BIOMASS POWER FOR RURAL DEVELOPMENT

REVISED DESIGN REPORT

NIAGARA MOHAWK POWER CORPORATION
Wood Fuel Processing Project
Dunkirk Station

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1.0 INTRODUCTION

The retrofit of Dunkirk Steam Station to fire biomass fuels is an important part of the Consortium's goal—demonstrating the viability of commercial scale willow energy crop production and conversion to power. The goal for the biomass facilities at Dunkirk is to reliably cofire a combination of wood wastes and willow biomass with coal at approximately 20% by heat input.

As a part of restructuring agreements in the State of New York, NMPC agreed to sell its generating assets, including Dunkirk Station. NRG, the new owner of Dunkirk Station, will participate in fulfilling the goals of the demonstration. As a result of the station transfer, the design of biomass facilities at Dunkirk must ultimately serve NRG operating requirements. The design of biomass facilities by Niagara Mohawk must take into account NRG concerns about the integration of the system with current operations. NRG design concerns and two redesign reviews have lead NMPC to make fundamental changes in its design for biomass facilities at Dunkirk.

Rational for the Design Change

Initial plans for the Dunkirk Station called for use of one of the station's coal unloading areas for receiving biomass material. The use of the coal unloading area was expected to produce a substantial cost savings over other alternatives. This facility is located across a small road from the silo storage site and includes a truck dumping station, conveyors, and hoppers. The retrofit design called for a hammer mill to be installed at the facility and the use of exhausters to pneumatically transport incoming biomass to the storage silo and final sizing operations. Transport lines were expected to be laid either underground or over top of the road via a pipeline superstructure.

During the course of completing the final system design, concerns were raised about transporting the biomass by underground tunnel. It was determined that such an arrangement would hinder access to the transport lines if plugging problems were encountered. When investigated in detail, overland pneumatic transport of wood chips from the coal unloading station to the silo was determined to be too costly. The problems included the need for elaborate support structures, poor accessibility for maintenance due to elevation, and exposure to weather. The potential difficulties in the original design concept were compounded by the lack of available space for ancillary equipment at the existing receiving facility. A redesign of the system unloading and primary handling system was initiated that resulted in a more efficient design.

The new design places the unloading and handling equipment near the silo. Transport lines were shortened with a bucket elevator to transport material from the truck to an elevated receiving hopper. This eliminated concerns related with long-distance pneumatic transport of the material and reduced the time required to unload a truck from one hour to 15 minutes. Although additional costs will be incurred for equipment and installation, the system will be better suited

for long-term, continuous cofiring operations. The results of the system design modifications are presented in this report.

In August 1999 NMPC engaged the services of McBurney to participate in a final design review. McBurney is a recognized A/E firm in the biomass power industry and the staff is very experienced in designing handling and processing systems for biomass projects. McBurney's detailed report is attached but the major recommendations are highlighted below. McBurney recommended that several actions needed to be taken, at a minimum, to upgrade the system to provide biomass at a 10 ton/hr (20MW) delivery rate to the boiler. These included, but may not be limited to, the following:

- Modify the venturi pick-ups from the hammer mills by maximizing the width of the pick-up box interface. Depending on their performance at lower biomass delivery rates and their ability to handle willow, adjustments may also be required in the hammer mills or other parts of the system.
- Upgrade the system's exhausters and blow lines to provide more air flow for a corresponding increase in capacity to achieve the design 10 ton/hr biomass delivery rate.

NMPC has decided to implement only the first recommendation in its final design and construction of the basic system is scheduled to be complete by December 1999.

Plan for System Construction, Testing and Operation.

NMPC plans to have the system completed by early November including the design modification recommended by McBurney. Upon completion, NMPC with NRG will give the system a dry run to test basic system functionality without fuel. December is a period of high production demand for the station and the first system test with biomass fuels will be delayed until March 2000.

In the spring of 2000 NRG will put the system through shakedown tests -- first on manufacturing wood waste and then willow. These tests will determine the operating capacity of the unit as designed and will form the basis for decisions about any further modifications recommended by McBurney needed to achieve full design capacity. The tests will also serve as a baseline for evaluating the processing and firing willow. Provided operational testing is successful, NRG will integrate the system into their operations. Once complete, the system will include silo storage for continuous cofiring capability and biomass processing equipment designed to handle willow and clean, woody, industrial residues.

2.0 FACILITY DESCRIPTION

Dunkirk Station is located in Dunkirk, NY approximately 45 miles southwest of Buffalo on a peninsula of Lake Erie. The station is equipped with two 200 MW and two 100 MW CE tangential fired boilers, circa 1950. The units currently burn eastern bituminous coals and have been retrofitted with low NO_x burners and upgraded combustion control systems.

Exhibit 1-1: Dunkirk Steam Station

The decision to retrofit at least one, and possibly two of Dunkirk Stations boiler to co-fire biomass fuels has been driven by NMPC's desire to:

- Reduce fuel costs;
- Reduce emission levels;
- Promote new business relationships;
- Provide services to customers generating biomass waste materials;
- Increase fuel diversity
- Respond probatively to proposed renewable resource portfolio requirements
- Reduce flyash production and reduced landfill issues

The system is currently designed to co-fire biomass at biomass thermal heat input rates up to 20 percent. This represents up to 20 MW of biomass power, requiring feed rates of up to 13 dry tons/hour. On an annual basis, average cofiring rates are expected to be lower since the unit operates at a capacity factor of approximately 80%.

Biomass fuel supplies will be derived from a number of sources. They include wood residues from proximal generators of wood wastes and willow. The willow fuel will be supplied via NMPC's participation in the Salix Consortium, an organization developed to demonstrate the commercial viability of hybrid willow as an energy crop. NMPC has commissioned a number of studies to determine the availability of suitable biomass fuel and is confident that the willow, combined with available residues, will allow Dunkirk to maintain high cofiring levels in the retrofitted boilers.

2.1 Cofiring Benefits

The environmental benefits resulting from the modifications are associated with the substitution of biomass for coal in the fuel mix. Biomass fuels available to Dunkirk typically contain less than 0.1% sulfur. Therefore, cofiring biomass with coal will proportionately reduce SO₂ emissions from dedicated coal-fueled plants. This can provide advantages in other aspects. First, the use of biomass may generate valuable SO₂ credits that can be used by the power generator,

traded for other credits, or sold. Second, using biomass may reduce a power generator's dependence on expensive low sulfur coals, thereby reducing fossil fuel costs without exceeding emission requirements.

Renewable biomass fuels are a near-zero generator of the greenhouse gases carbon dioxide and methane. Emissions of CO₂ from combustion of biomass are offset by photosynthesis and plant growth. Much of today's wood harvests by the wood products and paper industries are replenished by planting. Biomass resources obtained from these sources and ultimately from proposed energy crops (such as the hybrid willow being developed on NMPC land as part of a DOE grant program for Biomass R&D) meet the criteria for offsetting the combustion emissions of CO₂. As environmental regulations continue to become more stringent, the value of these offsets may become an important part of NRGs environmental and market strategy. Market prices for these credits may be on the order of 100\$/ton for SO₂. For CO₂, various sources have estimated that credits could be valued between \$0.50-\$15.00/ton based on proposed trades. Ontario Hydro and Southern California Edison Company agreed on a CO₂ emissions trade following the global climate change talks in Kyoto. The Canadian company purchased the right from So. Cal. Edison to emit 10,000 tons for \$30,000.¹

Exhibit 1-2: Willow Carbon Capture

The use of energy crops (especially willow) also provides other environmental benefits. Although these benefits do not directly contribute to the bottom line, supporting the use and development of energy crops may be a valuable marketing strategy in the deregulated market. Power marketers have already begun to sell "green" electricity in retail wheeling pilot markets in several states including New Hampshire, Massachusetts, New York, Colorado, and Vermont. Preliminary experience with these programs shows that some customers are willing to pay premiums for green power. The additional environmental benefits of willow include, but are not limited to, soil and water resource conservation and as buffer strips to protect water sheds.

3.0 COFIRING TESTS AT DUNKIRK

The primary concerns of combusting alternate fuels at the station are: 1) avoiding significant degradation in boiler operation; and 2) controlling by-product emissions. NMPC has conducted a scale test burn at Dunkirk Unit #1 to determine the feasibility of commercially burning biomass in its pulverized coal-fired boiler. The test used woody biomass in a reduced form from a local

¹ Antares Group Inc., Analytical Studies for Biomass Power, January 1998

generator of residues.

Initial co-fire tests at Dunkirk Station were conducted by NMPC while Fossil Energy Research Corporation performed emission monitoring via real time multi-point sampling. The tests were performed over a seven day period between December 3 and 9, 1997. The testing focused on determining the effects of cofiring on unit operation and emissions.

Tests were conducted through one corner of the Unit #1 boiler. Unit #1 is tangentially-fired with 16 burners located in four levels in each corners of the furnace. Coal is supplied to each level by a Raymond bowl mill and the unit has been retrofitted with a low NO_x burner system which incorporates a close-coupled overfire air system. Particulate emissions are controlled by a hot side ESP.

Cofiring tests were conducted at the maximum expected output of the nozzle which was 5% of the units thermal heat input. The tests showed that biomass can be burned with no significant changes in unit operation. The existing control system was able to adjust boiler operating parameters to allow for acceptable operation. Continuous measurement techniques were used to monitor the gaseous species during this program. Gaseous emissions species of NO , NO_x , CO , O_2 , and CO_2 were measured.

The results of the tests were favorable. No adverse impacts on NO_x emissions were measured and emission levels were within the range of those measured during normal unit operation. Testing at other stations has indicated that NO_x emission levels can actually be decreased due to lower nitrogen content of biomass fuel and lower flame temperatures associated with combustion of higher moisture content material.² During the tests at Dunkirk, CO emissions also remained unchanged from baseline levels. Exhibit 2-1 is a schematic of the cofiring test set-up at Dunkirk.

Exhibit 3-1: Schematic of Dunkirk Test Cofiring System

²Electric Power Research Institute, "Renewable Energy Technology Characterizations", December 1997

4.0 DUNKIRK RETROFIT DESIGN

Preliminary tests, Cold Flow Modeling and Computational Fluid Dynamics (CFD) simulations of the combustion process have indicated that cofiring levels of up to 20% are feasible. The design approach is to build a highly automated system capable of processing and storing sufficient fuel in one shift for 24-hour firing. The key elements of the system include:

- Receiving: Unloading conveyor, bucket elevators, receiving hopper
- Processing: Conveyors, metal separators, hammer mills, pneumatic transport
- Buffer Storage: Storage silo, bag filter house
- Fuel Metering and Feed to Boiler: Collecting conveyors, and pneumatic transport
- Injection Ports: Dedicated biomass burners

4.1 Design Evolution

The retrofit of Dunkirk Station has experienced significant design evolution during the course of the project. Exhibit 4-1 illustrates the original design.

EXHIBIT 4-1: Initial Dunkirk Retrofit Schematic

As work began on implementing this design it became apparent that several issues could only be addressed by redesigning portions of the biomass handling receiving and processing train. Initial plans for the Dunkirk Station called for use of one of the station's coal unloading areas for receiving biomass material. The use of the coal unloading area would have generated substantial cost savings over other alternatives. This facility is located across a small road from the silo storage site and includes a truck dumping station, conveyors, and hoppers. The retrofit design called for a hammer mill to be installed at the facility and the use of exhausters to pneumatically transport incoming biomass to the storage silo and final sizing operations. Transport lines were expected to be laid either underground or over top of the road via a pipeline superstructure.

It was determined that transporting the biomass by underground tunnel would hinder access to the transport lines if plugging problems were encountered. Additionally, when investigated in detail, overland pneumatic transport of wood chips from the coal unloading station to the silo was determined to be too costly. The problems included the need for elaborate support structures, poor accessibility for maintenance due to elevation, and exposure to weather. The potential difficulties in the original design concept were compounded by the lack of available space for ancillary equipment at the existing receiving facility. A redesign of the system unloading and primary handling system was initiated that resulted in a more efficient design.

The revised design calls for several new pieces of equipment and more foundation work. A larger hopper and new bucket elevator will allow trucks to be unloaded in fifteen minutes instead of an hour. However, the new equipment required additional concrete for new foundations; new electrical work, and additional controls. The costs for the increased concrete requirement were exacerbated by the close proximity of the plant cooling water tunnel to the facility.

4.2 Biomass Handling and Processing Train

4.2.1 *Material Specifications*

The Dunkirk retrofit has been designed to accommodate cofiring treated and untreated wood. Specifically, untreated wood is defined as wood that does not contain any potential contaminants such as preservatives or glues. This classification includes logging residues, "clean" mill residues generated from certain wood products industries, and willow. Treated wood is defined as wood products manufactured with resins, adhesives, preservatives, paints, stains, coatings, or metal (staples, nails, etc.). The latter category can be removed using mechanical means, and if otherwise clean material was used, this type of wood may be considered untreated. Currently, the plant expects to utilize untreated wood, and two different types of treated wood. For any treated material fired in the boiler, protocols for firing must be established in accordance with state and federal regulations. Tests are planned for the treated material in the near term to certify these fuels.

NMPC material specifications for incoming feedstock include:

- a nominal size restriction of 2 X 2 X 1 inches
- and moisture contents of less than 50%.

The last specification should be qualified with additional explanation. A moisture content of less than 20% is expected for most of the fuels received at the plant. Some fuels, such as dry sawmill residues may even be less than 10%. In contrast, green willow may have a moisture content of approximately 50%. However, even such high moisture contents are not expected to significantly impact boiler operations at lower heat input levels. This assumption is based on NYSE&G's anecdotal experience cofiring green sawdust (38% moisture) at heat input levels of 4-5% at Greenidge Station [Greenidge Station also uses a tangentially fired pulverized coal boiler to produce power]. The experience at this plant and others suggests that small decrements in boiler efficiency (2-3%) will be experienced when using high moisture biomass at heat input levels less than 10%. The performance of the system at higher heat input levels at high moisture contents remains to be determined.

These specifications have been made to protect the new equipment and address material flow issues associated with biomass feedstocks.

4.2.2 Material Receiving

Available fuel supplies will be delivered in self unloading trucks. Each truck is estimated to have a capacity of 20-25 tons of biomass and biomass will be unloaded from the truck via a 52" belt conveyor. The conveyor empties into a below ground bunker.

Material Receiving System

- 1) Truck unloading ramp
 - 2) 52" belt conveyor
 - 2) Below ground bunker
-

Truck unloading time is estimated to be 10-15 minutes. However, the capacity of the receiving hopper and subsequent processing is the true limiting factor to truck deliveries, the actual unloading time of the truck could be substantially longer without adverse effects to the daily delivery schedule.

Adverse weather could also impact truck delivery and unloading times. For that reason a roof was designed to cover the first unloading belt and feed chute, which should eliminate the majority of the precipitation that could enter the system.

4.2.3 Processing/Handling Upstream of Silo

A bucket elevator moves material from the material receiving bunker to a hopper. The bucket elevator is equipped with a 44" wide belt and 10 steel buckets. Each bucket row is made using three 14" x 9" buckets on 12" centers. The nominal capacity of the bucket elevator is 21,400 CFH conveying "wood chips, pellets, chunks" with a belt speed of 420 ft/min and a wood waste density of 25 lbs/cu.ft. or less.

Primary Processing/Handling System

- 1) Bucket elevator
 - 2) Hopper w/ bottom unloader
 - 3) Conveyor w/ metal detection
 - 4) Hammer mill #1
 - 5) Pneumatic transport to silo
-

Independent review has confirmed that the system meets the minimum requirements to move biomass material as designed.

The hopper, capable of handling approximately one truck load of biomass, will be fitted with a Flying Dutchman to ensure smooth material flows. The hopper is 20' diameter with 13'-3" straight sides and a 45 degree conical hopper with a 2'-6" outlet. A bottom unloader will be used to cause the 2" minus wood waste to flow down and out the hopper bottom outlet.

Another conveyor, moves material from the receiving hopper to the first of two hammer mills in the retrofit design. This belt conveyor is 36" wide with smooth 4 1/2" high sidewalls. A magnetic separator will be installed over this conveyor.

Two hammer mills have been specified for the Dunkirk retrofit. The first is located upstream of the storage silo. This hammer mill is 60" wide and is belt-driven by a 200 HP motor. The hammer mill discharges into an integral pyramidal hopper. The hammer mill outlet is close-coupled to a venturi pickup box located beneath the mill. The hammer mill is rated at capacity of 20 tons/hr when reducing wood waste from 2" minus to 1/4" minus. Since no sizing tests have been conducted with willow, the processing capacity of the mill on this material remains uncertain. However, should issues arise when processing, the plant may try to blend the willow with other fuels during processing or make adjustments to the processing system as they arise.

In response to an independent design review of the system, a change has been made to the venturi pick-up box beneath the mill. The original interface between the mill outlet and the pick-up opening was 10" square. This opening will be widened to approximately 10" x 24" to facilitate better material flow through the system.

Although rigid fuel specifications have been established to limit the introduction of tramp material into the system, it is recognized that some oversized materials will be introduced. The bucket elevator has been fitted with a magnetic drive that has "torque sensing" capabilities. In the event that oversized materials are received which could jam the system, the system will trip and initiate an alarm. In addition, both of the hammer mills in the system are capable of processing materials up to five feet in length.

Protection from hammer mill damage because of metallic tramp material is provided via a magnetic separator located over the transfer conveyor leading to the first hammer mill. The hammer mills themselves are also equipped with a metal separation system. If during shakedown operations these systems do not provide adequate protection, a magnetic trip system may need to be added.

Material will be pneumatically transported from the hammer mill to the storage silo via 20" blow lines. Transport air will be supplied by an ABB exhaustor refitted for this purpose. The exhaustor is fitted with a variable speed drive and the fan can operate at a maximum speed of 1800 RPM. The expected speed of the exhaustor is 1400 RPM for proper conveyance of the material.

NMPC's basis for design was predicated upon the actual trial burn, which used the currently proposed air/fuel ratios and transport velocities. However, in the event that actual cofiring data suggests that higher air/fuel ratios are needed, a higher output drive may be required.

4.2.4 Buffer Storage

A storage silo will be installed as part of the system. The steel silo has a level full capacity of 37,632 cu.ft. (1,394 cu.yds.) but this figure is highly dependent on the types of fuels

processed and stored. The silo is 64'-7 1/4" tall

straight sides and is 30'-9 1/4" inside diameter. The silo floor is 14' above the ground floor. A radial reclaim auger delivers the 1/4" minus wood waste to a center discharge hopper box. The silo is charged using pneumatic transport of the biomass material from the first hammer mill to the top of the storage pile. This ensures first-in, first-out material handling.

The silo is also equipped with a bag filter system. The bin vents for the system were sized by Scientific Dust Collectors for various fuel types while discharging 10,000cfm. While NMPC believes that this capacity is sufficient to ensure proper dust control, this design may need to be revisited if higher air flows are required for fuel transport.

The silo is sized to provide 14-18 hours of buffer storage for 24 hr/day operation on single shift loading. This capacity was selected based on the dispatch schedule of the boiler and expected fuel delivery schedule. For example, the furniture waste supplier has only limited on-site storage capacity. Currently, NRG expects to receive some deliveries on weekends. In such circumstances, biomass cofiring may occur 7 days/week.

The reclaim system is rated for 20 tons/hour and the feed screws of the auger are equipped with magnetic VSD units to regulate the feed to the hammer mills. The auger fills a charging hopper, which is fitted with level detectors to ensure that fuel supply to the feed screws is always present. The system is oversized for the current needs of cofiring at Unit #1 to accommodate the possibility of cofiring at Unit #2.

4.2.5 Secondary Processing and Transport to Boiler

Fuel is withdrawn from the storage silo and undergoes additional size reduction via the second hammer mill located under the material storage silo. The second hammer mill is designed to reduce particles stored in the silo down to 1/8th of an inch minus at a rate of 10 tons per hour. Material is then drawn from the hammer mill in the same fashion as hammer

Biomass Storage System

- 1) Silo
 - 2) Reclaim auger
 - 3) Bag filter system
-

Secondary Processing and Delivery

- 1) Hammer mill #2
 - 2) Pneumatic transport
 - 3) Flow split / fuel delivery
-

mill #1 via a pneumatic system that includes a venturi pick-up box. Similar modifications to this system were made as those discussed previously for the first hammer mill.

Pneumatic transport of the material from the second hammer mill is made using a second exhaustor and a 16" blow line. The second exhaustor is sized the same as the first. Based on NMPC's calculations the combination of this exhaustor and the smaller transport line will result in adequate transport of the fuel to the boiler without having an adverse impact on boiler emissions. However, an independent review of the design suggests that a larger pipe and higher flow velocities may be required to obtain the maximum flow capacity. This issue will be clarified during operational tests.

The 16" blow line leads to a riffler designed to evenly split the flow between four 8" lines. These lines lead to each of the four corners of the boiler. Riffles are used extensively for flow splitting in the coal industry. However, this unit has been modified to account for some of the unique characteristics of biomass. NMPC is confident that this unit will function adequately for this purpose and the use of such a system has significant cost benefits to the project.

Pluggage problems have been considered in this design. To address them, the final transport exhaustor has been fitted with a pressure transmitter and gauge to alarm in the event of high discharge pressure. Increased discharge pressure would be indicative of a plug in the riffler or in the transport lines. In such an event the system could be shut-down to resolve the problem.

4.2.6 Modifications at the Boiler

Exhibit 4-2: Unit #1 Design

Boiler modifications at Dunkirk will be limited to refitting existing, unused oil gun ports to accept biomass (refer to Exhibit 4-2 for a diagram of Dunkirk boiler). Wood burning nozzles with swirl plates will be installed in each of the four corners of the boiler. Swirl nozzles were used to help promote combustion, since the fuel must be burnt in approximately 1.8 seconds. The wood nozzle is located between two air nozzles in the unused oil injection port. Two overfired air ports are located at the top of the fuel compartment and are separated from the wood nozzle by two levels of coal nozzles. The clearances used for the wood nozzle are typical for that of the coal nozzles. This configuration worked well during the cofiring tests.

4.3 Summary of Retrofit Costs & Added Value Benefits

The plant retrofit cost estimates have been revised to reflect all of the design changes. Retrofit costs have exceeded the original estimates because of increases in 1) Niagara Mohawk design and installation labor as a result of changes in the location and connection of the system; and 2) increases in equipment, materials, and contract installation costs. The increases stem primarily from the redesign and relocation of the receiving and processing systems due to problems encountered with the use of existing coal unloading facilities for the biomass project. These costs were unique to this, a first-of-a-kind demonstration project. A summary of the revised total estimate is provided below, but a detailed list of equipment and materials costs are provided in the appendix.

<u>Line Item</u>	<u>Cost Estimate</u>
NMPC Labor/Travel	\$ 1,115,646
Materials, Equipment, Installation	\$ 2,629,861
Environmental Studies & Permitting	\$ 424,000
Total	\$ 4,169,507

Initially, Dunkirk will use available residue fuel supplies. Later, willow fuel will be tested and will be introduced into the fuel mix. NMPC anticipates that furniture mill residues and other waste biomass streams could be obtained for \$0.50-1.00/MMBtu. Although the target cost for willow in the demonstration is \$1.80 per MMBtu, the Salix Consortium estimates that commercially grown willow could be delivered to the plant on the order of \$1.75-2.50/MMBtu depending on annual yields, planting survival rates and other factors. The small amounts of fuels available from the demonstration acreage may be available for less, possibly \$1.00 to \$1.50 per MMBtu. Using the more conservative range, a fuel blend of 70% residues and 30% willow translates to an effective biomass cost range of \$0.88-1.45/MMBtu. Assuming an average price of \$1.37/MMBtu for coal and a biomass fuel cost of \$0.88/MMBtu, Dunkirk could save up to \$300,000/year in fuel costs, while cofiring at a heat input of 10%. At recent market values of \$150/allowance and \$1,700/allowance for SO₂ and NO_x respectively, emission credits could also accrue to the plant in the amount of \$190,000/year. As further incentive, recently proposed Federal legislation may make it possible for the plant to claim 1.7 cents/kWh for the portion of the plant's generation attributable to biomass. This translates to an after tax benefit of over \$1,000,000 per year. Lastly, green power markets that allow for a premium to be recovered on renewable power, could also be translated to increased plant profitability.

5.0 CONCLUSIONS

The retrofit of Dunkirk Station to cofire biomass was predicated on the assumption that biomass can provide a low-cost, renewable fuel alternative to coal. Once shakedown tests are complete, the Station will be ready to take advantage of local fuel supplies and new incentives for using renewable fuels.

The retrofit design has undergone significant changes during the course of this project, but the Station's staff are enthusiastic about initiating operations. Several design reviews have facilitated a refined retrofit design and increased confidence in the project's success. In the long term, the Salix Consortium hopes that these changes will allow the station to become the first utility scale power using willow energy crops on a sustained basis.

APPENDIX A

DESIGN REVIEW - McBURNEY

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Design Review Report

Date: _____ Page: 1 of 16

To: ANTARES Engineers & Economists
Ed Gray / Chris Lindsey

Fax No. 301/ 731-1904

From: Mike Cantrell, P.E.

Prop No.: 600009

Subject: **DESIGN REVIEW**

Niagara Mohawk Power Corporation for NRG
Biomass Co-Firing Project - Dunkirk Station

Message:

McBurney was retained by Antares to perform a quick design review of the biomass firing system currently being installed at the NRG - Dunkirk Steam Station's Unit No. 1.

On August 24, 1999, a design review meeting was held at the Dunkirk, NY station to review the planned modifications to facilitate biomass firing in Unit No. 1.

In attendance were:

NMPC	NRG - Dunkirk	Antares	NREL	McBurney
Tim Lee	Tom Kilburn	Ed Gray	Ralph Overend	Mike Cantrell
Bob Anderson	Carson Leikam	Chris Lindsey		
Jim Meyers	Frank Fabian			
Joseph Schwab	Mike Boismenu			
	Bob Nichols			

Since this meeting, we have been in contact with several equipment suppliers and manufacturers. We have also made a cursory review of certain drawings and vendor correspondence.

Our key findings and conclusions are summarized on the next page.

This design review is made based on our understanding of the types of wood wastes that were discussed at the August 24, 1999 meeting in Dunkirk. The biomass fuel is expected to consist of furniture plant dry wood residues and green willow bush. Dry biomass fuel is typically defined as less than 10% moisture content. Green biomass fuel is material that has not been kiln dried and is typically in the 40%-50% moisture content range. We understand that these wood wastes will not be pre-mixed and will be received by separate truck shipments. We see the green willow bush material as more of a material handling challenge as compared to the dry furniture plant wood waste material.

If the material handled and fired is limited to dry wood waste material, which tends to be easier to reduce in size and has better flow characteristics, the system as currently designed may work as-is but at a capacity less than the 20MW design point. Changes may still be found necessary which are likely to include the hammermill venturi pick-ups and blow line sizes. The equivalent power output from dry biomass firing, based on a plant heat rate of 10,000 Btu/kwh and a dry biomass heating value of 8,500 Btu/lb, is expected to be in the 6.8 - 10.2 MW range.

We believe several actions need to be taken, at a minimum, to upgrade the system to provide biomass at a 10 ton/hr (20MW) delivery rate to the boiler. These include, but may not be limited to, the following:

Upgrade the system's exhausters and blow lines to provide more air flow for a corresponding increase in capacity to achieve the design 10 ton/hr biomass delivery rate.

Modify the venturi pick-ups from the hammermills by maximizing the width of the pick-up box interface. Depending on their performance at lower biomass delivery rates and their ability to handle willow, adjustments may also be required in the hammermills or other parts of the system.

Closing

In general, for a wood waste system that handles green wood residues of any kind, McBurney would not normally use a pneumatic handling system. For strictly dry wood residues, pneumatic conveying systems are quite common. This is not to say that green wood residues cannot be handled pneumatically, because they are, it simply is not our standard method of handling green wood residues. We normally use a mechanical handling system for green wood residues. However, in this application, a mechanical type system may not be practical given the limited space and budget considerations.

McBurney appreciates the opportunity to perform this design review and hopes that our statements herein are helpful to the successful start-up of this biomass system.

As always, we remain available to discuss this report at your request.

Mike Cantrell, P.E.
Design Review Basis

Our review is based on the following design/operating criteria:

Wood waste design firing rate is 20,000 lbs/hr on a 24 hour/ 7 day/ 365 day basis.

Wood waste will be injected into the Unit No. 1 furnace through four (4) wood burners, one in each corner.

Wood waste will be received Monday through Friday during the day shift.

Wood waste is defined as dry furniture plant wood residues and green willow bush.

Material Bulk Density

For this review, we have assumed the bulk density of the as-received wood waste to be 20 lbs/cu.ft. We do not have any actual density data for this wood waste nor any weight split between the different types (pelletized dry sawdust, dry shavings, hogged dry board trim, green willow).

While we know that the bulk density of the wood waste will change after passing through the hammermills, however, we have assumed this change will be small.

Project Schedule

The current project schedule is for NMPC to finish construction by November and to test the system pneumatically (air only, no biomass). The installation will then be stood down, so as to not interfere with the peak winter season operations of the Dunkirk station.

In the Spring of 2000, the unit will be commissioned using wood waste fuel from Bush Industries located in Jamestown, NY who have considerable quantities of dry wood waste ranging from pelletized saw dust and shavings to board endcuts and trimmings.

Biomass Supply

Two different sources of biomass were discussed in the meeting.

We understand that Bush Industries, along with pelletizing the sawdust and shavings, will reduce the size of board endcuts and trimmings to 2" minus using their equipment. We understand this will be done to improve fugitive dust control and to increase bulk density for truck transportation.

Biomass System Layout

The biomass system is constructed in a space between the existing coal handling system and the fly ash storage tower at the East end of the station which is closest to Unit No. 1. Space is very limited as a main road also borders the biomass system.

Wood wastes will be delivered by self-unloading tractor-trailers. A standard trailer is 48' long, 8' wide and about 9' high. The gross trailer volume is 3,456 cu.ft., or 128 cu.yds. For this review, we have used a trailer volume of 125 cu.yds.

While the trailer volume is 125 cu.yds., it may be that due to New York highway weight limits that the trailer cannot be filled completely. Using the 125 cu.yd. trailer volume and a material bulk density of 20 lbs/cu.ft., the truck can haul almost 34 tons of material. This weight probably exceeds the allowable weight limit which is usually more like 20-25 tons. The number of truck deliveries cannot be estimated until this is clarified.

The equipment is reviewed piece-by-piece in the order of wood waste flow. Starting with the receiving hopper and ending with the wood nozzles on the boiler, the order is as follows:

- 1.0 Receiving Hopper/Belt Feeder Unloader -to-
- 2.0 Bucket Elevator -to-
- 3.0 Wood Hopper w/ Flying Dutchman -to-
- 4.0 Transfer Belt Feeder Conveyor -to-
- 5.0 Hammer Mill # 1 -to-
- 6.0 Exhauster # 1 and 20 " Dia. Blow Line -to-
- 7.0 Wood Silo -to-
- 8.0 Hammer Mill # 2 -to-
- 9.0 Exhauster # 2 and 16 " Dia. Blow Line -to-
- 10.0 Riffle Distributor Assembly and 8" Dia. Blow Lines -to-
- 11.0 Wood Burners (Nozzles)

Areas of Concern

As stated previously, one of our primary concerns is the performance of the hammermills when reducing green willow bush. We strongly recommend that tests be conducted at Buffalo Hammer Mill to determine the ability of the units to make full load capacity on willow. It may be found that a different type of hammer (knife-type) may be required to successfully reduce the green willow material at rated capacity. While we have not seen the willow bush material, we suspect it is high in moisture and fibrous. However, we are fairly certain that the material handling/firing rate will be need to be derated from its target of 10 tons per hour and 20 MW capability. Based on the bottleneck being the exhauster air flow, the system derating is estimated to be in the 4 - 6 tons/hr range.

The willow bush material, yet unseen, is a concern in general. Not only is it a concern regarding the hammermills as stated above, but it may also be difficult to unload and transfer to the bucket elevator and to get it to flow through the wood hopper with the flying dutchman to the belt feeder. If it can get to the first hammermill and be reduced to 1/4" minus material, then with the proper venturi pick-ups and transport air flows, this material has a good chance of being fired successfully.

Areas of concern that we feel have a high potential to become real operating problems are summarized below:

- No pre-testing of hammermills [green willow]
- No protection against receiving oversized material [both fuels]
- No metal detector in system [both fuels]
- Flowability to Hammer Mill # 1 [green willow]
- No air being pulled down through Hammer Mill # 1 [both fuels]
- Venturi pick-up from Hammer Mill # 1 [both fuels]
- Air flow from Exhauster # 1 [both fuels]
- Blow line size from Exhauster # 1 [both fuels]

Capacity of bag filter system on top of wood silo [both fuels]
Venturi pick-up from Hammer Mill # 2 [both fuels]
Air flow from Exhauster # 2 [both fuels]
Blow line size from Exhauster # 2 [both fuels]
Size of blow lines from riffle distributor [both fuels]

Areas of concern, that may or may not result in a real operating problem, include the following:

Truck unloading area exposed to weather [both fuels]
Belt feeder unloader - bucket elevator width - elevator boot design [green willow]
A day shift Monday-Friday truck delivery schedule will not be possible [both fuels]
Ability of riffle distributor to split flow equally [both fuels]
Pluggage of riffle distributor and possibly wood burner nozzles [both fuels]

1.0 Receiving Hopper/Belt Feeder Unloader

As stated above, wood waste is to be received by self-unloading tractor-trailers. All wood waste is supposed to be 2 inch minus. The trucks will back up to a receiving hopper with a 52" wide belt feeder unloader. We understand that the truck unloading time will be about 10 minutes. The belt feeder unloader transfers the 2" minus wood waste into a 55' tall bucket elevator. No details of the receiving hopper/belt feeder were available to review.

We do not have the belt speed of this conveyor to be able to confirm capacity.

Using a bulk density of 20 lbs/cu.ft. for the delivered wood waste and a trailer capacity of 125 cu.yds. and no weight limit, there will be a minimum 10-12 truck deliveries each day based on a day shift Monday-Friday delivery schedule. The actual number of truck deliveries will depend on percent trailer fill, actual material bulk density and any New York weight limit. About 33,600 cu.ft. of biomass will need to be delivered each weekday in order to maintain/build inventory in the wood silo for nightly and weekend drawdown. Silo levels will vary and will require management

The equivalent unloading rate on a weight basis is just over 200 tons/hr.

Given a truck capacity of 125 cu.yds. and an unloading time of 10 minutes, the belt feeder unloader will need to have a minimum capacity of 12.5 cu.yds/minute (20,250 cu.ft/hr). Ideally, this conveyor has a 10% capacity cushion for a design rating of 22,275 cu.ft/hr (CFH).

We understand that the truck unloading/receiving hopper area will be outside with no enclosure. Given the weather conditions for the Dunkirk, NY area, we feel that a heated enclosure would help avoid unloading problems.

There is no protection for the unloading equipment against receiving oversized material. This lack of protection can cause bridging/plugging and damage. The bucket elevator is especially subject to damage due to oversize material.

The width of the belt feeder unloader is 52". The trailer width is assumed to be 96" wide. Our typical truck unloading design calls for a take-away conveyor, normally a drag chain type conveyor, that is the same width as the trailer. This avoids any potential for bridging/plugging especially with green, fibrous wood residues.

While we believe that the 10 minute truck unloading time is aggressive, it is possible assuming no delays or hangups.

2.0 Bucket Elevator

Using Sweet Manufacturing drawings SD2520-1 and -2, the "Titan 30" bucket elevator is equipped with a 44" wide belt with bolted on 10 gage steel buckets. Each bucket row is made using three (3) 14" x 9" buckets on 12" centers. The stated capacity of the bucket elevator is 21,400 CFH conveying "wood chips, pellets, chunks" with a belt speed of 420 ft/min and a wood waste density of 25 lbs/cu.ft. or less. The boot hopper (receiving chute) has a 45 degree sloped bottom plate. The bucket elevator transfers the 2" minus wood waste into a hopper equipped with a flying dutchman.

Again, using a 10% capacity cushion, the bucket elevator ideally would have a design capacity of 24,500 CFH. The elevator does have the minimum required capacity.

Boot hopper on bucket elevator is 45 degrees. Prefer an angle of 60 degrees from horizontal.

We are concerned about the entry point into the bucket elevator when receiving the green willow bush material. If this material is stringy, fibrous as we suspect, there may be difficulties experienced with it flowing into the elevator. This statement is qualified based on an inspection of the as-received willow bush material.

3.0 Wood Hopper w/ Flying Dutchman

Although we have no detail drawings of the hopper, we do have general arrangements by NMPC. Using NMPC drawings F-54356-W Shts. 6 and 7, the hopper is 20' diameter with 13'-3" straight sides and a 45 degree conical hopper with a 2'-6" outlet. These dimensions give a gross capacity of about 190 cu.yds. A Flying Dutchman, Inc. bottom unloader will be used to cause the 2" minus wood waste to flow down and out the hopper bottom outlet. Wood waste flows out of the hopper outlet onto a transfer belt feeder conveyor.

Using a 70% capacity factor to account for the angle of repose for the wood waste gives a net capacity of about 130 cu.yds. Given that a tractor-trailer can haul and deliver up to 125 cu.yds. of wood waste, the hopper has the capacity to handle one truck delivery when starting empty and no wood waste take-away.

Like the entry point to elevator, we are concerned about the flowability of the willow bush material through the wood hopper, even with the flying dutchman. This statement is qualified based on an inspection of the as-received willow bush material.

4.0 Transfer Belt Feeder Conveyor

Using Cambelt International Corp. drawing 1992536, this belt conveyor is 36" wide with smooth 4 1/2" high sidewalls. From material inlet to material outlet, the conveyor is 9'-9 1/4" long. Speed will vary from 50 to 150 ft/min utilizing a variable-frequency drive. This conveyor is driven by a 3 HP, 1750 RPM, inverter duty motor through a Falk shaft-mounted gear reducer. Further speed reduction is obtained through a V-belt pulley arrangement. We understand that a magnetic separator will be installed over this conveyor. The 2" minus wood waste is transferred to Hammer Mill # 1.

While no capacity is stated on the conveyor drawing, we calculate it to be about 6,900 CFH, or about 138,000 lbs/hr (70 tons/hr) at full speed of 150 ft/min. This is based on an 80% belt fill and a useable belt width of 30.5". Based on this estimated capacity and a full hopper at 125 cu.yds., it will take about 30 minutes to empty the hopper.

This capacity seems reasonable since it will take 1 truck load about 40 minutes to be processed and delivered to the wood silo, assuming zero take-away from the wood hopper. Allowing 60 minutes for 1 truck load to be processed and the wood hopper emptied, truck deliveries will take anywhere from 10-12 hours each day Monday-Friday. Actual truck deliveries can probably be two trucks/hour based on wood flowing out of the wood hopper on a continuous basis. [See subsequent discussion on the Hammer Mill # 1 capacity limitation which will affect the truck delivery schedule].

While there is a magnetic separator on this conveyor for tramp iron removal, there is no metal detector to trip the conveyor in the event that a piece makes it by the magnet or if it is non-ferrous. Metal that makes it into the hammermill can damage the unit and is a spark hazard. Since this conveyor is short, locating a metal detector may be difficult when considering conveyor coast-down time.

5.0 Hammer Mill # 1

Using Buffalo Hammer Mill drawing 8087C, this hammermill is 60" wide and is belt-driven by a 200 HP motor. The hammermill discharges into an integral pyramidal hopper with a square outlet (approx. 10" square). We understand that this hammermill will reduce the wood waste size from 2" minus to 1/4" minus.

The manufacturer, Mr. Tom Warren at Buffalo Hammer Mill, confirmed the rated capacity of the unit is 40,000 lbs/hr (20 tons/hr) when fed 2" minus wood waste and reducing it to 1/4" minus. Wood waste is defined as "particleboard, railroad ties, construction debris, pallets and green timber derived from willow bush". Mr. Warren stated that there was a test run on material received from Bush Industries, but that no test was run on willow bush.

It appears that the capacity of the belt feeder is much higher than the hammermill (70 vs. 20 tons/hr). The belt feeder can be slowed down using the variable-frequency drive in order to avoid jamming the hammermill infeed chute. However, this will prolong the unloading time of the wood hopper to about 1 hour and 45 minutes.

The P&I Diagram, NMPC drawing F-60212-W, does not show air being pulled down through the hammermill. In order to assist material flow through the unit, air should be ducted to the inlet chute (as shown for Hammer Mill # 2) so that a portion of the total air can be drawn down through the hammermill.

The 10" square hammermill outlet is close-coupled to a venturi pickup box located beneath the hammermill. Wood waste is entrained into the air stream and pneumatically conveyed to Exhauster # 1.

The pneumatic pick-up is an area of concern. The shallow-angled pyramidal hopper with a 10" square outlet is an ideal spot for the material to plug or bridge. Access for cleanout is very limited. A more detailed review of the venturi pick-up design is needed.

6.0 Exhauster # 1 and Blow Line

Using an ABB letter dated November 5, 1998 from Mr. M.W. Swiatek to Mr. Mark Rhode with NMPC, this exhauster, along with Exhauster # 2, were re-built for use in the biomass storage and firing system.

The stated exhauster rating by ABB is 8,100 CFM at 25" WG at 1200 RPM requiring 100 BHP.

The blow line from the exhauster to the wood silo is shown to be 20" diameter.

To convey 40,000 lbs/hr (20 tons/hr) of wood waste, the air flow needs to conservatively be about 36,000 CFM. Depending on the fan curve characteristic for the ABB exhauster and with the actual static pressure required to overcome the system resistance, it may be that the ABB exhauster can be made to work - this will require a more detailed review.

Along with the higher air flow, the blow line size will need to be increased in order to maintain the air velocity in the range of 5,000-6,000 ft/min. Using 6,000 ft/min velocity, the blow line will need to be a 33" or 34" dia. line.

7.0 Wood Silo

Using the Laidig Industrial Systems drawing 50-30-82498-00, the steel silo has a level full capacity of 37,632 cu.ft. (1,394 cu.yds.). The silo is 64'-7 1/4" tall straight sides and is 30'-9 1/4" inside diameter. The silo floor is 14' above the ground floor. A radial reclaim auger delivers the 1/4" minus wood waste to a center discharge hopper box. A variable-speed metering auger delivers the wood waste to Hammer Mill # 2. Laidig shows the 1/4" minus wood waste compacted bulk density to be 25 lbs/cu.ft.

Based on the design burn rate, the silo provides about 1-1/4 days of storage using an 80% fill and 20 lbs/cu.ft. bulk density or just over 1-1/2 days of storage using a 25 lbs/cu.ft. bulk density. The silo size does not appear to have enough capacity to support a day shift Monday-Friday truck delivery schedule. To be able to operate through a weekend at the design burn rate, off-hour or weekend truck deliveries probably will be required.

We have contacted Laidig and confirmed the capacity of the radial auger unloading system to be 33 cu.ft/min. At a bulk density of 20 lbs/cu.ft., this is equivalent to just under 20 tons/hr. This capacity is almost double the design burn rate of 10 tons/hr.

The variable-speed metering auger, located in the wood silo outlet hopper, can be slowed down to avoid choking the feed chute to Hammer Mill # 2.

The capacity of the bag filter system on top of the wood silo has not been checked. Based on the recommended air flow, we suspect this may be a problem.

8.0 Hammer Mill # 2

Using Buffalo Hammer Mill drawing 8087C, this hammermill is 60" wide and is belt-driven by a 200 HP motor. The hammermill discharges into an integral pyramidal hopper with a square outlet (approx. 10" square). We understand that this hammermill will reduce the wood waste size from 1/4" minus to 1/8" minus.

The manufacturer (Mr. Tom Warren at Buffalo Hammer Mill) confirmed the rated capacity of the unit is 20,000 lbs/hr (10 tons/hr) when fed 1/4" minus wood waste and reducing it to 1/8" minus. Wood waste is defined as "particleboard, railroad ties, construction debris, pallets and green timber derived from willow bush".

No testing has been done with willow bush in these hammermills.

The 10" square hammermill outlet is close-coupled to a venturi pickup box located beneath the hammermill. Wood waste is entrained into the air stream and pneumatically conveyed to Exhauster # 2.

Like Hammer Mill # 1, the pneumatic pick-up is an area of concern. The shallow-angled pyramidal hopper with a 10" square outlet is an ideal spot for the material to plug or bridge. Access for cleanout is very limited. A more detailed review of the venturi pick-up design is needed.

9.0 Exhauster # 2 and Blow Line

Using an ABB letter dated November 5, 1998 from Mr. M.W. Swiatek to Mr. Mark Rhode with NMPC, this exhauster, identical to Exhauster # 1, were re-built for use in the biomass storage and firing system.

The blow line from the exhauster to the riffle distributor is shown to be 16" diameter.

The stated exhauster rating by ABB is 8,100 CFM at 25" WG at 1200 RPM requiring 100 BHP.

To convey 20,000 lbs/hr (10 tons/hr) of wood waste, the air flow needs to probably be in the 12,000 - 18,000 CFM range. The reason we state a range here is that the application isn't simply transporting material. It is important to recognize that this air-wood flow will be entering the furnace and in our experience we know that the air quantity needs to be as low as possible from a combustion standpoint, however it can't get too low to cause material too settle/stratify in the blow line. It seems prudent here to have the ability to supply what we see as the maximum air flow and then have the ability to reduce air flow based on actual system performance. Depending on the fan curve characteristic for the ABB exhauster and with the actual static pressure required to overcome the system resistance, it may be that the ABB exhauster can be made to work - this will require a more detailed review.

Along with the higher air flow, the blow line size will need to be increased in order to maintain the air velocity in the range of 5,000-6,000 ft/min. Using an air flow of 15,000 CFM and an air velocity of 5,500 ft/min, the blow line will need to be a 22" or a 23" dia. line. This sizing needs to be studied carefully to select the optimum size.

In reviewing the system resistance calculations, we did not see any allowance for the riffle distributor assembly. However, given the current air flow basis of 8,100 CFM and in view of the recommended air flows, we did not review these calculations closely.

10.0 Riffle Distributor Assembly and Blow Lines

Using R-V Industries drawings, phone conversations with Mr. Tom Underwood of R-V Industries and a field inspection of the riffle assembly, the unit splits the single 16" dia. blow line into four separate 8" dia. blow lines.

According to Mr. Underwood, R-V does not have an application using this design on biomass. This unit is commonly used to split pulverized coal flows. For pulverized coal applications, Mr. Underwood reports a typical pressure drop of 2" - 3" WG through the riffle distributor.

While we are unsure as to whether this device will split the biomass flow equally, we have no basis to believe that it won't. Even if the flow doesn't split exactly equal, we are not convinced that the impact on combustion will be noticeable.

Based on the new design air flow, each of the 4 blow lines from the riffle distributor may need to change.

11.0 Wood Burners (Nozzles)

Using the R-V Industries drawing and our notes from the walkdown of the boiler, each of the four wood burners will replace the unused oil burner level on each corner. The wood nozzles appear to have swirl plates.

Wood waste will be injected into the furnace through dedicated nozzles located between an upper and lower secondary air level. There will also be two coal and oil nozzle levels above and below the wood nozzle level. Additionally, two levels of overfire air nozzles will be above the wood nozzles and one straight secondary air level will be below the wood nozzles. This location in the furnace looks good.

While the swirl plates are probably good in terms of promoting air/fuel mixing, it is hard to tell what the clearances are in the wood nozzles. If they are too tight, pluggage may be a problem.

APPENDIX B

LIST OF EQUIPMENT AND MATERIALS

CONTRACTORS

Building, Hopper, Misc. Steel	\$ 415,000
Spark Detection System	\$ 15,335
Willow Fuel Chipping	\$ 8,600
Concrete Foundations	\$ 450,000
Hydrogen Tank Relocation	\$ 65,000
Concrete Testing	\$ 5,000
Piping to Boiler	\$ 100,000
Other Piping	\$ 10,000
Burner Installation	\$ 20,000
Electrical Installation	\$ 110,000
Contractor Equipment Setup	\$ 150,000
Controls System (NRG)	\$ 60,000
Variable Speed Drive Installation	\$ 3,119
Total Contractors	\$ 1,412,054

MATERIALS & EQUIPMENT

Exhauster Rebuild	\$ 215,755
Hammer Mills	\$ 111,820
Victaulic Fittings	\$ 7,135
Knife Gate Valve	\$ 2,914
Magnetic Separator	\$ 12,760
Control Cabinet	\$ 2,100
Flying Dutchman	\$ 34,181
Ultrasonic Level Control	\$ 3,065
Level Detection System	\$ 495
Motor Starters	\$ 17,602
Motor Starter & Thermal Unit	\$ 2,400
Cable Tray	\$ 2,151
Electrical Cabinets	\$ 1,805
Wood Silo	\$ 281,712
24" Butterfly Valves	\$ 7,992
Air Intake Box	\$ 2,970
Exhauster Transition Fittings	\$ 2,973
Annunciator	\$ 1,150
Pressure Transmitters	\$ 4,157
Burners	\$ 17,766
Riffler Distributer	\$ 21,600
Pressure Switch	\$ 1,243
Bag Houses	\$ 44,790
Bucket Elevator	\$ 58,200
Belt Feeders	\$ 18,000
Remote Monitoring Equipment	\$ 1,181
Adjustable Speed Drives	\$ 31,420
Variable Speed Drives	\$ 13,665
Misc. Materials, Electrical	\$ 20,492
Stock Materials, Supplies	\$ 20,600
Stores Handling/Receiving	\$ 49,900
Total Materials & Equipment	\$ 1,013,994