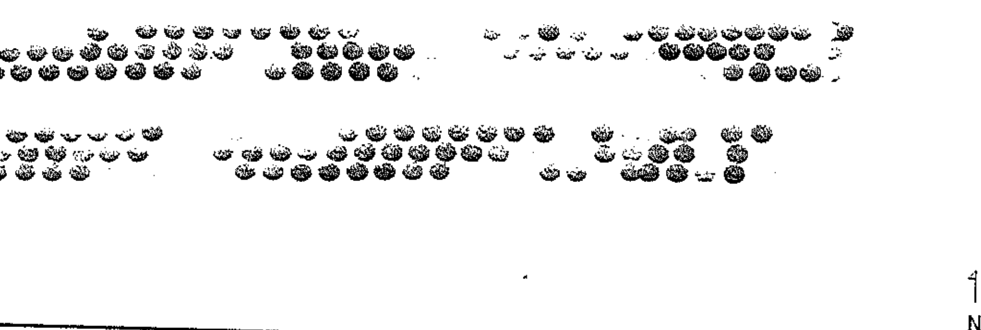
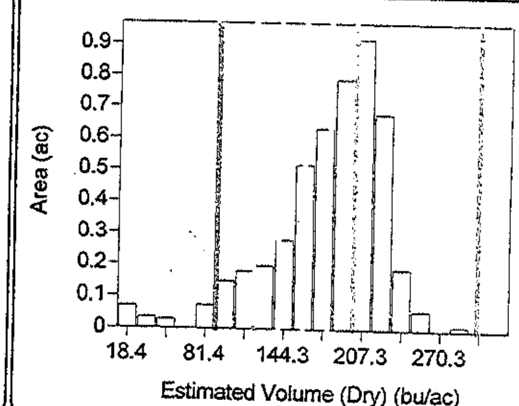
Grain Harvest 2008 - DD(CORN)

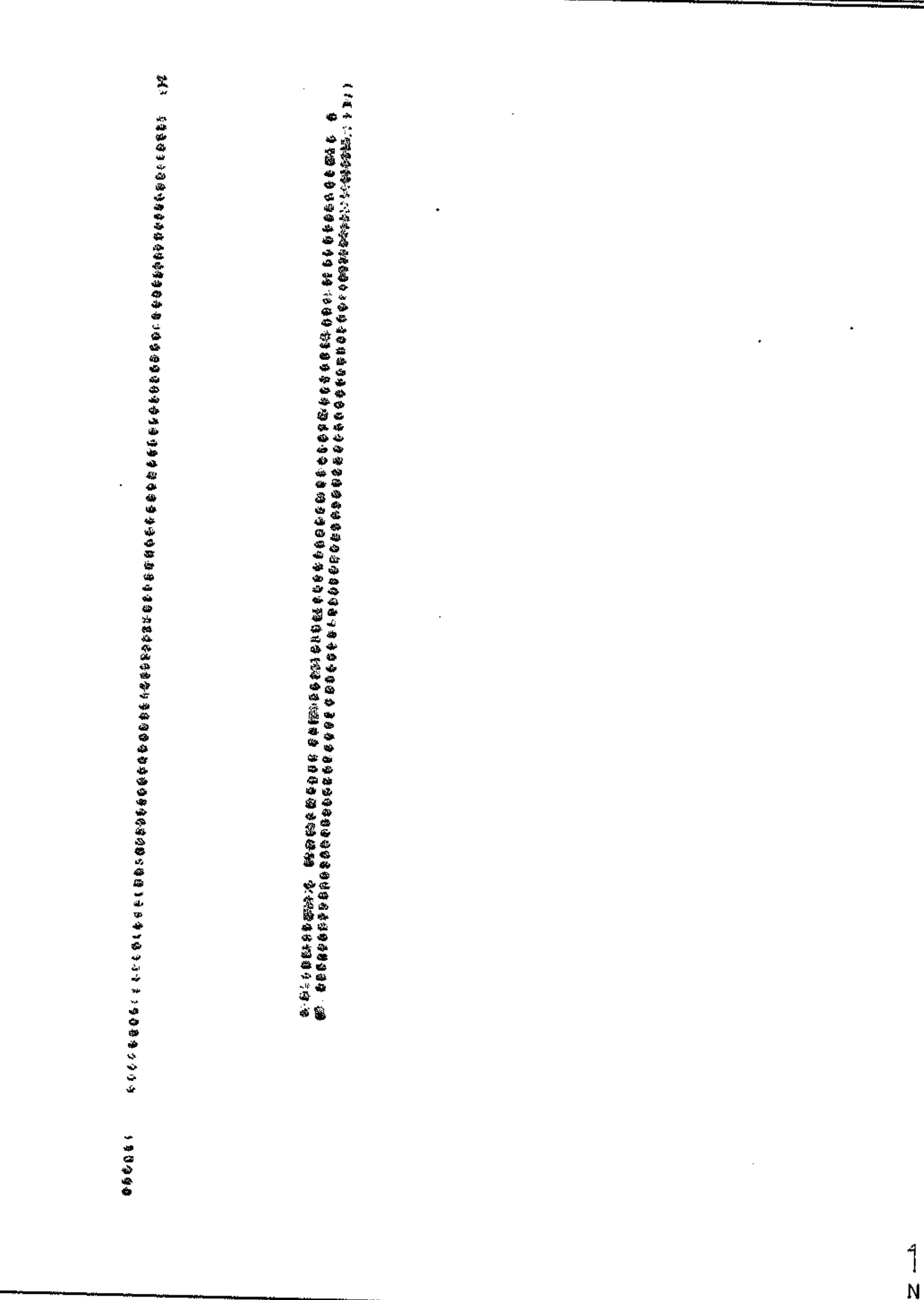


Grower : Folkedahl Consulting
Farm : FOSSO
Field : DD
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 4.797 ac
Avg. Yield : 186.50 bu/ac
Avg. Moisture : 21.11 %

Estimated Volume (Dry) (bu/ac)	
200.00 - 300.00	(1.804 ac)
180.00 - 200.00	(1.056 ac)
160.00 - 180.00	(0.744 ac)
140.00 - 160.00	(0.430 ac)
120.00 - 140.00	(0.267 ac)
90.00 - 120.00	(0.282 ac)
10.00 - 90.00	(0.213 ac)



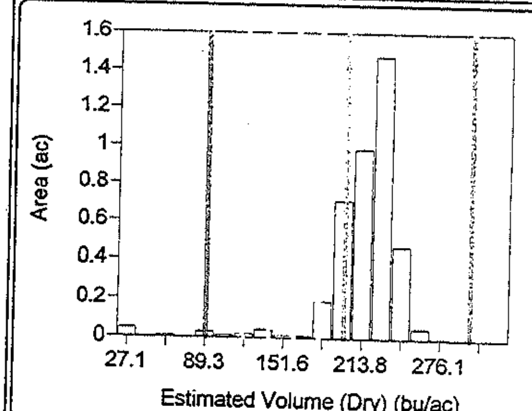
Grain Harvest 2008 - DD(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : DD
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 4.064 ac
Avg. Yield : 200.76 bu/ac
Avg. Moisture : 21.06 %

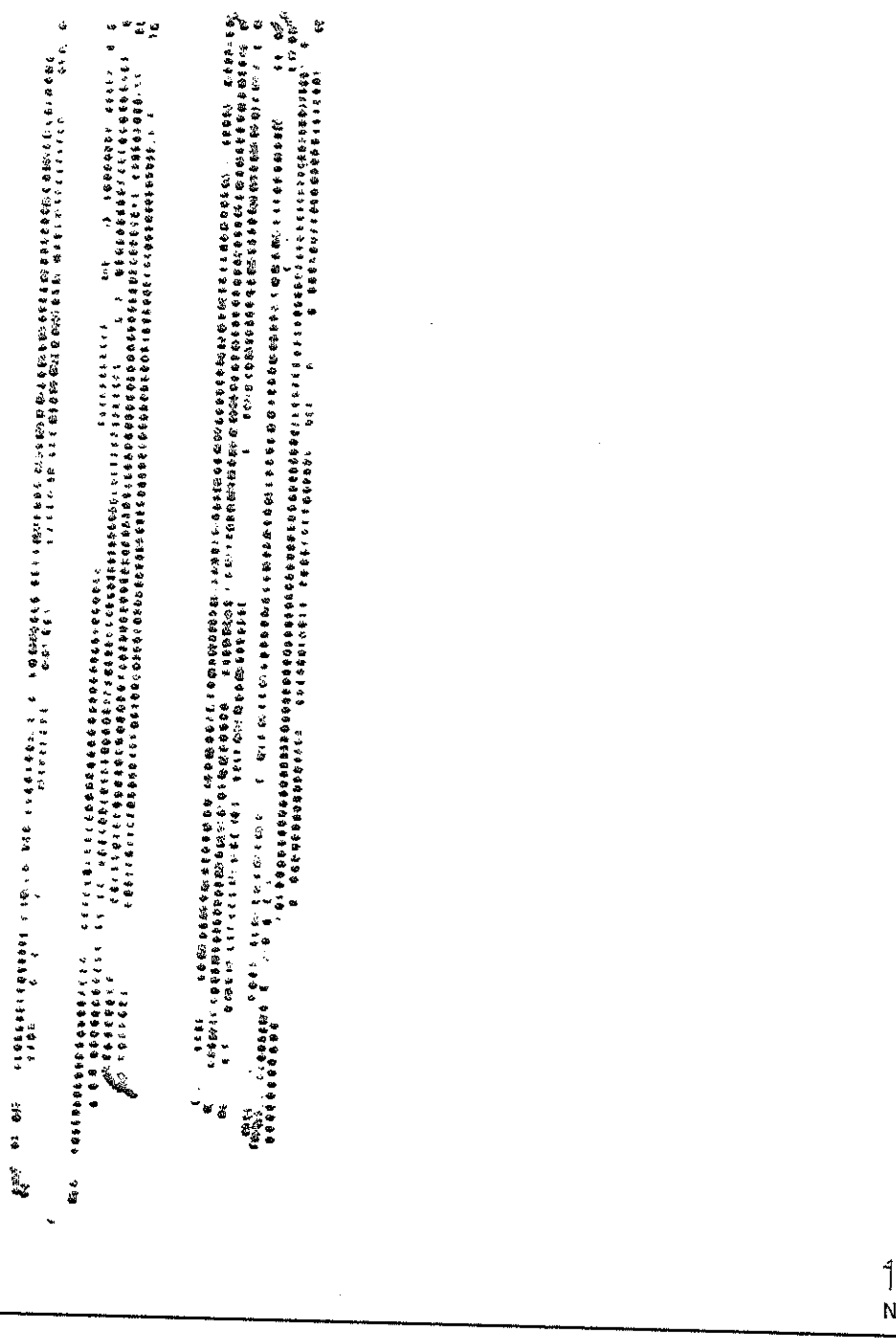
Estimated Volume (Dry)
(bu/ac)

200.00 - 300.00 (3.33 ac)
180.00 - 200.00 (0.49 ac)
160.00 - 180.00 (0.08 ac)
140.00 - 160.00 (0.03 ac)
120.00 - 140.00 (0.04 ac)
90.00 - 120.00 (0.03 ac)
10.00 - 90.00 (0.07 ac)



CASE IH AFS Software

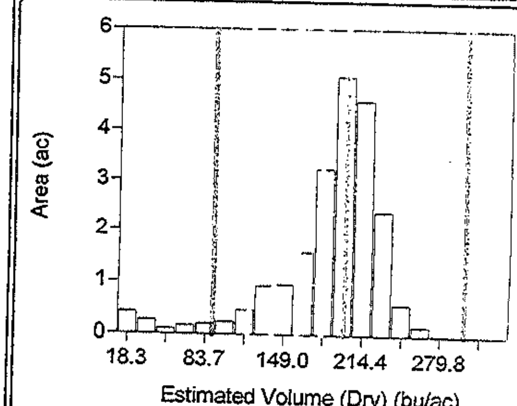
Grain Harvest 2008 - EE(CORN)



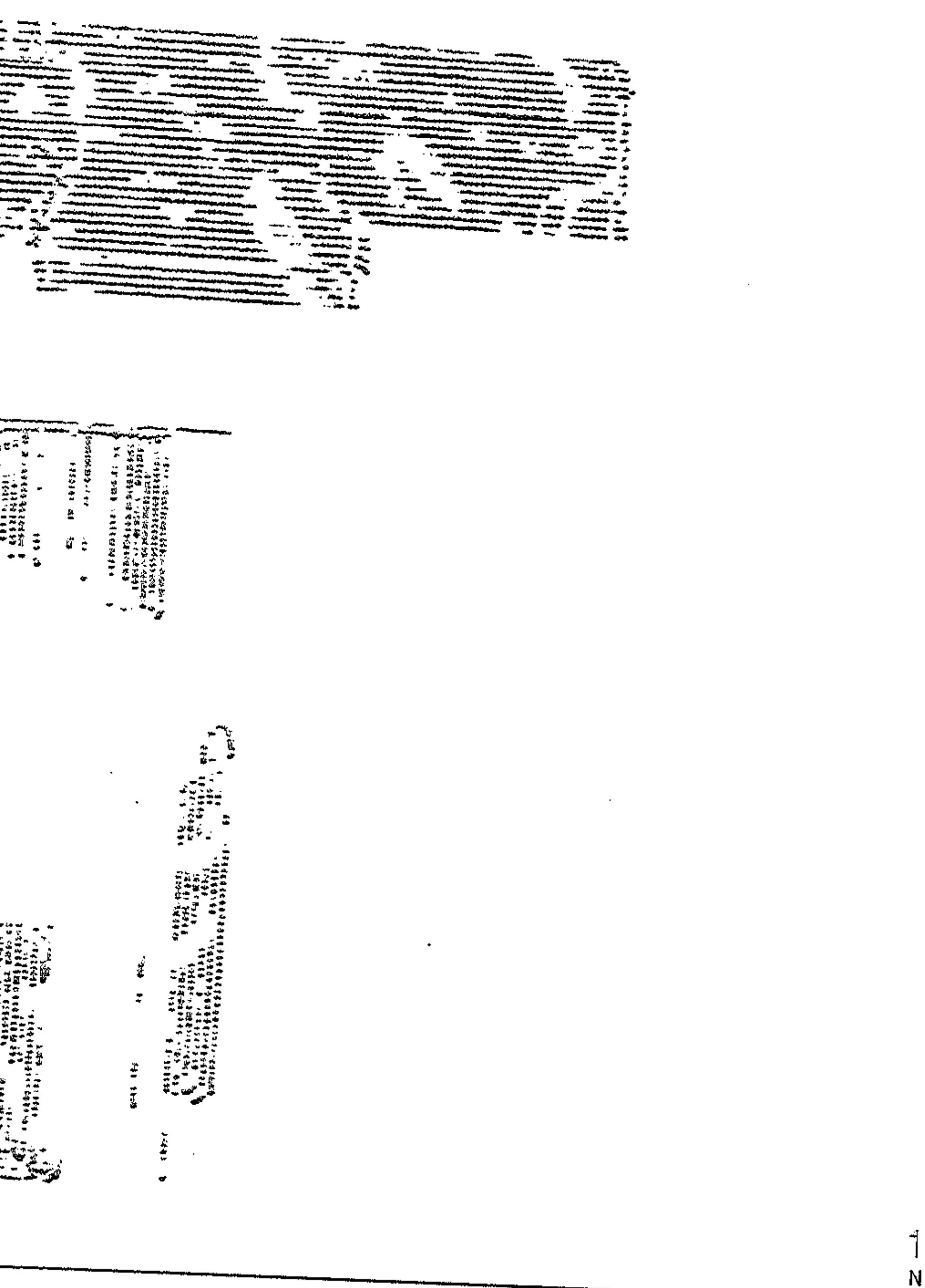
Grower : Folkedahl Consulting
Farm : FOSSO
Field : EE
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 21.39 ac
Avg. Yield : 176.41 bu/ac
Avg. Moisture : 21.02 %

Estimated Volume (Dry) (bu/ac)

200.00	300.00	(9.698 ac)
180.00	200.00	(5.619 ac)
160.00	180.00	(2.014 ac)
140.00	160.00	(1.339 ac)
120.00	140.00	(1.045 ac)
90.00	120.00	(0.511 ac)
10.00	90.00	(1.146 ac)



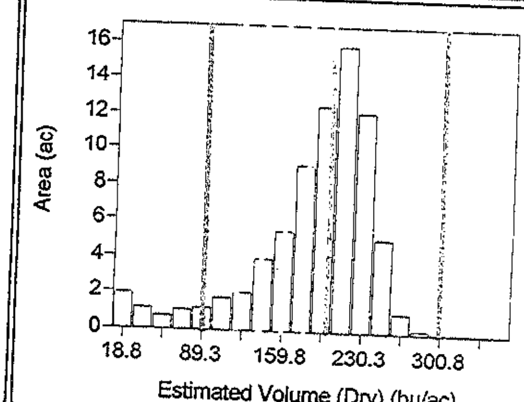
Grain Harvest 2008 - FFGG(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : FFGG
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 75.41 ac
Avg. Yield : 160.99 bu/ac
Avg. Moisture : 21.24 %

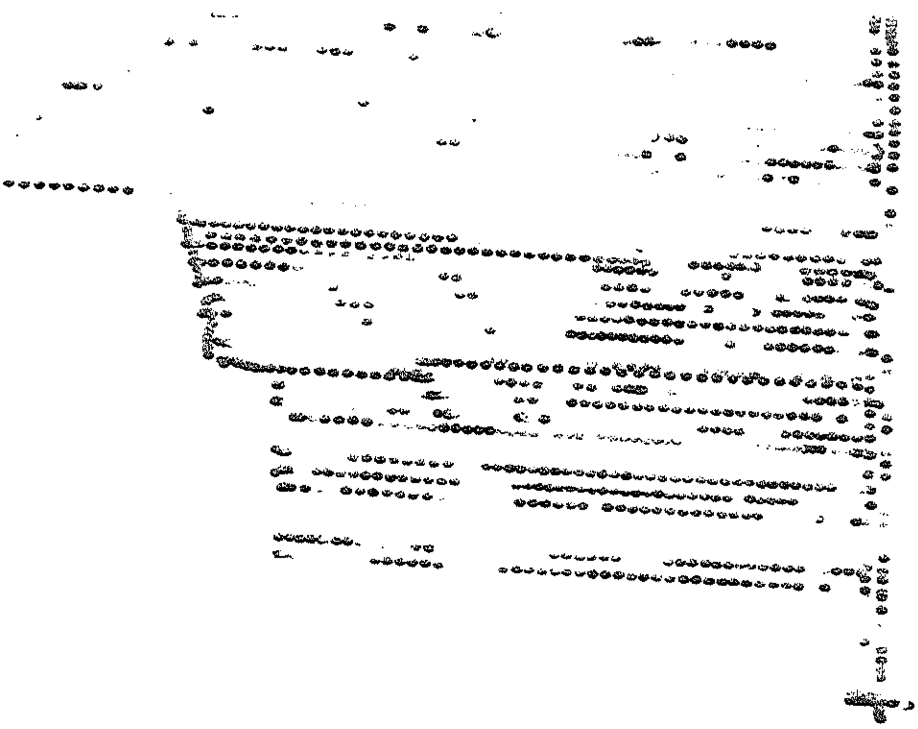
Estimated Volume (Dry)
(bu/ac)

200.00	– 300.00	(37.43 ac)
180.00	– 200.00	(13.40 ac)
160.00	– 180.00	(8.15 ac)
140.00	– 160.00	(5.19 ac)
120.00	– 140.00	(2.92 ac)
90.00	– 120.00	(2.64 ac)
10.00	– 90.00	(5.58 ac)



CASE IH AFS Software

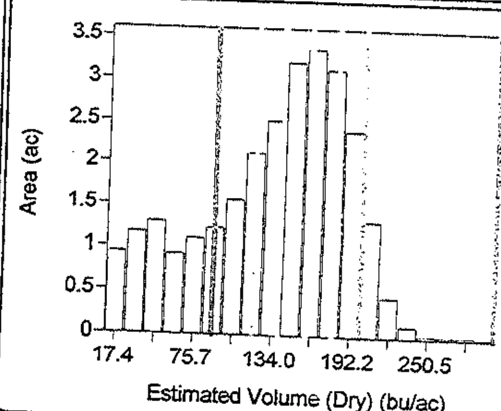
Grain Harvest 2008 - GG(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : GG
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 26.94 ac
Avg. Yield : 114.72 bu/ac
Avg. Moisture : 21.69 %

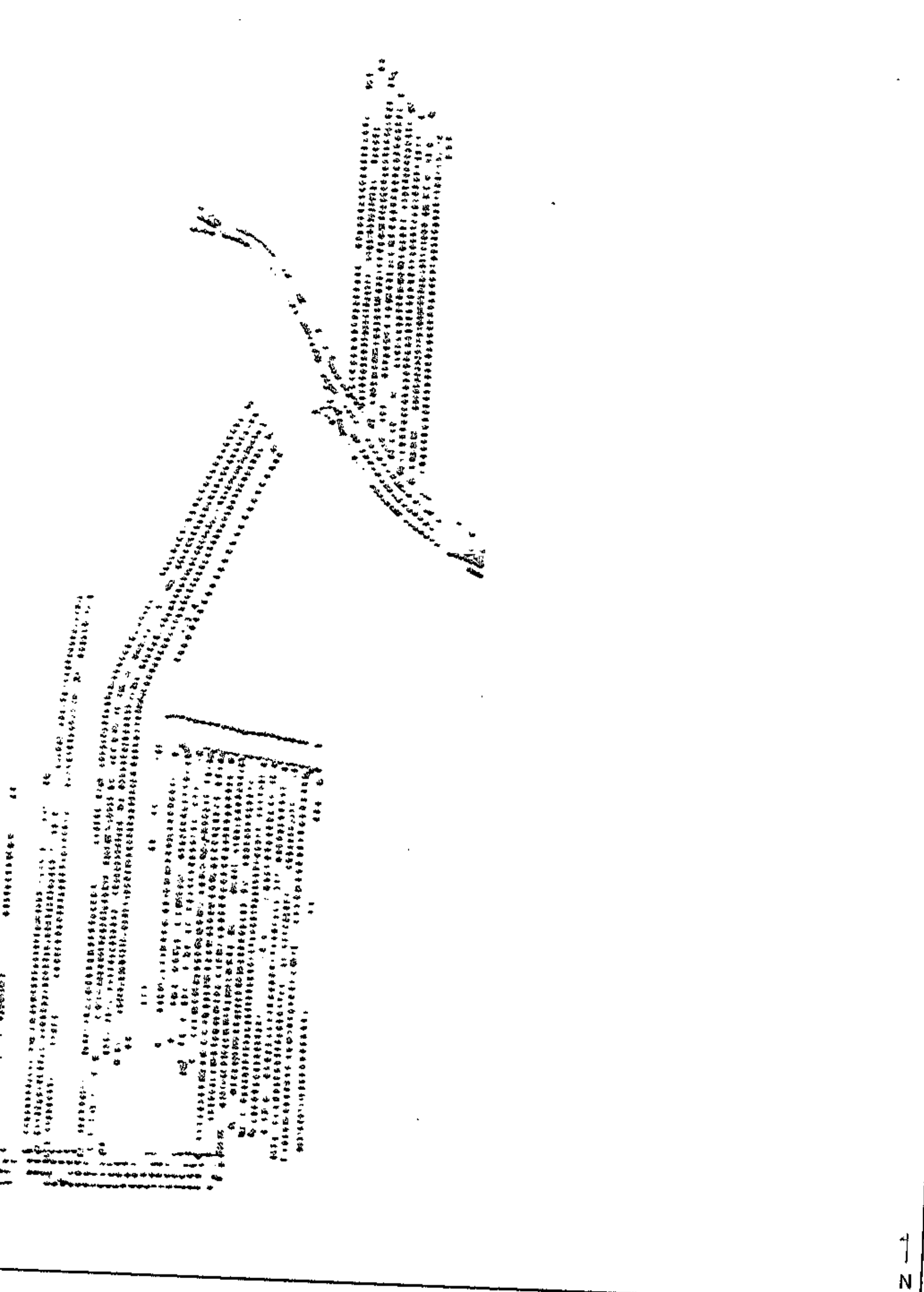
Estimated Volume (Dry) (bu/ac)

200.00 - 300.00	(1.966 ac)
180.00 - 200.00	(3.374 ac)
160.00 - 180.00	(4.603 ac)
140.00 - 160.00	(4.304 ac)
120.00 - 140.00	(3.462 ac)
90.00 - 120.00	(3.117 ac)
10.00 - 90.00	(6.101 ac)



CASE IH AFS Software

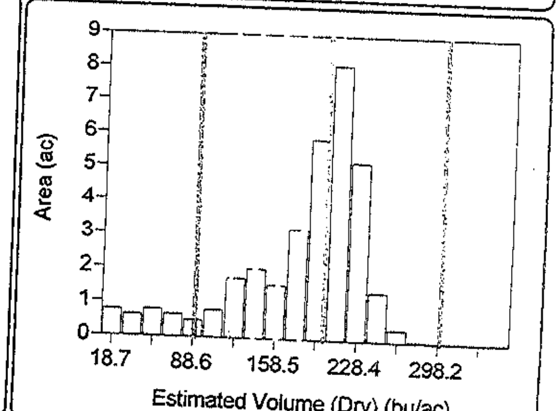
Grain Harvest 2008 - HH(CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : HH
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 33.74 ac
Avg. Yield : 162.46 bu/ac
Avg. Moisture : 22.34 %

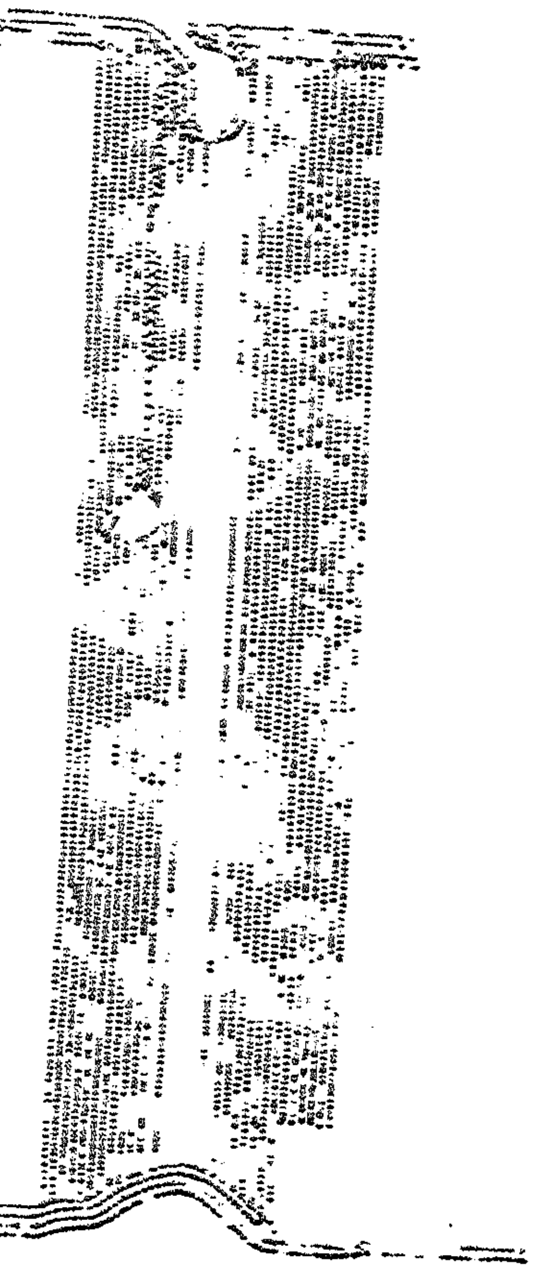
Estimated Volume (Dry)
(bu/ac)

200.00 - 300.00 (16.133 ac)
180.00 - 200.00 (5.790 ac)
160.00 - 180.00 (2.978 ac)
140.00 - 160.00 (1.806 ac)
120.00 - 140.00 (2.606 ac)
90.00 - 120.00 (1.213 ac)
10.00 - 90.00 (3.140 ac)



CASE IH AFS Software

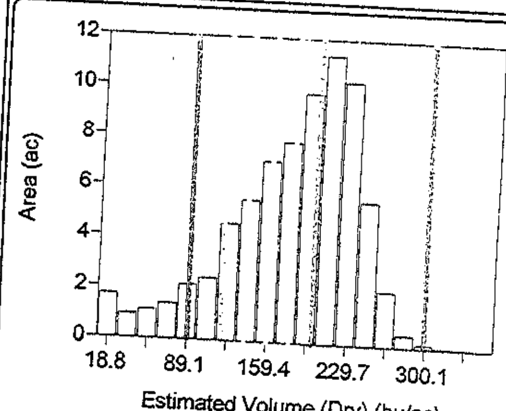
...a... Harvest 2008 - II (CORN)



Grower : Folkedahl Consulting
Farm : FOSSO
Field : II
Year : 2008
Operation : Grain Harvest
Crop / Product : CORN
Op. Instance : Harvest - 1
Area : 74.80 ac
Avg. Yield : 166.52 bu/ac
Avg. Moisture : 20.20 %

Estimated Volume (Dry) (bu/ac)

200.00 - 300.00	(31.67 ac)
180.00 - 200.00	(11.19 ac)
160.00 - 180.00	(7.98 ac)
140.00 - 160.00	(7.59 ac)
120.00 - 140.00	(5.40 ac)
90.00 - 120.00	(4.44 ac)
10.00 - 90.00	(6.38 ac)



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[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
[illegible]

Cause wagon for [illegible] [illegible] by Fleming

[illegible] [illegible] [illegible] [illegible] by [illegible]

[illegible] wagon [illegible] [illegible] [illegible] [illegible] by [illegible]

[illegible]

Fleming [illegible] [illegible] one [illegible] [illegible] one [illegible] button

[illegible] [illegible] [illegible] [illegible] [illegible] button [illegible] [illegible]
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Fleming [illegible] [illegible] [illegible]

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APPENDIX D

Corn Cob–Coal Co-Combustion Moisture-Cost Chart

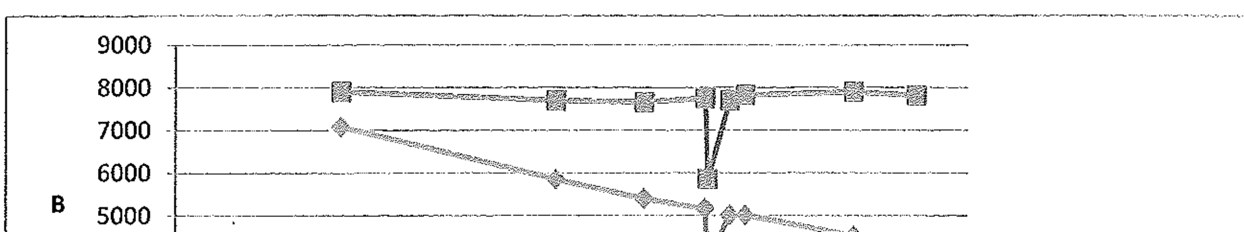
WMU Corn Cob-Coal Co-Combustion Study

Harvest Date	Harvest Location	Cob Moisture		Cob Btu wet	Cob Btu dry
8/21/2008	Ne	10%	0.10	7078	7901
8/22/2008	Tx	24%	0.24	5852	7699
6/19/2009	StackTest	30%	0.30	5400	7662
11/12/2008	Stockpile	33%	0.33	5168	7755
6/17/2009	StackTest	34%	0.34	~~3901~~	~~5867~~
6/18/2009	StackTest	35%	0.35	5017	7707
12/10/2008	Stockpile	36%	0.36	5015	7827
1/21/2009	Stockpile	43%	0.43	4527	7906
4/1/2009	Stockpile	47%	0.47	4167	7821
AVERAGES		32%		5278	7785

	32% Moisture	Dry
Cob Btu/lb	5,278.00	7,784.75
Cob Mm Btu/ton	10.56	15.57
Cob Total $/ton	$61.02	$90.00
Cob Total $/Mm Btu	$5.78	$5.78
Cob $/ton with USDA Cost Match	$30.51	$45.00
Cob $/Mm Btu with USDA Cost Match	$2.89	$2.89

Coal Btu/lb	8800
Coal Mm Btu/ton	17.6
Coal $/ton	45
Coal $/Mm Btu	$2.56

Tons Coal/Yr	25% by Btu Tons Cobs/Yr	10% by Btu Tons Cobs/Yr	5% by Btu Tons Cobs/Yr
50,000	27,788	9,263	4,388
75,000	41,682	13,894	6,581
100,000	55,577	18,526	8,775



APPENDIX E

Corn Cob–Coal Co-Combustion Photos

Photo 1

Cob injection system. Cobs flow vertically downward through the larger tube into the injector. Air for entrainment into the furnace comes from the duct pipe at the left of the injector. Furnace entrance is through a view port in the furnace wall at the right side of image.

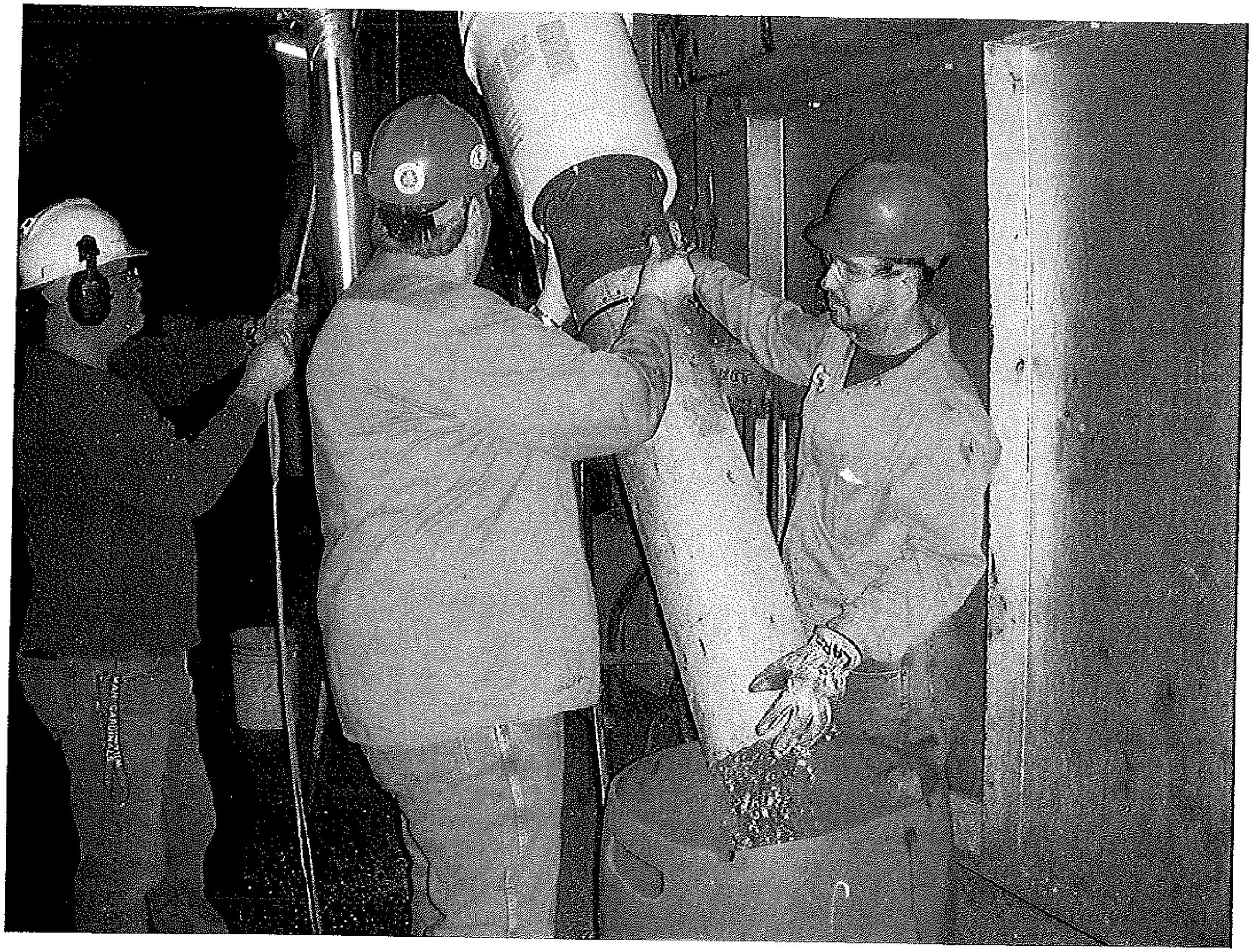


Photo 2

Illustration of flow rate testing. Cobs are diverted from the injection system through the hand held pipe into a barrel for a specified period of time. The barrel is then weighed to give cob flow rates into the furnace.

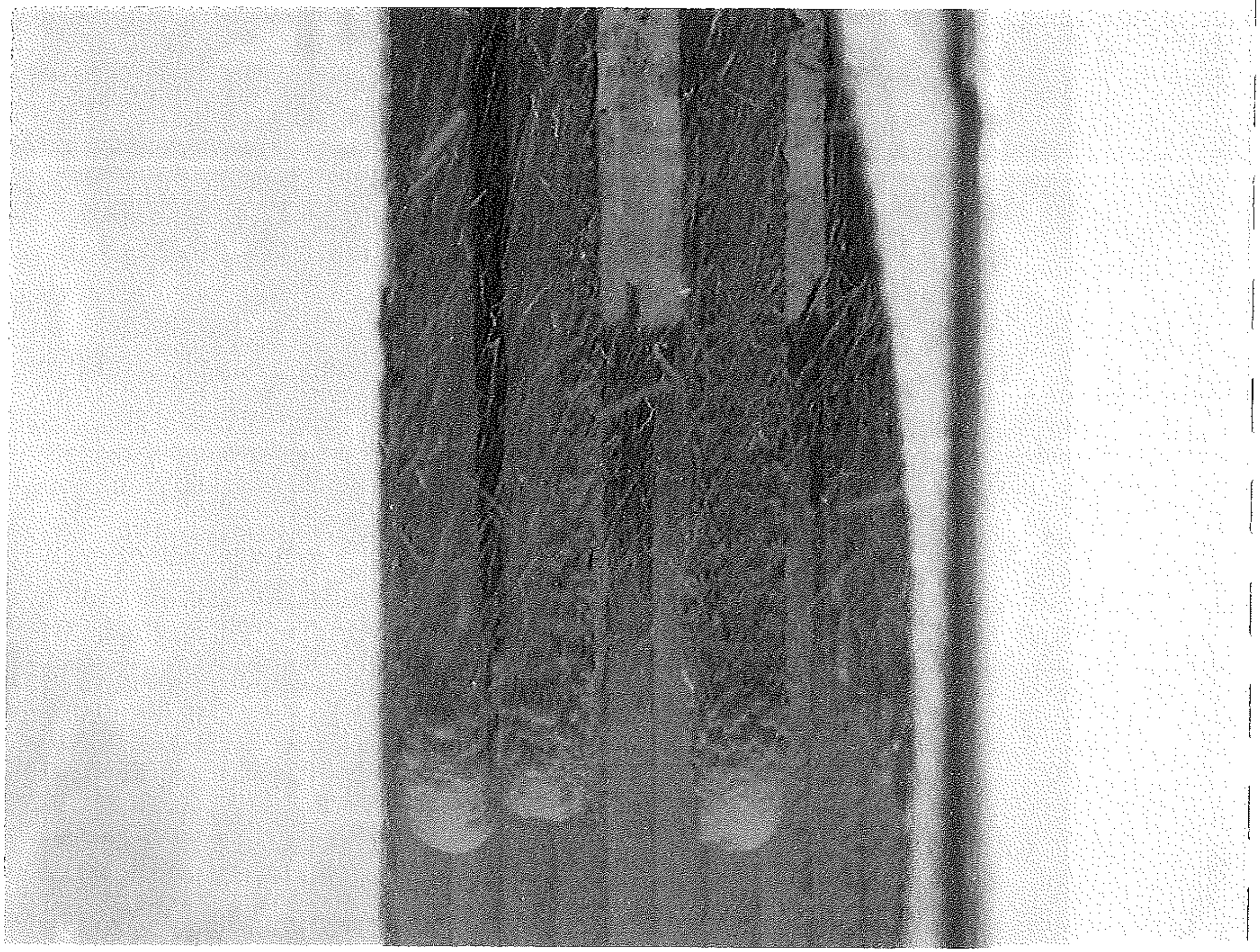


Photo 3

View of the pendant heat exchanger under coal-only firing.

Photo 4

View of the pendant heat exchanger under cobs and coal firing, illustrating more combustion and ash entrained in the gas.

APPENDIX F

Laboratory Analysis Reports

Corn Cob Proximate Ultimate Laboratory Analysis Reports

MINNESOTA VALLEY TESTING LABORATORIES, INC.
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1411 S. 12th St. ~ Bismarck, ND 58502 ~ 800-279-6885 ~ Fax 701-258-9724
51 E. Avenue ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885
www.mvtl.com

MEMBER ACIL

Sample Number: 08-F314

Report Date: 9/ 9/08

Work Order #: 81-1038

Jon Folkedahl
Folkedahl Consulting
4900 15th St NE
Willmar MN 56201

Date Received 8/21/08

Sample Description: Corn Cobs
Sample Site: Vernon Flamme, N.Bend,Nebraska

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	10.42	wt. %		
Ash	1.52	wt. %	[illegible]	wt. %
Volatile Matter	[illegible]	wt. %	80.00	wt. %
Fixed Carbon	16.42	wt. %	[illegible]	wt. %
BTU/lb	7048	BTU/lb	[illegible]901	BTU/lb
Total Sulfur	0.11	wt. %	0.1[illegible]	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	10.42	wt. %		
Ash	1.52	wt. %	1.70	wt. %
Carbon	39.[illegible]	wt. %	[illegible]	wt. %
Hydrogen	6.44	wt. %	[illegible].09	wt. %
Nitrogen	0.61	wt. %	[illegible].68	wt. %
Total Sulfur	0.11	wt. %	[illegible]	wt. %
Oxygen by Difference	[illegible]	wt. %	[illegible]	wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	[illegible]	wt. %	[illegible]	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS	
Silicon Dioxide in Ash	19.[illegible]	wt. %
Aluminum Oxide in Ash	1.8[illegible]	wt. %
Titanium Dioxide in Ash	0.00	wt. %
Iron Oxide in Ash	0.95	wt. %
Calcium Oxide in Ash	3.6[illegible]	wt. %
Magnesium Oxide in Ash	5.21	wt. %
Potassium Oxide in Ash	[illegible]	wt. %
Sodium Oxide in Ash	[illegible]	wt. %
SO3 in Ash	[illegible]	wt. %
P2O5 in Ash	8.16	wt. %
Strontium Oxide in Ash	0.0[illegible]	wt. %
Barium Oxide in Ash	0.03	wt. %
Manganese Dioxide in Ash	0.00	wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace ug/g	< 0.0[illegible] ug/g	< 0.0[illegible] ug/g

Comment: Bulk Density: [illegible] lbs/cu.ft
Density: [illegible] g/cu cm ([illegible] lbs/cu.ft)

The bulk density in lbs/cu.ft was determined on the corn cobs as received. The density in g/cu cm was determined on corn cobs after [illegible] ground

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MEMBER ACIL

Sample Number: 08-F331

Report Date: 9/ 5/08

Work Order #: 81-1053

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Date Received: 8/22/08

Sample Description: Corn Cobs
Sample Site: Averhoff - Waxahatchie, TX

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	23.99	wt. %		
Ash	0.88	wt. %	1.16	wt. %
Volatile Matter	62.19	wt. %	[illegible]	wt. %
Fixed Carbon	12.94	wt. %	17.02	wt. %
Btu/lb	[illegible]	BTU/lb	7699	BTU/lb
Total Sulfur	0.05	wt. %	0.07	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	23.99	wt. %		
Ash	0.88	wt. %	1.16	wt. %
Carbon	33.50	wt. %	44.70	wt. %
Hydrogen	7.05	wt. %	5.30	wt. %
Nitrogen	0.13	wt. %	[illegible]	wt. %
Total Sulfur	0.05	wt. %	0.07	wt. %
Oxygen by Difference	[illegible]	wt. %	[illegible]	wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.05	wt. %	0.07	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS	
Silicon Dioxide in Ash	41.90	wt. %
Aluminum Oxide in Ash	[illegible]	wt. %
Titanium Dioxide in Ash	2.04	wt. %
Iron Oxide in Ash	[illegible]	wt. %
Calcium Oxide in Ash	[illegible]	wt. %
Magnesium Oxide in Ash	[illegible]	wt. %
Potassium Oxide in Ash	[illegible]	wt. %
Sodium Oxide in Ash	11.25	wt. %
SO3 in Ash	[illegible]	wt. %
P2O5 in Ash	[illegible]	wt. %
Strontium Oxide in Ash	[illegible]	wt. %
Barium Oxide in Ash	[illegible]	wt. %
Manganese Dioxide in Ash	[illegible]	wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Total ug/g	< 0.02 ug/g	< 0.026ug/g

Comment Bulk Density: 13.1 lbs/cu ft
Density: 0.222 g/cu cm ([illegible] lbs/cu ft)

The bulk density in lb/cu.ft was determined on the corn cobs as received. The density in g/cu.cm was determined on corn cobs after being ground.

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www.mvtl.com

MEMBER ACIL

Sample Number: 08-F321

Report Date: 9/ 3/08

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 81-1053

Date Received: 8/22/08

Sample Description Corn Cobs
Sample Site Averhoff - Waxahachie, TX

* PROXIMATE *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	23.93	wt. %		
Ash	0.88	wt. %	1.16	wt. %
Volatile Matter	62.59	wt. %	81.0[illegible]	wt. %
Fixed Carbon	12.96	wt. %	17.02	wt. %
Btu/lb	5952	Btu/lb	7699	Btu/lb
Total Sulfur	0.05	wt. %	0.07	wt. %

* ULTIMATE *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	23.57	wt. %		
Ash	0.88	wt. %	1.16	wt. %
Carbon	33.50	wt. %	43.70	wt. %
Hydrogen	7.65	wt. %	5.80	wt. %
Nitrogen	0.33	wt. %	0.44	wt. %
Total Sulfur	0.05	wt. %	0.07	wt. %
Oxygen by Difference	57.[illegible]	wt. %	4[illegible].87	wt. %

* SULFUR FORMS *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.05	wt. %	0.07	wt. %

* ASH FUSION *

ANALYTE	REDUCING	OXIDIZING

* MINERAL ANALYSIS OF ASH *

ANALYTE	DRY BASIS	
Silicon Dioxide in Ash	41.90	wt. %
Aluminum Oxide in Ash	[illegible]	wt. %
Titanium Dioxide in Ash	2.04	wt. %
Iron Oxide in Ash	[illegible]	wt. %
Calcium Oxide in Ash	5.34	wt. %
Magnesium Oxide in Ash	[illegible].06	wt. %
Potassium Oxide in Ash	20.1[illegible]	wt. %
Sodium Oxide in Ash	11.29	wt. %
SO3 in Ash	[illegible].98	wt. %
P2O5 in Ash	[illegible].46	wt. %
Strontium Oxide in Ash	[illegible].02	wt. %
Barium Oxide in Ash	[illegible].03	wt. %
Manganese Dioxide in Ash	[illegible].09	wt. %

* MISCELLANEOUS *

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace ug/g	< 0.02 ug/g	< 0.026ug/g

Comment. Bulk Density. 13.1 lbs/cu ft
Density: 0.222 g/cu cm (13.8 lbs/cu ft)

The bulk density in lb/cu.ft was determined on the corn cobs as received. The density in g/cu.cm was determined on corn cobs after being ground.

MVTL

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51 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885

MEMBER
ACIL

Sample Number: 08-F402

Report Date: 12/ 2/08

Work Order #: 81-1419

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Date Received: 11/12/08

Sample Description: Corn Cobs

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	33.36	wt. %		
Ash	1.45	wt. %	2.18	wt. %
Volatile Matter	53.16	wt. %	79.77	wt. %
Fixed Carbon	12.03	wt. %	18.05	wt. %
BTU/lb	5168	BTU/lb	7755	BTU/lb
Total Sulfur	0.02	wt. %	0.03	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	33.36	wt. %		
Ash	1.45	wt. %	2.18	wt. %
Carbon	28.70	wt. %	43.07	wt. %
Hydrogen	7.95	wt. %	6.33	wt. %
Nitrogen	0.46	wt. %	0.69	wt. %
Total Sulfur	0.02	wt. %	0.03	wt. %
Oxygen by Difference	61.42	wt. %	47.71	wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.02	wt. %	0.03	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS	
Silicon Dioxide in Ash	33.08	wt. %
Aluminum Oxide in Ash	0.88	wt. %
Titanium Dioxide in Ash	0.09	wt. %
Iron Oxide in Ash	1.11	wt. %
Calcium Oxide in Ash	3.52	wt. %
Magnesium Oxide in Ash	5.60	wt. %
Potassium Oxide in Ash	32.58	wt. %
Sodium Oxide in Ash	6.42	wt. %
SO3 in Ash	2.65	wt. %
P2O5 in Ash	11.09	wt. %
Strontium Oxide in Ash	0.02	wt. %
Barium Oxide in Ash	0.06	wt. %
Manganese Dioxide in Ash	0.08	wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	< 0.02 ug/g	< 0.03 ug/g

Comment: Bulk Density: 10.0 lbs/cu.ft
Density: 0.304 g/cu.cm (19.0 lbs/cu.ft)

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51 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885

MEMBER
ACIL

Sample Number: 08-F402

Report Date: 12/ 2/08

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 81-1419

Date Received: 11/12/08

Sample Description: Corn Cobs

The bulk density in lb/cu.ft was determined on the corn cobs as received. The density in g/cu.cm was determined on corn cobs after being ground.

3/31 4/1 Test Burn Ash Analysis Laboratory Reports

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MEMBER ACIL

Sample Number: 09-C695

Report Date: 4/10/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 89-291

Date Collected: 4/ 1/09 15:00

Date Received: 4/ 6/09

Sample Description: Coal Sample

• PROXIMATE •

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	28.12	wt. %		
Ash	9.30	wt. %	12.94	wt. %
Volatile Matter	26.54	wt. %	36.92	wt. %
Fixed Carbon	36.04	wt. %	50.14	wt. %
BTU/lb	8334	BTU/lb	11594	BTU/lb
Total Sulfur	0.87	wt. %	1.21	wt. %

• ULTIMATE •

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	28.12	wt. %		
Ash	9.30	wt. %	12.94	wt. %
Carbon	48.77	wt. %	67.85	wt. %
Hydrogen	6.53	wt. %	4.71	wt. %
Nitrogen	0.77	wt. %	1.07	wt. %
Total Sulfur	0.87	wt. %	1.21	wt. %
Oxygen by Difference	33.76	wt. %	12.22	wt. %

• SULFUR FORMS •

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.87	wt. %	1.21	wt. %

• ASH FUSION •

ANALYTE	REDUCING	OXIDIZING

• MINERAL ANALYSIS OF ASH •

ANALYTE	DRY BASIS

• MISCELLANEOUS •

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.079	ug/g	0.110	ug/g

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MEMBER ACIL

Sample Number: 09-M894

Report Date: 4/21/09

Work Order #: 81-413

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Date Collected: 3/31/09 9:30

Date Received: 4/ 6/09

Sample Description: Pre Cob Injection
Sample Site: Cyclone Ash

*** PROXIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.09 wt. %	
Ash	96.18 wt. %	96.27 wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.09 wt. %	
Ash	96.18 wt. %	96.27 wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED	DRY BASIS

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS
Silicon Dioxide in Ash	51.44 wt. %
Aluminum Oxide in Ash	19.34 wt. %
Titanium Dioxide in Ash	0.83 wt. %
Iron Oxide in Ash	3.20 wt. %
Calcium Oxide in Ash	13.51 wt. %
Magnesium Oxide in Ash	4.91 wt. %
Potassium Oxide in Ash	0.88 wt. %
Sodium Oxide in Ash	0.40 wt. %
SO3 in Ash	1.05 wt. %
P2O5 in Ash	0.70 wt. %
Strontium Oxide in Ash	0.23 wt. %
Barium Oxide in Ash	0.86 wt. %
Manganese Dioxide in Ash	0.16 wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	< 0.02 ug/g	< 0.02 ug/g
Loss on Ignition		3.73 wt. %

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MEMBER
ACIL

Sample Number: 09-M895

Report Date: 4/21/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 81-413

Date Collected: 4/ 1/09 14:40

Date Received: 4/ 6/09

Sample Description: Cobs and Coal
Sample Site: Cyclone Ash

*** PROXIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.09 wt. %	
Ash	94.46 wt. %	94.55 wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.09 wt. %	
Ash	94.46 wt. %	94.55 wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED	DRY BASIS

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS
Silicon Dioxide in Ash	54.19 wt. %
Aluminum Oxide in Ash	19.91 wt. %
Titanium Dioxide in Ash	0.83 wt. %
Iron Oxide in Ash	2.34 wt. %
Calcium Oxide in Ash	12.21 wt. %
Magnesium Oxide in Ash	4.61 wt. %
Potassium Oxide in Ash	1.74 wt. %
Sodium Oxide in Ash	0.39 wt. %
SO3 in Ash	1.48 wt. %
P2O5 in Ash	0.69 wt. %
Strontium Oxide in Ash	0.22 wt. %
Barium Oxide in Ash	0.60 wt. %
Manganese Dioxide in Ash	0.15 wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	0.024 ug/g	0.024 ug/g
Loss on Ignition		5.45 wt. %

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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MEMBER ACIL

Sample Number: 09-M896

Report Date: 4/21/09

Work Order #: 81-413

Date Collected: 4/ 1/09 12:48

Date Received: 4/ 6/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Sample Description: Cobs

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	46.72	wt. %		
Ash	1.23	wt. %	2.31	wt. %
Volatile Matter	42.31	wt. %	79.41	wt. %
Fixed Carbon	9.74	wt. %	18.28	wt. %
BTU/lb	4167	BTU/lb	7821	BTU/lb
Total Sulfur	0.03	wt. %	0.06	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	46.72	wt. %		
Ash	1.23	wt. %	2.31	wt. %
Carbon	23.65	wt. %	44.39	wt. %
Hydrogen	8.20	wt. %	5.58	wt. %
Nitrogen	< 0.2	wt. %	< 0.38	wt. %
Total Sulfur	0.03	wt. %	0.06	wt. %
Oxygen by Difference	66.69	wt. %	47.29	wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.03	wt. %	0.06	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	< 0.02 ug/g	< 0.038ug/g

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MEMBER ACIL

Sample Number: 09-M897

Report Date: 4/21/09

Work Order #: 81-413

Date Collected: 4/ 1/09 14:30

Date Received: 4/ 6/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Sample Description: Cobs and Coal
Sample Site: Bottom Ash

*** PROXIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.03 wt. %	
Ash	98.48 wt. %	98.51 wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.03 wt. %	
Ash	98.48 wt. %	98.51 wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED	DRY BASIS

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS
Silicon Dioxide in Ash	53.31 wt. %
Aluminum Oxide in Ash	19.42 wt. %
Titanium Dioxide in Ash	0.87 wt. %
Iron Oxide in Ash	7.43 wt. %
Calcium Oxide in Ash	10.71 wt. %
Magnesium Oxide in Ash	3.54 wt. %
Potassium Oxide in Ash	0.65 wt. %
Sodium Oxide in Ash	0.31 wt. %
SO3 in Ash	0.92 wt. %
P2O5 in Ash	0.56 wt. %
Strontium Oxide in Ash	0.16 wt. %
Barium Oxide in Ash	0.81 wt. %
Manganese Dioxide in Ash	0.13 wt. %

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	< 0.02 ug/g	< 0.02 ug/g
Loss on Ignition		1.49 wt. %

MVTL

MINNESOTA VALLEY TESTING LABORATORIES, INC.

1126 N. Front St. ~ New Ulm, MN 56073 ~ 800-782-3557 ~ Fax 507-359-2890
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51 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885

MEMBER ACIL

Sample Number: 09-M898

Report Date: 4/21/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 81-413

Date Collected: 3/31/09

Date Received: 4/ 6/09

Sample Description: Coal
Sample Site: Bottom Ash

*** PROXIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.04 wt. %	
Ash	99.56 wt. %	99.60 wt. %

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED	DRY BASIS

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS
Silicon Dioxide in Ash	54.52 wt. %
Aluminum Oxide in Ash	18.81 wt. %
Titanium Dioxide in Ash	0.95 wt. %
Iron Oxide in Ash	8.06 wt. %
Calcium Oxide in Ash	10.78 wt. %
Magnesium Oxide in Ash	3.53 wt. %
Potassium Oxide in Ash	0.59 wt. %
Sodium Oxide in Ash	0.24 wt. %
SO3 in Ash	0.82 wt. %
P2O5 in Ash	0.53 wt. %
Strontium Oxide in Ash	0.17 wt. %
Barium Oxide in Ash	0.35 wt. %
Manganese Dioxide in Ash	0.13 wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED	DRY BASIS
Total Moisture	0.04 wt. %	
Ash	99.56 wt. %	99.60 wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED	DRY BASIS
Mercury, Trace	< 0.02 ug/g	< 0.02 ug/g
Loss on Ignition		0.40 wt. %

6/17-19/09 Emission Testing
Cob Feed Data & Laboratory Analysis Reports

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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51 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885

MEMBER
ACIL

Sample Number: 09-M1606

Report Date: 7/10/09

Work Order #: 81-756

Date Collected: 6/17/09 9:45

Date Received: 6/23/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Sample Description: 6/17 Cob Composite
Sample Site: Co-Combustion Stack Test

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	33.52	wt. %		
Ash	18.89	wt. %	28.41	wt. %
Volatile Matter	41.92	wt. %	63.06	wt. %
Fixed Carbon	5.68	wt. %	8.54	wt. %
BTU/lb	3901	BTU/lb	5867	BTU/lb
Total Sulfur	0.06	wt. %	0.09	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	33.52	wt. %		
Ash	18.89	wt. %	28.41	wt. %
Carbon	23.36	wt. %	35.14	wt. %
Hydrogen	6.52	wt. %	4.16	wt. %
Nitrogen	0.33	wt. %	0.50	wt. %
Total Sulfur	0.06	wt. %	0.09	wt. %
Oxygen by Difference	50.84	wt. %	31.69	wt. %
Chlorine	1550	ug/g	2330	ug/g
Fluorine in Coal	< 70	ug/g	< 105	ug/g

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.06	wt. %	0.09	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.026	ug/g	0.039	ug/g

Comment: Waste pH measured in water at 24C: 6.4

MVTL

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MEMBER
ACIL

Sample Number: 09-M1607

Report Date: 7/10/09

Work Order #: 81-756

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Date Collected: 6/18/09 8:15

Date Received: 6/23/09

Sample Description: 6/18 Cob Composite
Sample Site: Co-Combustion Stack Test

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	34.91	wt. %		
Ash	6.48	wt. %	9.96	wt. %
Volatile Matter	47.29	wt. %	72.65	wt. %
Fixed Carbon	11.32	wt. %	17.40	wt. %
BTU/lb	5017	BTU/lb	7707	BTU/lb
Total Sulfur	0.06	wt. %	0.09	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	34.91	wt. %		
Ash	6.48	wt. %	9.96	wt. %
Carbon	28.67	wt. %	44.05	wt. %
Hydrogen	7.35	wt. %	5.29	wt. %
Nitrogen	0.53	wt. %	0.81	wt. %
Total Sulfur	0.06	wt. %	0.09	wt. %
Oxygen by Difference	56.91	wt. %	39.80	wt. %
Chlorine	1780	ug/g	2730	ug/g
Fluorine in Coal	< 70	ug/g	< 108	ug/g

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.06	wt. %	0.09	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.022	ug/g	0.034	ug/g

Comment: Waste pH measured in water at 24C: 6.3

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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MEMBER
ACIL

Sample Number: 09-M1608

Report Date: 7/10/09

Work Order #: 81-756

Date Collected: 6/19/09 8:15

Date Received: 6/23/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Sample Description: 6/19 Cob Composite
Sample Site: Co-Combustion Stack Test

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	29.52	wt. %		
Ash	3.77	wt. %	5.35	wt. %
Volatile Matter	53.29	wt. %	75.61	wt. %
Fixed Carbon	13.42	wt. %	19.04	wt. %
BTU/lb	5400	BTU/lb	7662	BTU/lb
Total Sulfur	0.04	wt. %	0.06	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	29.52	wt. %		
Ash	3.77	wt. %	5.35	wt. %
Carbon	30.86	wt. %	43.79	wt. %
Hydrogen	7.21	wt. %	5.54	wt. %
Nitrogen	0.47	wt. %	0.67	wt. %
Total Sulfur	0.04	wt. %	0.06	wt. %
Oxygen by Difference	57.65	wt. %	44.60	wt. %
Chlorine	1860	ug/g	2640	ug/g
Fluorine in Coal	< 70	ug/g	< 99.3	ug/g

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.04	wt. %	0.06	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.022	ug/g	0.031	ug/g

Comment: Waste pH measured in water at 23C: 7.1

MVTL

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MEMBER
ACIL

Sample Number: 09-C1221

Report Date: 7/10/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Work Order #: 89-530

Date Collected: 6/17/09

Date Received: 6/23/09

Sample Description: WMU 25% Test
Sample Site: Co-Combustion Stack Test

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.61	wt. %		
Ash	8.88	wt. %	11.78	wt. %
Volatile Matter	28.26	wt. %	37.49	wt. %
Fixed Carbon	38.25	wt. %	50.74	wt. %
BTU/lb	8833	BTU/lb	11716	BTU/lb
Total Sulfur	0.73	wt. %	0.97	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.61	wt. %		
Ash	8.88	wt. %	11.78	wt. %
Carbon	50.66	wt. %	67.20	wt. %
Hydrogen	6.39	wt. %	4.82	wt. %
Nitrogen	0.82	wt. %	1.09	wt. %
Total Sulfur	0.73	wt. %	0.97	wt. %
Oxygen by Difference	32.52	wt. %	14.15	wt. %
Chlorine	< 20	ug/g	< 26.5	ug/g
Fluorine in Coal	< 70	ug/g	< 92.9	ug/g

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.73	wt. %	0.97	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.060	ug/g	0.080	ug/g

Comment: Waste pH measured in water at 22C: 7.2

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51 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885

MEMBER
ACIL

Sample Number: 09-C1222

Report Date: 7/10/09

Work Order #: 89-530

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Date Collected: 6/18/09

Date Received: 6/23/09

Sample Description: WMU 15% Test
Sample Site: Co-Combustion Stack Test

* PROXIMATE *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.88	wt. %		
Ash	8.71	wt. %	11.59	wt. %
Volatile Matter	28.30	wt. %	37.67	wt. %
Fixed Carbon	38.11	wt. %	50.73	wt. %
BTU/lb	8840	BTU/lb	11768	BTU/lb
Total Sulfur	0.59	wt. %	0.79	wt. %

* ULTIMATE *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.88	wt. %		
Ash	8.71	wt. %	11.59	wt. %
Carbon	50.92	wt. %	67.78	wt. %
Hydrogen	6.44	wt. %	4.87	wt. %
Nitrogen	0.78	wt. %	1.04	wt. %
Total Sulfur	0.59	wt. %	0.79	wt. %
Oxygen by Difference	32.56	wt. %	13.93	wt. %
Chlorine	< 20	ug/g	< 26.6	ug/g
Fluorine in Coal	< 70	ug/g	< 93.2	ug/g

* SULFUR FORMS *

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.59	wt. %	0.79	wt. %

* ASH FUSION *

ANALYTE	REDUCING	OXIDIZING

* MINERAL ANALYSIS OF ASH *

ANALYTE	DRY BASIS

* MISCELLANEOUS *

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.077	ug/g	0.103	ug/g

Comment: Waste pH measured in water at 22C: 7.3

MVTL

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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MEMBER
ACIL

Sample Number: 09-C1286

Report Date: 7/10/09

Work Order #: 89-530

Date Collected: 6/19/09

Date Received: 6/29/09

Jon Folkedahl
Folkedahl Consulting
4000 15th St NE
Willmar MN 56201

Sample Description: WMU 5% Test
Sample Site: Co-Combustion Stack Test

*** PROXIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.07	wt. %		
Ash	10.08	wt. %	13.28	wt. %
Volatile Matter	28.41	wt. %	37.42	wt. %
Fixed Carbon	37.44	wt. %	49.31	wt. %
BTU/lb	8683	BTU/lb	11436	BTU/lb
Total Sulfur	0.79	wt. %	1.04	wt. %

*** ULTIMATE ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Moisture	24.07	wt. %		
Ash	10.08	wt. %	13.28	wt. %
Carbon	50.92	wt. %	67.06	wt. %
Hydrogen	6.26	wt. %	4.70	wt. %
Nitrogen	0.81	wt. %	1.07	wt. %
Total Sulfur	0.79	wt. %	1.04	wt. %
Oxygen by Difference	31.14	wt. %	12.86	wt. %
Chlorine	< 20	ug/g	< 26.3	ug/g
Fluorine in Coal	< 70	ug/g	< 92.2	ug/g

*** SULFUR FORMS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Total Sulfur	0.79	wt. %	1.04	wt. %

*** ASH FUSION ***

ANALYTE	REDUCING	OXIDIZING

*** MINERAL ANALYSIS OF ASH ***

ANALYTE	DRY BASIS

*** MISCELLANEOUS ***

ANALYTE	AS RECEIVED		DRY BASIS	
Mercury, Trace	0.057	ug/g	0.075	ug/g

Comment: Waste pH measured in water at 22C: 7.4

2 SUMMARY AND DISCUSSION

The important results of the emission compliance tests are summarized on the following pages. An overview of the results is presented below:

Summary of Performance Test Results

1(a) Emission Unit Tested	1(b) Limitation Basis	1(c) Pollutant and Emission Limit	1(d) Test Result
Boiler No. 3 (SV003) (25% cob)	40 CFR 52.21; Minn. R.7011.0510; Minn. R.7007.0800 subp. 2,4,and 5	**PM** 0.6 lbs/million Btu heat input	**PM** 0.355 lb/mmBtu(A) 0.356 lb/mmBtu (B)
	40 CFR 52.21; Minn. R.7007.0800 subp. 2,4,and 5		**PM10** 0.298 lb/mmBtu (C) **NOx** 0.54 lb/mmBtu **CO** 0.18 lb/mmBtu **VOC** 2.03 ppm,d C 0.19Lbs/Hr
	40 CFR 63; 40 CFR 52.21; Minn. R.7007.0800 subp.4,and 5		**HCl** 44.37 ppm@ 7% O2 8.34 Lbs/Hr **HF** 3.47 ppm@ 7% O2 0.355 Lbs/Hr

Table References:
(A) Filterable particulate matter as determined by U.S. Environmental Protection Agency (EPA) Method 5.
(B) Filterable plus organic condensable particulate matter as determined by EPA Method 5 and Method 202/ Minn. R. 7011.0725.

[illegible]	[illegible]	[illegible]	[illegible]
Boiler No. 3 (SV003) **(15% cob)**	40 CFR 52.21; Minn. R.7011.0510; Minn. R.7007.0800 subp. 2,4,and 5	**PM** 0.6 lbs/million Btu heat input	**PM** 0.372 lb/mmBtu(A) 0.376 lb/mmBtu (B)
	40 CFR 52.21; Minn. R.7007.0800 subp. 2,4,and 5		**PM10** 0.306 lb/mm Btu (C) **NOx** 0.68 lb/mmBtu **CO** 0.29 lb/mmBtu **VOC** 0.99 ppm,d C 0.10 Lbs/Hr
	40 CFR 63; 40 CFR 52.21; Minn. R.7007.0800 subp.4,and 5		**HCl** 31.41 ppm,d @ 7% O2 5.46 Lbs/Hr **HF** 3.45 ppm,d @ 7% O2 0.331 Lbs/Hr

Table References:
(A) Filterable particulate matter as determined by U.S. Environmental Protection Agency (EPA) Method 5.
(B) Filterable plus organic condensable particulate matter as determined by EPA Method 5 and Method 202/ Minn. R. 7011.0725.
(C) Particles with an aerodynamic diameter less than or equal to a nominal ten micrometers (PM_{10}) as determined by EPA Methods 5 and 202.

[illegible]	[illegible]	(c) Pollutant and Emission Limit	(d) Test Result
Boiler No. 3 (SV003) (5% cob)	40 CFR 52.21; Minn. R.7011.0510; Minn. R.7007.0800 subp. 2,4,and 5	**PM** 0.6 lbs/million Btu heat input	**PM** 0.435 lb/mmBtu(A) 0.439 lb/mmBtu (B)
	40 CFR 52.21; Minn. R.7007.0800 subp. 2,4,and 5		**PM10** 0.273 lb/mmBtu (C) **NOx** 0.74 lb/mmBtu **CO** 0.22 lb/mmBtu **VOC** 1.12 ppm,d 0.12 Lb/Hr
	40 CFR 63; 40 CFR 52.21; Minn. R.7007.0800 subp.4,and 5		**HCL** 15.43 ppm@ 7% O2 2.73 Lbs/Hr **HF** 3.83 ppm@ 7% O2 0.368 Lbs/Hr

Table References:
(A) Filterable particulate matter as determined by U.S. Environmental Protection Agency (EPA) Method 5.
(B) Filterable plus organic condensable particulate matter as determined by EPA Method 5 and Method 202/ Minn. R. 7011.0725.
(C) Particles with an aerodynamic diameter less than or equal to a nominal ten micrometers (PM_{10}) as determined by EPA Methods 5 and 202.

No difficulties were encountered in the field or in the laboratory evaluation of the samples. On the basis of these facts and a complete review of the data and results, it is our opinion that the

the June 17, 2009 PM-10 Emission Performance Test on the No. 3 Boiler Stack
r Municipal Utilities facility in Willmar, Minnesota. (25% cob)

Item		Run 1	Run 2	Run 3	Average
		06-17-09	06-17-09	06-17-09	
	(Hrs)	0940 / 1131	1215 / 1357	1450 / 1651	
	(ACFM)	83817	85543	89973	86445
	(DSCFM)	48754	49843	52122	50240
	(°F)	335	335	338	336
	(%v/v)	8.54	8.44	8.64	8.54
	(%v/v, dry)				
		8.06	8.16	8.59	8.27
		12.04	11.88	11.40	11.77
		79.90	79.96	80.01	79.96
	(%)	94.9	94.7	90.7	93.4
		9680	9680	9680	
Actual	(GR/ACF)	0.045905	0.046983	0.051677	0.048188
Standard	(GR/DSCF)	0.078918	0.080633	0.089202	0.082918
	(LB/HR)	32.974	34.443	39.846	35.754
-(f-factor method	(LB/MMBTU)	0.2575	0.2584	0.2714	0.2624
Actual	(GR/ACF)	0.045933	0.047176	0.052405	0.0485
Standard	(GR/DSCF)	0.078965	0.080964	0.090459	0.0835
	(LB/HR)	32.994	34.584	40.407	35.9950
-(f-factor method	(LB/MMBTU)	0.2576	0.2594	0.2752	0.2641
Actual	(GR/ACF)	0.053133	0.052765	0.058435	0.0548
Standard	(GR/DSCF)	0.091344	0.090557	0.100867	0.0943
	(LB/HR)	38.166	38.682	45.056	40.6347
-(f-factor method	(LB/MMBTU)	0.2980	0.2902	0.3069	0.2984

l based upon the heat input ratio of the coal and corn cobs during testin, using an ultimate analysis of each of the fuels.

(1) Emission Unit Tested	(2) [illegible]	(3) Pollutant and Emission Limit	(4) Test Results
Boiler No. 3 (SV003) (5% cob)	40 CFR 52.21; Minn. R.7011.0510; Minn. R.7007.0800 subp. 2,4,and 5	**PM** 0.6 lbs/million Btu heat input	**PM** 0.435 lb/mmBtu(A) 0.439 lb/mmBtu (B)
	40 CFR 52.21; Minn. R.7007.0800 subp. 2,4,and 5		**PM10** 0.273 lb/mmBtu (C) **NOx** 0.74 lb/mmBtu **CO** 0.22 lb/mmBtu **VOC** 1.12 ppm,d 0.12 Lb/Hr
	40 CFR 63; 40 CFR 52.21; Minn. R.7007.0800 subp.4,and 5		**HCL** 15.43 ppm@ 7% O2 2.73 Lbs/Hr **HF** 3.83 ppm@ 7% O2 0.368 Lbs/Hr

Table References:
(A) Filterable particulate matter as determined by U.S. Environmental Protection Agency (EPA) Method 5.
(B) Filterable plus organic condensable particulate matter as determined by EPA Method 5 and Method 202/ Minn. R. 7011.0725.
(C) Particles with an aerodynamic diameter less than or equal to a nominal ten micrometers (PM_{10}) as determined by EPA Methods 5 and 202.

No difficulties were encountered in the field or in the laboratory evaluation of the samples. On the basis of these facts and a complete review of the data and results, it is our opinion that the results reported herein are accurate and closely reflect the actual values which existed at the time the

the June 17, 2009 PM-10 Emission Performance Test on the No. 3 Boiler Stack
r Municipal Utilities facility in Willmar, Minnesota. (25% cob)

Item		Run 1	Run 2	Run 3	Average
		06-17-09	06-17-09	06-17-09	
	(Hrs)	0940 / 1131	1215 / 1357	1450 / 1651	
	(ACFM)	83817	85543	89973	86445
	(DSCFM)	48754	49843	52122	50240
	(°F)	335	335	338	336
	(%v/v)	8.54	8.44	8.64	8.54
	(%v/v, dry)				
		8.06	8.16	8.59	8.27
		12.04	11.88	11.40	11.77
		79.90	79.96	80.01	79.96
	(%)	94.9	94.7	90.7	93.4
		9680	9680	9680	
Actual	(GR/ACF)	0.045905	0.046983	0.051677	0.048188
Standard	(GR/DSCF)	0.078918	0.080633	0.089202	0.082918
	(LB/HR)	32.974	34.443	39.846	35.754
-(f-factor method	(LB/MMBTU)	0.2575	0.2584	0.2714	0.2624
Actual	(GR/ACF)	0.045933	0.047176	0.052405	0.0485
Standard.	(GR/DSCF)	0.078965	0.080964	0.090459	0.0835
	(LB/HR)	32.994	34.584	40.407	35.9950
-(f-factor method	(LB/MMBTU)	0.2576	0.2594	0.2752	0.2641
Actual	(GR/ACF)	0.053133	0.052765	0.058435	0.0548
Standard	(GR/DSCF)	0.091344	0.090557	0.100867	0.0943
	(LB/HR)	38.166	38.682	45.056	40.6347
-(f-factor method	(LB/MMBTU)	0.2980	0.2902	0.3069	0.2984

d based upon the heat input ratio of the coal and corn cobs during testin, using an ultimate analysis of each of the fuels.

June 17, 2009 Particulate Emission Performance Test on the No. 3 Boiler Stack
unicipal Utilities facility in Willmar, Minnesota.

		Run 1	Run 2	Run 3	Average
		06-17-09	06-17-09	06-17-09	
	(Hrs)	0940 / 1130	1215 / 1400	1500 / 1640	
	(ACFM)	85675	85807	89126	86869
	(DSCFM)	49830	50130	50892	50284
	(°F)	338	328	339	335
	(%v/v)	8.23	8.90	9.69	8.94
	(%v/v, dry)				
		8.06	8.16	8.59	8.27
		12.04	11.88	11.40	11.77
		79.90	79.96	80.01	79.95
	(%)	104.5	99.2	101.6	101.8
al	(GR/ACF)	0.05451	0.08092	0.05900	0.06481
dard	(GR/DSCF)	0.09373	0.13853	0.10334	0.11186
	(LB/HR)	40.025	59.512	45.070	48.202
	(LB/MMBTU)	0.306	0.444	0.314	0.355
al	(GR/ACF)	0.000028	0.000193	0.000728	0.000316
dard	(GR/DSCF)	0.000047	0.000331	0.001257	0.000545
	(LB/HR)	0.020	0.142	0.548	0.237
	(LB/MMBTU)	0.0002	0.001	0.004	0.002
al	(GR/ACF)	0.054537	0.081116	0.059731	0.065128
dard	(GR/DSCF)	0.093774	0.138857	0.104595	0.112409
	(LB/HR)	40.045	59.654	45.618	48.439
	(LB/MMBTU)	0.3060	0.4450	0.3183	0.3564

A sample train

June 17, 2009 HF, HCl Emission Performance Test on the No. 3 Boiler Stack
unicipal Utilities facility in Willmar, Minnesota.

	Run 1	Run 2	Run 3	Average
	06-17-09	06-17-09	06-17-09	
(Hrs)	0940 / 1130	1215 / 1400	1500 / 1640	
(ACFM)	85675	85807	89126	86869
(DSCFM)	49830	50130	50892	50284
(°F)	338	328	339	335
(%v/v)	8.23	8.90	9.69	8.94
(%v/v, dry)				
	8.06	8.16	8.59	8.27
	12.04	11.88	11.40	11.77
	81.30	79.96	80.01	80.42
(%)	104.5	99.2	101.6	101.8
(DSCF)	32.07	35.72	37.15	34.98
(ug)	34000	43700	51000	42900
(gr/dscf)	0.0168	0.0194	0.0218	0.0193
(ppm,d)	25.39	29.30	32.88	29.19
(ppm d. @7 %O2	39.85	45.15	48.12	44.37
(mg/dscm)	38.49	44.41	49.84	44.25
(LB/HR)	7.18	8.34	9.50	8.34
(TPY)	31.46	36.52	41.61	36.53
36.461				
(ug)	1890	1720	1680	1763
(gr/dscf)	0.0010	0.0008	0.0007	0.0008
(ppm,d)	2.634	2.152	2.021	2.269
(ppm d. @7 %O2	4.134	3.316	2.958	3.469
(mg/dscm)	2.191	1.790	1.681	1.887
(LB/HR)	0.409	0.336	0.320	0.355
(TPY)	1.791	1.472	1.403	1.555
20.006				

7, 2009 Oxides of Nitrogen, Carbon Monoxide and VOC Emission Compliance Test
k at the Willmar Municipal Utilities facility in Willmar, Minnesota. (25% Cobs)

	Run 1	Run 2	Run 3	Average
	06-17-09	06-17-09	06-17-09	
(Hrs)	0940 / 1130	0940 / 1329	1500 / 1640	
(ACFM)	85,661	85,777	89,110	86,849
(DSCFM)	49,838	50,181	50,905	50,308
(°F)	338	328	339	335
(%v/v)	8.20	8.77	9.65	8.87
(%v/v, dry)				
	8.07	8.17	8.60	8.28
	12.15	11.99	11.51	11.88
	79.78	79.84	79.89	79.84
(ppm, w)	191.336	180.386	175.997	182.57
(ppm, d)	208.428	197.733	194.790	200.32
(LB/MMBTU)	0.575	0.536	0.501	0.54
(LB/HR)	74.404	71.073	71.024	72.17
(ppm, w)	96.017	103.774	96.260	98.68
(ppm, d)	104.595	113.753	106.538	108.30
(LB/MMBTU)	0.176	0.188	0.167	0.18
(LB/HR)	22.736	24.897	23.654	23.76
(TGNM ppm, w as C)	1.28	2.33	1.93	1.85
(TGNM ppm, d as C)	1.40	2.56	2.14	2.03
(LB/HR)	0.13	0.24	0.20	0.19

of the June 18, 2009 PM10 Emission Performance Test on the No. 3 Boiler Stack
nar Municipal Utilities facility in Willmar, Minnesota. (15% Cobs)

tem		Run 1	Run 2	Run 3	Average
		06-18-09	06-18-09	06-18-09	
	(Hrs)	0735 / 0907	0945 / 1127	1200 / 1326	
	(ACFM)	94835	97994	86907	93246
	(DSCFM)	54885	56442	50000	53776
	(°F)	338	343	342	341
	(%v/v)	8.16	8.02	8.25	8.14
	(%v/v, dry)				
de		7.46	7.13	7.24	7.28
		12.63	12.90	12.88	12.80
		79.91	79.97	79.88	79.92
	(%)	85.4	84.2	95.2	88.3
		9685	9685	9685	
- Actual	(GR/ACF)	0.047872	0.039205	0.034951	0.040676
- Standard	(GR/DSCF)	0.082716	0.068066	0.060748	0.070510
e	(LB/HR)	38.907	32.924	26.031	32.621
tor	(LB/MMBTU)	0.2893	0.2461	0.2191	0.2515
- Actual	(GR/ACF)	0.048105	0.039407	0.036479	0.0413
- Standard	(GR/DSCF)	0.083119	0.068418	0.063404	0.0716
e	(LB/HR)	39.096	33.094	27.169	33.1197
tor	(LB/MMBTU)	0.2907	0.2473	0.2286	0.2555
- Actual	(GR/ACF)	0.055611	0.047938	0.045115	0.0496
- Standard	(GR/DSCF)	0.096087	0.083228	0.078414	0.0859
e	(LB/HR)	45.196	40.258	33.601	39.6850
tor	(LB/MMBTU)	0.3360	0.3009	0.2828	0.3065

ted based upon the heat input ratio of the coal and corn cobs during testin, using an ultimate analysis of each of the fuels.

e 18, 2009 Particulate Emission Performance Test on the No. 3 Boiler Stack
cipal Utilities facility in Willmar, Minnesota. (15% Cobs)

	Run 1	Run 2	Run 3	Average
	06-18-09	06-18-09	06-18-09	
(Hrs)	0735 / 0917	0948 / 1125	1202 / 1327	
(ACFM)	93591	88375	91433	91133
(DSCFM)	54004	51132	52608	52582
(°F)	339	341	342	341
(%v/v)	8.36	7.83	8.25	8.15
(%v/v, dry)				
	7.46	7.12	7.24	7.27
	12.63	12.89	12.88	12.80
	79.91	79.99	79.89	79.93
(%)	99.8	99.3	100.0	99.7
(GR/ACF)	0.06637	0.05840	0.05565	0.06014
(GR/DSCF)	0.11502	0.10095	0.09673	0.10423
(LB/HR)	53.234	44.235	43.609	47.026
(LB/MMBTU)	0.402	0.364	0.349	0.372
(GR/ACF)	0.000233	0.000202	0.001528	0.000654
(GR/DSCF)	0.000403	0.000352	0.002656	0.001137
(LB/HR)	0.189	0.170	1.138	0.499000
(GR/ACF)	0.066599	0.058603	0.057177	0.060793
(GR/DSCF)	0.115426	0.101297	0.099381	0.105368
(LB/HR)	53.42	44.41	44.75	47.525
(LB/MMBTU)	0.403	0.366	0.358	0.376

ised from 201A sample train

ne 18, 2009 HF and HCl Emission Performance Test on the No. 3 Boiler Stack
cipal Utilities facility in Willmar, Minnesota. (15% cob)

	Run 1	Run 2	Run 3	Average
	06-18-09	06-18-09	06-18-09	
(Hrs)	0735 / 0917	0948 / 1125	1202 / 1327	
(ACFM)	93591	88375	91433	91133
(DSCFM)	54004	51132	52608	52582
(°F)	339	341	342	341
(%v/v)	8.36	7.83	8.25	8.15
(%v/v, dry)				
	7.46	7.12	7.24	7.27
	12.63	12.89	12.88	12.80
	79.91	79.99	79.89	79.93
(%)	99.8	99.3	100.0	99.7
(DSCF)	38.74	36.47	37.82	37.68
(ug)	29200	30200	26900	28767
(gr/dscf)	0.01196	0.01313	0.01128	0.01212
(ppm,d)	18.05	19.83	17.03	18.31
(LB/HR)	5.53	5.76	5.09	5.46
(TPY)	24.24	25.21	22.28	23.91
(mg/dscm)	27.362	30.061	25.819	27.748
(ppm d. @7 %O2)	30.323	34.396	29.505	31.408
(ug)	2010	1510	1590	
(gr/dscf)	0.0008	0.0007	0.0007	0.0007
(ppm,d)	2.319	1.850	1.879	2.016
(ppm d. @7 %O2)	3.895	3.209	3.254	3.453
(mg/dscm)	1.929	1.539	1.563	1.677
(LB/HR)	0.390	0.295	0.308	0.331
(TPY)	1.708	1.291	1.349	1.449
20.006				

18, 2009 Oxides of Nitrogen, Carbon Monoxide and VOC Emission Compliance Test
ck at the Willmar Municipal Utilities facility in Willmar, Minnesota. (15% Cobs)

	Run 1	Run 2	Run 3	Average
	06-18-09	06-18-09	06-18-09	
(Hrs)	0735 / 0917	0948 / 1125	1202 / 1327	
(ACFM)	93,576	88,360	91,419	91,118
(DSCFM)	54,014	51,140	52,618	52,591
(°F)	339	341	342	341
(%v/v)	8.33	7.80	8.22	8.12
(%v/v, dry)				
	7.47	7.14	7.25	7.28
	12.74	13.01	12.99	12.92
	79.79	79.85	79.76	79.80
(ppm, w)	216.760	207.757	196.844	207.12
(ppm, d)	236.464	225.327	214.480	225.42
(LB/MMBTU)	0.700	0.690	0.655	0.68
(LB/HR)	91.486	82.539	80.836	84.95
(ppm, w)	148.968	162.254	129.236	146.82
(ppm, d)	162.509	175.977	140.814	159.77
(LB/MMBTU)	0.293	0.328	0.262	0.29
(LB/HR)	38.285	39.252	32.316	36.62
(TGNM ppm, w as C)	1.53	0.85	0.35	0.91
(TGNM ppm, d as C)	1.67	0.92	0.38	0.99
(LB/HR)	0.17	0.09	0.04	0.10

he June 19, 2009 PM10 Emission Performance Test on the No. 3 Boiler Stack
r Municipal Utilities facility in Willmar, Minnesota. (7.55% cob)

m		Run 1	Run 2	Run 3	Average
		06-19-09	06-19-09	06-19-09	
	(Hrs)	0720 / 0857	0930 / 1105	1135 / 1304	
	(ACFM)	93352	94856	95713	94641
	(DSCFM)	54768	54930	55660	55119
	(°F)	340	341	343	341
	(%v/v)	6.46	7.60	6.91	6.99
	(%v/v, dry)				
		6.84	7.00	6.77	6.87
		13.20	13.02	13.26	13.16
		79.96	79.98	79.97	79.97
	(%)	85.6	88.2	85.8	86.5
		9914	9914	9914	
Actual	(GR/ACF)	0.036726	0.035296	0.030964	0.034329
Standard	(GR/DSCF)	0.062598	0.060949	0.053245	0.058931
	(LB/HR)	29.381	28.692	25.398	27.824
F factor	(LB/MMBTU)	0.2407	0.2290	0.2063	0.2253
Actual	(GR/ACF)	0.037970	0.035608	0.031100	0.0349
Standard.	(GR/DSCF)	0.064719	0.061488	0.053479	0.0599
	(LB/HR)	30.376	28.945	25.510	28.2770
F factor	(LB/MMBTU)	0.2488	0.2310	0.2072	0.2290
Actual	(GR/ACF)	0.045547	0.041001	0.038371	0.0416
Standard	(GR/DSCF)	0.077634	0.070802	0.065981	0.0715
	(LB/HR)	36.438	33.330	31.474	33.7473
F Factor	(LB/MMBTU)	0.2985	0.2660	0.2557	0.2734

d based upon the heat input ratio of the coal and corn cobs during testin, using an ultimate analysis of each of the fuels.

19, 2009 Particulate Emission Performance Test on the No 3 Boiler Stack
al Utilities facility in Willmar, Minnesota. (7.55% Cob)

	Run 1	Run 2	Run 3	Average
	06-19-09	06-19-09	06-19-09	
(Hrs)	0720 / 0900	0930 / 1105	1135 / 1310	
(ACFM)	93304	98721	93997	95341
(DSCFM)	54361	57317	54786	55488
(°F)	341	342	343	342
(%v/v)	7.13	7.33	6.79	7.08
(%v/v, dry)				
	6.84	7.00	6.77	6.87
	13.20	13.02	13.26	13.16
	79.96	79.97	79.97	79.97
(%)	98.2	99.7	98.6	98.8
(GR/ACF)	0.06430	0.06985	0.06431	0.06616
(GR/DSCF)	0.11038	0.12031	0.11035	0.11368
(LB/HR)	51.422	59.099	51.810	54.110
(LB/MMBTU)	0.425	0.452	0.428	0.435
(GR/ACF)	0.065548	0.070161	0.064448	0.066719
(GR/DSCF)	0.112498	0.120851	0.110581	0.114643
(LB/HR)	52.417	59.352000	51.922000	54.564
(LB/MMBTU)	0.433	0.454	0.429	0.439
(GR/ACF)	0.001244	0.000312	0.000136	0.000564
(GR/DSCF)	0.002121	0.000539	0.000234	0.000964667
(LB/HR)	0.995	0.253	0.112	0.453333333

M10 sample train

e 19, 2009 HF, HCl Emission Compliance Test on the No 3 Boiler Stack
cipal Utilities facility in Willmar, Minnesota. (7.55% cob)

	Run 1	Run 2	Run 3	Average
	06-19-09	06-19-09	06-19-09	
(Hrs)	0720 / 0900	0930 / 1105	1135 / 1310	
(ACFM)	93304	98721	93997	95341
(DSCFM)	54361	57317	54786	55488
(°F)	341	342	343	342
(%v/v)	7.13	7.33	6.79	7.08
(%v/v, dry)				
	6.84	7.00	6.77	6.87
	13.20	13.02	13.26	13.16
	79.96	79.97	79.97	79.97
(%)	98.2	99.7	98.6	98.8
(DSCF)	38.37	41.08	38.83	39.43
(ug)	11900	19500	11400	14267
(gr/dscf)	0.0049	0.0075	0.0047	0.0057
(ppm,d)	7.43	11.37	7.03	8.61
(ppm d. @7 %O2)	13.41	20.06	12.80	15.43
(mg/dscm)	11.26	17.23	10.66	13.05
(LB/HR)	2.29	3.70	2.19	2.73
(TPY)	10.04	16.20	9.58	11.94
36.461				
(ug)	1840	2020	1780	
(gr/dscf)	0.0008	0.0008	0.0007	0.0008
(ppm,d)	2.143	2.198	2.049	2.130
(ppm d. @7 %O2)	3.871	3.879	3.729	3.826
(mg/dscm)	1.782	1.828	1.704	1.771
(LB/HR)	0.363	0.392	0.350	0.368
(TPY)	1.589	1.719	1.531	1.613
20.006				

19, 2009, Oxides of Nitrogen, Carbon Monoxide and VOC Emission Compliance Test
ack at the Willmar Municipal Utilities facility in Willmar, Minnesota. (7.55% cob)

	Run 1	Run 2	Run 3	Average
	06-19-09	06-19-09	06-19-09	
(Hrs)	0745 / 0844	0940 / 1039	1145 / 1244	
(ACFM)	93,335	98,754	94,028	95,372
(DSCFM)	54,343	57,298	54,767	55,469
(°F)	341	342	343	342
(%v/v)	7.10	7.30	6.76	7.06
(%v/v, dry)				
	6.84	7.01	6.78	6.88
	13.32	13.14	13.38	13.28
	79.83	79.85	79.84	79.84
(ppm, w)	207.361	215.605	210.105	211.02
(ppm, d)	223.220	232.591	225.350	227.05
(LB/MMBTU)	0.729	0.742	0.742	0.74
(LB/HR)	86.887	95.458	88.401	90.25
(ppm, w)	96.301	115.420	103.306	105.01
(ppm, d)	103.665	124.513	110.801	112.99
(LB/MMBTU)	0.206	0.242	0.222	0.22
(LB/HR)	24.571	31.117	26.467	27.38
(TGNM ppm, w as C)	0.30	1.37	1.45	1.04
(TGNM ppm, d as C)	0.32	1.47	1.55	1.12
(LB/HR)	0.03	0.16	0.16	0.12