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RENEWABLE ENERGY STUDY SUBGRANT
Missouri Department of Natural Resources

Technical And Economic Feasibility Of Adding Heat Recovery With Electric Generation To A 7-Hearth Rotary Wood Char Furnace

Subgrant Award No: G11-SEP-RES-10

Prepared for -

Missouri Department of Natural Resources

July 15, 2011

Prepared by -

Garnett Wood Products
Brandsville, Missouri

GARNETT WOOD PRODUCTS

The Energize Missouri Renewable Energy Study Subgrant program was created to increase the ability of businesses, governments and organizations to make informed decisions about complex renewable energy systems by understanding and solving information deficiency and technical uncertainties. Program funds are made possible through the American Recovery and Reinvestment Act and the Transform Missouri initiative and administered by the Missouri Department of Natural Resources.

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1.0 EXECUTIVE SUMMARY

Garnett Wood Products is evaluating increasing its wood char production capacity by adding a 7-hearth rotary wood furnace. Under a grant awarded by the Missouri Department of Natural Resources, Division of Energy from the Energize Missouri Renewable Energy Study Subgrant Program, Garnett Wood Products evaluated technical and economic feasibility of adding heat recovery electric generation to a new 7-hearth rotary wood furnace.

Lutz, Daily & Brain, Consulting Engineers in Overland Park, Kansas provided the engineering feasibility assessment and detailed cost estimate. Garnett Wood Products staff contributed the remaining sections of the study.

Based on this feasibility level of investigation, it was determined that combining a multi hearth furnace with a combined cycle heat recovery electric generation plant is sound from an engineering standpoint. However, from a practical and economic standpoint there are significant challenges to the feasibility of this and similar projects.

Even with waste heat recovery, due to the relatively small generating capacity of this or similar projects they would be only marginally competitive in the current electricity market. In addition to the cost of power generated, accessing potential customers through interconnection with the regional transmission system would be challenging and very expensive for the typical developer of a rotary wood furnace combined cycle electric generation project.

Such projects do offer considerable non-energy benefits to the local communities and regions. They represent significant capital investments that will result in increasing local real estate and personal property tax bases. Additionally, such projects would be expected to generate fifteen to twenty quality jobs in typically rural areas. From an environmental perspective these are renewable electric generation resources that will offset regional emissions of CO_2, CH_4, and SO_2. The Garnett Wood Products project would also utilize over 66,000 tons of logging waste slash annually.

Adding combined cycle heat recovery electric generation to new or existing multi-hearth rotary wood furnaces is technologically sound. Such projects would result in additional local and regional economic and environmental benefits. However, in the current electricity market finding a viable customer for the power, while not impossible, is expected to be difficult. The generation of certified renewable energy credits could make such projects more attractive to certain potential customers.

2.0 INTRODUCTION

Garnett Wood Products (GWP) has owned and operated a 4-hearth rotary furnace at its facility in Brandsville, Missouri for over 30 years. They have used this furnace to produce a variety of char products including charcoal and activated carbon from wood stock ranging from dry sawdust to green wood chips. During the process volatile constituents of the wood are driven off in a very low oxygen environment and result in a high temperature combustible flue gas rich in volatile organic compounds but no oxygen. To control these VOC emissions air is admitted into refractory lined stacks where the VOCs combust and are destroyed. The result is a significant amount of waste heat exiting the stacks.

In the past, GWP has evaluated adding heat recovery to its existing furnace but found it too small to be economically justified and therefore a detailed feasibility study has not been performed. However, GWP is now considering increasing its char production capacity by adding a 7-hearth rotary furnace. Such a furnace would be about twice the size of their existing furnace and therefore consideration is again being given to incorporation of combined cycle technology for heat recovery. Combined cycle technology has been successfully applied in both the electric production and various process industries for many decades.

The production of char in this process relies on wood, which is classified as biomass, as its only raw material feed. Heat recovery from a biomass supplied source is considered to be a renewable energy source. As such, electric generation from combined cycle technology applied to a wood char furnace will generate renewable energy credits that can be used as offsets for carbon emission from fossil fuel generation.

Early in the planning process, recognizing the improved economies of scale and potential additional value of renewable energy credits, GWP conducted a screening level cost study. They found it possible the addition of heat recovery combined cycle would be economically feasible. However, some engineering design challenges were identified and a more complete cost assessment was needed. GWP applied for and was awarded a grant from the Energize Missouri Renewable Energy Study Subgrant Program to conduct a feasibility study of applying heat recovery combined cycle technology to a 7-hearth rotary wood char furnace. This report provides the results of that study and includes the Lutz, Daily & Brain Engineering Feasibility and Project Cost Assessment Study as Appendix A.

3.0 PROCESS DESCRIPTION

The wood char furnace that is the subject of this study could produce a variety of char products from a combination of dry sawdust from local manufacturers and green wood chips recovered from logging slash, normally a forest waste product. The raw wood feed stock is fed to the top of the rotary hearth furnace where it enters a reducing or low oxygen high temperature environment. Air cooled rotating arms or rakes move the material across each hearth to slots where it falls to the next lower hearth. Temperatures are carefully controlled at each level to produce the desired product. The volatile organic materials in the wood are driven off and exit the furnace in a high temperature zero oxygen flue gas. Figure 3-1 is an engineering cut away drawing of a 7-hearth furnace.

Volatile organic compounds (VOCs) are considered an air contaminant that must be treated or removed before being emitted from the process. The flue gas exiting the furnace passes to refractory lined stacks where air is admitted to the process. This is called a thermal oxidizer and the VOCs are destroyed through combustion. The volume and temperature of the flue gas both increase producing approximately 300,000 pounds of flue gas per hour at 1800 degrees F. or approximately 120 million Btu per hour of waste heat.

In the plant's gas path, effluent flue gas from the thermal oxidizer in the process stack is ducted to an unfired heat recovery steam generator (HRSG) to recover waste heat from the flue gas. The flue gas from the HRSG then passes through an economizer to recover additional waste heat, then through a mechanical dust collector and fabric filter baghouse to remove ash (particulate matter). The flue gas, with constituents in compliance with environmental emission regulations, is drawn by an induced draft fan (ID) to the combined cycle stack for discharge to the atmosphere.

In a combined cycle application, electric power is produced via a conventional steam cycle. Steam is produced by the HRSG as a result of the heat being exchanged from the flue gas to the boiler feedwater. This high pressure superheated steam is used to drive a steam turbine generator, steam turbine drives for the ID fan and boiler feed pump and for certain process steam loads in the plant. The cycle is completed when low pressure steam from the three turbines is returned to the condenser. The generator connected to the main steam turbine produces electricity with the resulting electrical output is available for sale to local utilities or other customers. The heat recovery process is illustrated in Figure 3.2 "Multi-hearth Wood Char and Cogeneration Process Flow Diagram". A potential Site Plan and General Arrangement is shown in Figure 3.3.

With the 120 million Btu per hour heat input, the net generating capacity of the proposed unit will be about 8,600 KW. Utility grade equipment of high reliability, with redundant auxiliary equipment has been selected for this project. As described in the next section, the boiler feed pumps and ID fan are equipped with alternate electric motor and steam turbine drives. Such design features and the use of high quality components are expected to result in a capacity factor of 95%. Additionally, to assure safe operations of the combined furnace and heat recovery system, a high temperature automatic bypass damper on the process stack is set to maintain negative pressure at that point.

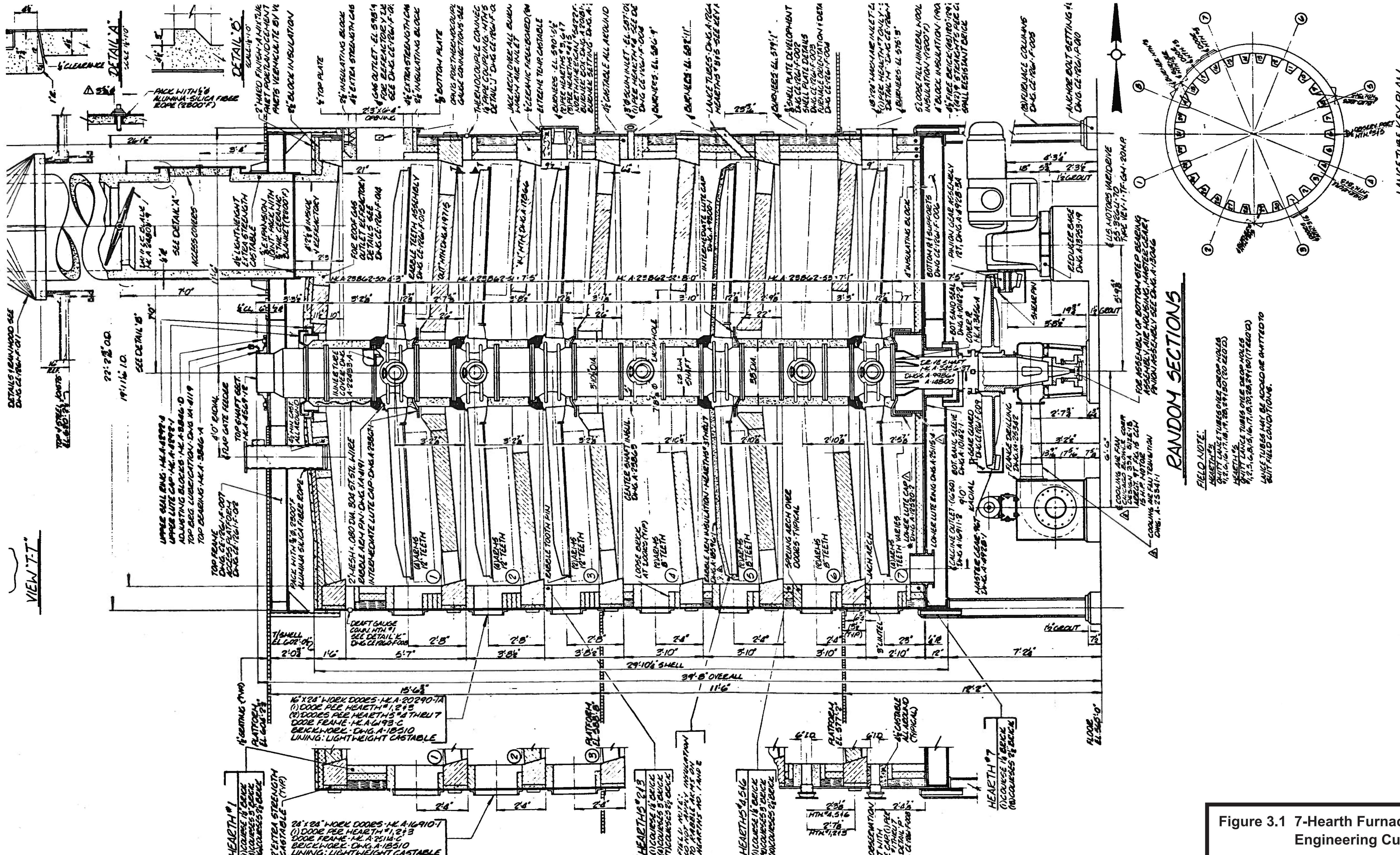
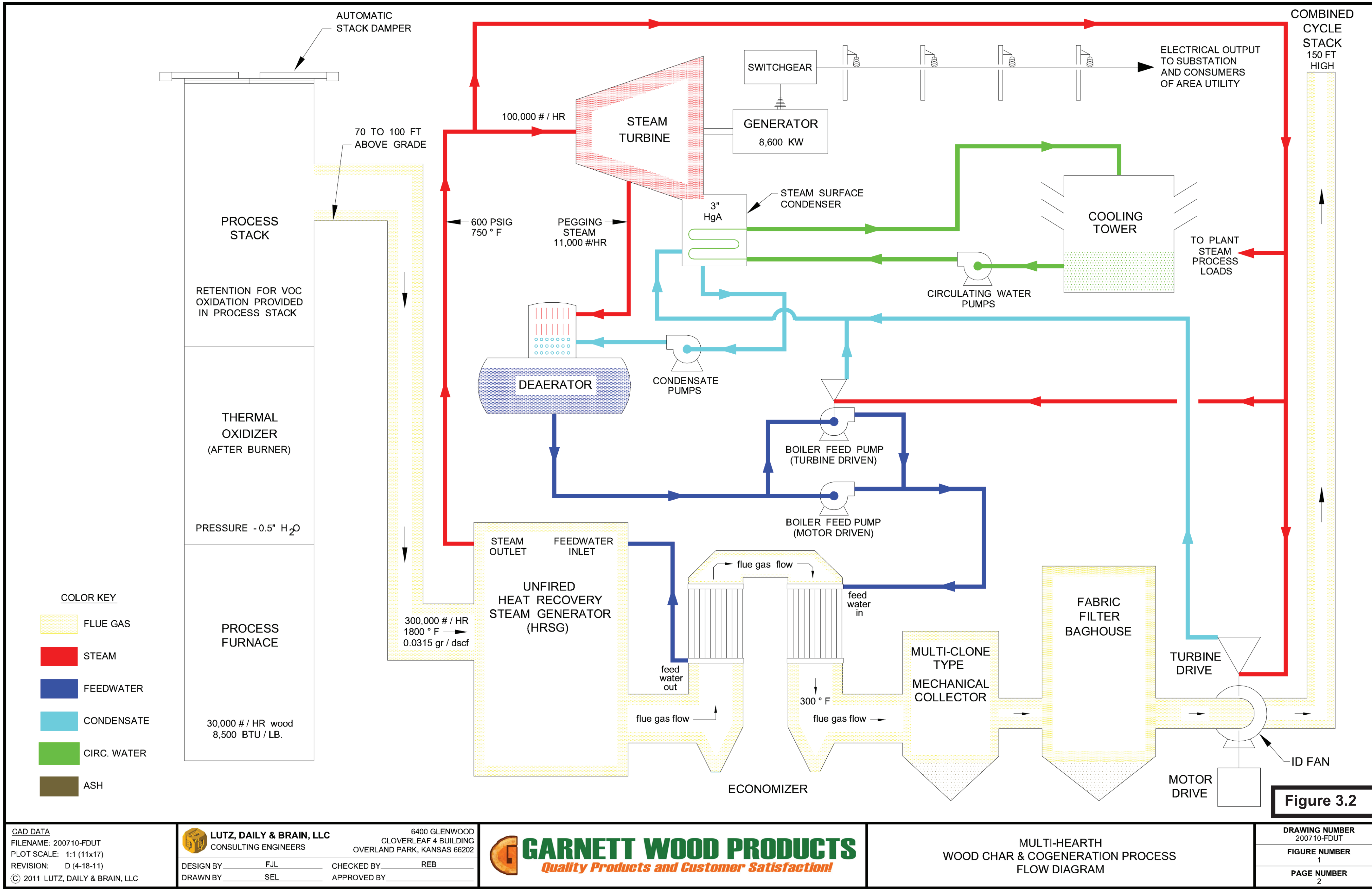


Figure 3.1 7-Hearth Furnace Engineering Cut-away


AUTOMATIC STACK DAMPER
70 TO 100 FT ABOVE GRADE
PROCESS STACK
RETENTION FOR VOC OXIDATION PROVIDED IN PROCESS STACK
THERMAL OXIDIZER (AFTER BURNER)
PRESSURE - 0.5" H_2O
PROCESS FURNACE
30,000 # / HR wood 8,500 BTU / LB.
300,000 # / HR 1800 ° F 0.0315 gr / dscf
100,000 # / HR
600 PSIG 750 ° F
PEGGING STEAM 11,000 #/HR
STEAM TURBINE
SWITCHGEAR
GENERATOR 8,600 KW
ELECTRICAL OUTPUT TO SUBSTATION AND CONSUMERS OF AREA UTILITY
COMBINED CYCLE STACK 150 FT HIGH
3" HgA
STEAM SURFACE CONDENSER
COOLING TOWER
CIRCULATING WATER PUMPS
TO PLANT STEAM PROCESS LOADS
DEAERATOR
CONDENSATE PUMPS
BOILER FEED PUMP (TURBINE DRIVEN)
BOILER FEED PUMP (MOTOR DRIVEN)
STEAM OUTLET
FEEDWATER INLET
UNFIRED HEAT RECOVERY STEAM GENERATOR (HRSG)
flue gas flow
feed water in
feed water out
300 ° F
ECONOMIZER
MULTI-CLONE TYPE MECHANICAL COLLECTOR
FABRIC FILTER BAGHOUSE
TURBINE DRIVE
MOTOR DRIVE
ID FAN
COLOR KEY
FLUE GAS
STEAM
FEEDWATER
CONDENSATE
CIRC. WATER
ASH
CAD DATA
FILENAME: 200710-FDUT
PLOT SCALE: 1:1 (11x17)
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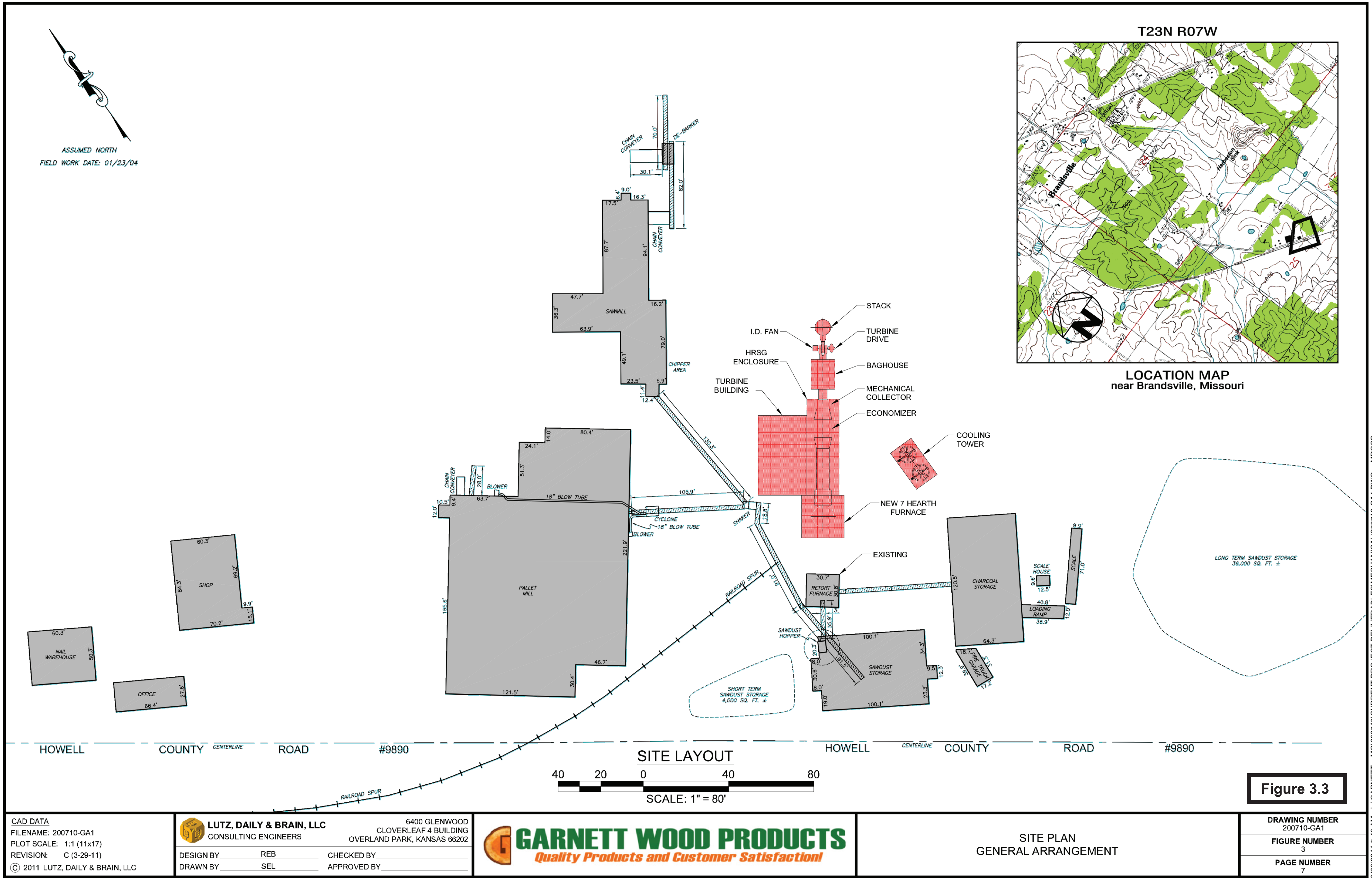
CONSULTING ENGINEERS
6400 GLENWOOD
CLOVERLEAF 4 BUILDING
OVERLAND PARK, KANSAS 66202
DESIGN BY FJL
CHECKED BY REB
DRAWN BY SEL
APPROVED BY
GARNETT WOOD PRODUCTS
Quality Products and Customer Satisfaction!
MULTI-HEARTH WOOD CHAR & COGENERATION PROCESS FLOW DIAGRAM
DRAWING NUMBER 200710-FDUT
FIGURE NUMBER 1
PAGE NUMBER 2
Figure 3.2


ASSUMED NORTH
FIELD WORK DATE: 01/23/04
T23N R07W
LOCATION MAP
near Brandsville, Missouri
STACK
I.D. FAN
TURBINE DRIVE
HRSG ENCLOSURE
BAGHOUSE
TURBINE BUILDING
MECHANICAL COLLECTOR
ECONOMIZER
COOLING TOWER
NEW 7 HEARTH FURNACE
EXISTING
CHAIN CONVEYER
DE-BARKER
SAWMILL
CHIPPER AREA
PALLET MILL
18" BLOW TUBE
BLOWER
CYCLONE
SHAKER
SHOP
NAIL WAREHOUSE
OFFICE
RETORT FURNACE
CHARCOAL STORAGE
SCALE HOUSE
SCALE
LOADING RAMP
SAWDUST HOPPER
SAWDUST STORAGE
SHORT TERM SAWDUST STORAGE 4,000 SQ. FT. ±
LONG TERM SAWDUST STORAGE 36,000 SQ. FT. ±
RAILROAD SPUR
HOWELL COUNTY ROAD #9890
CENTERLINE
SITE LAYOUT
40 20 0 40 80
SCALE: 1" = 80'
Figure 3.3
CAD DATA
FILENAME: 200710-GA1
PLOT SCALE: 1:1 (11x17)
REVISION: C (3-29-11)
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GARNETT WOOD PRODUCTS
Quality Products and Customer Satisfaction!
SITE PLAN
GENERAL ARRANGEMENT
DRAWING NUMBER 200710-GA1
FIGURE NUMBER 3
PAGE NUMBER 7
3/29/2011 9:48 AM - L:\GARNETT, MO\200710\CURRENT PROJECT DELIVERABLES\MECHANICAL\200710-GA1.DWG - MROSS

4.0 ENGINEERING FEASIBILITY

This analysis was conducted to adapt the cogeneration process to the 7-hearth furnace that is under consideration for addition by GWP. However, we believe this assessment would be applicable to any similar high temperature heat recovery process.

4.1 Safety and Operational Challenges

Based on previous screening level assessments, it is understood that there are two key operational and safety concerns which can result from combining the rotary hearth furnace and heat recovery technologies. First, there is considerable heat stored in both the furnace and the heat recovery equipment at any time the process is operational. The project must be designed to safely dissipate this stored energy, without damaging the equipment, if there is a loss of power to the plant.

The other, and more critical, design consideration is the explosive nature of the flue gas leaving the furnace. The furnace operates in a reducing stoichiometric environment with very low oxygen concentrations. Should there be any process disruptions in the heat recovery equipment that pressurizes the furnace, the resulting addition of oxygen could result in an explosion risk. For this project to be feasible, it is necessary that any failure which could cause such conditions, such as a failure of the ID fan, allow for rapid venting of the furnace. This challenge is made greater due to the high temperature of the flue gas, potentially exceeding 1800 degrees F.

Lutz, Daily and Brain, Consulting Engineers (LD&B), was tasked to analyze these characteristics and assess designs that would address these concerns. As discussed below, LD&B believes properly engineered systems can address those safety and operational issues.

4.2 Engineering Solutions

LD&B evaluated the dissipation of stored heat during a loss of power and concluded it can be addressed by using steam driven auxiliary equipment. Specifically, a steam driven boiler feed pump and an ID fan with a steam turbine drive would allow the process to extract residual heat from the furnace on a loss of electrical power as the steam side of the plant coasts to shut down. A parallel electric motor driven boiler feed pump and an electric motor drive on the ID fan would provide for plant startup. LD&B concluded that these features, while adding some cost to the project, will satisfactorily address the residual heat concern.

With respect to pressurizing the furnace and creating a potentially explosive situation, LD&B investigated experience in the industry to deal with the high temperatures and the volatile gases. Specifically they looked at high temperature dampers and cupola vents similar to those used in the steel industry. LD&B found that there are several HRSG's operating under similar conditions with high temperature dampers, and one HRSG manufacturer has recently signed a contract for a new unit significantly larger than the proposed HRSG, also utilizing high temperature dampers. It is therefore believed negative pressures can be safely maintained with a high temperature bypass damper on the furnace stack outlet.

4.3 Scalability

The heat recovery combined cycle technology that would be utilized on this project has a long successful history and can be applied to virtually any waste heat source. As with most projects such as this, economies of scale will adversely affect the feasibility of smaller projects. As described in the next section, the economic feasibility of the subject 7-hearth furnace project is marginal. While the combined cycle heat recovery technology could be applied to a smaller furnace, it does not appear the power costs would be competitive in the current electricity market. With respect to larger or multiple furnaces, combined cycle systems could easily be scaled up and the economics of larger projects would likely improve.

4.4 Unknowns

This is a feasibility study, not a detailed engineering design study. As such there are numerous unknowns that are beyond the scope of this feasibility and cost study that could affect the feasibility of this or similar projects. LD&B identified several key unknowns including how the power would be exported from the project and the availability and delivery time for key project components. Also, specific air permit requirements are not known and could adversely affect project costs and feasibility. Another key unknown they mentioned is the water supply for a project. Such supplies are site specific regarding availability and quality and the cost of obtaining and treating water for a project could affect its feasibility. Another unknown identified by GWP is the ability to obtain financing for a project. Unknowns such as these would be addressed in the detailed engineering phase.

4.5 Conclusions

LD&B concluded that, unknowns notwithstanding, combining a multi-hearth furnace with a heat recovery electric generation plant is sound from an engineering standpoint. Systems can be designed to satisfactorily address safety and operational concerns. Additionally, the combined cycle technology is scalable and could be applied to virtually any heat source, however is unlikely that it would be economically feasible for furnaces smaller than the 7-hearth that is the subject of this study.

5.0 PROJECT COST ESTIMATES

LD&B conducted a detailed capital cost estimate for the subject 7-hearth furnace combined cycle heat recovery system. They also investigated and provided typical operating cost factors. GWP utilized these costs to estimate power costs for various capital recovery and interest rate scenarios.

5.1 Capital Costs

LD&B developed cost estimates for the engineering design, site development, permitting, equipment procurement, construction and contingency for a heat recovery combined cycle plant sized for the heat input from a 7-hearth rotary wood furnace. The cost estimates were based on the use of new equipment and installation meeting the quality standards prevalent in the electric generation utility industry. Detailed quotations were obtained from individual component vendors. Other costs, such as site preparation and building improvements are based on current factors known and used by LD&B.

Consideration was given to utilizing used equipment to reduce project costs. However, the availability of such equipment is very uncertain as is its quality and suitability for service. Additionally, used equipment typically does not have warranties which would likely complicate financing for a project. For these reasons used equipment was not considered an capital cost estimates are based solely on new equipment.

The total estimated capital cost for the subject project combined cycle heat recovery equipment is $23,098,000. The detailed cost estimate breakout is provided in Table 5.1.

5.2 Operating and Maintenance Costs

LD&B surveyed similar installations and developed cost factors for labor, maintenance and supplies and miscellaneous items. Their review resulted in a labor cost of $75,000 per employee. This is substantially higher that the expected wages in rural south central Missouri. To estimate O&M costs we have used $45,000 per employee. This is slightly higher than that used in the socieoeconomics section reflecting some additional costs for benefits. The design capacity factor of 95% was used to calculate the operating and maintenance cost estimates.

The estimated first year O&M cost for the project is $948,000. The breakout of these costs is provided in Table 5-2

5.3 Resulting Power Costs

For this report we have chosen to provide the estimated break even cost of power from the project for four different interest rate and capital recovery period scenarios. These scenarios are for illustrative purposes only as any number of reasonable scenarios could be evaluated. Also, note that the costs in cents/kwh are based on the design capacity factor of 95% or an annual generation of 71,569,000 kwh. The actual cost of power sold would be increased by the required return on investment or profit which would be very project specific.

Table 5-1 Detailed Capital Cost Estimate

Item				Estimated Cost All New Equipment
I.	SITEWORK			$ 150,000
II.	BUILDING IMPROVEMENTS			
	A.	Steam Turbine Generator Building 46 X 75 pre-insulated metal building		$ 320,000
	B.	HRSG Enclosure 30 x 90 x 45 H		$ 227,000
	C.	Foundations and Support Steel		
		1.	HRSG, Baghouse, Economizer, Multicone, and ID Fan with Motor and Turbine Drives, and Stack	$ 277,000
		2.	Steam Turbine Generator, Condenser, Boiler Feedwater Pumps, and Condensate Pumps	$ 167,000
		3.	Cooling Tower Basin and Circulating Water Pumps	$ 59,000
III.	MECHANICAL			
	A.	Equipment		
		1.	HRSG	$ 3,263,000
		2.	Stack Cap Damper	$ 200,000
		3.	Inlet Duct	$ 108,000
		4.	Outlet Duct	$ 54,000
		5.	Multicone Dust Collector	$ 150,000
		6.	Baghouse Fabric Filter System	$ 950,000
		7.	ID Fan with Motor Drive and Steam Turbine Drive	$ 221,900
		8.	Stack Steel 150 feet height	$ 150,000
		9.	CEMS NOx, CO, O2, CO2, PM	$ 250,000
		10.	Steam Turbine Generator	$ 4,600,000
		11.	Condenser, Condensate Pumps & Circulating Water Pumps	$ 750,000
		12.	Cooling Tower two cell	$ 250,000
		13.	Boiler Feed Pumps - One Motor Drive and one Turbine Drive	$ 227,000
		14.	Deaerator including freight	$ 114,000
		15.	Heating Boiler	$ 350,000
		16.	Plant Service Well	$ 160,000
		17.	Boiler Water Makeup System Dual RO & Softener Trains	$ 150,000

Table 5-1(cont.) Detailed Capital Cost Estimate

Item				Estimated Cost All New Equipment
	B.	Equipment Erection		
		1.	HRSG & Economizer Including Assoc. Ductwork & Damper	$ 1,631,500
		2.	Multicone Dust Collector	$ 25,000
		3.	Steam Turbine Generator	$ 380,000
		4.	Condenser	$ 50,000
		5.	Cooling Tower	$ 30,000
		6.	Condensate Pumps	$ 15,000
		7.	Circulating Water Pumps	$ 25,000
		8.	Baghouse Fabric Filter System	$ 757,000
		9.	Start-up and Commissioning	$ 60,000
		10.	Training	Included with equipment
	C.	Piping Systems including Insulation and Lagging		$ 1,500,000
IV.	CONTROLS			$ 100,000
V.	ELECTRICAL			$ 757,000
VI.	TIE LINE TO UTILITY (TBD)			TBD
VII.	GRAND SUBTOTAL DIRECT CONSTRUCTION COST			$ 18,478,000
	(Nearest $1,000)			
VIII.	ENVIRONMENTAL PERMITTING, ENGINEERING & CONTINGENCIES			$ 4,620,000
	(Nearest $1,000)			
IX	TOTAL ESTIMATED COST (TEC)			$ 23,098,000
	(Nearest $1,000)			

Table 5 -2 First Year O&M Costs

Cost Component	Cost Factor	Multiplier	Annual Cost
Maintenance Supplies and Miscellaneous Items	7 mills/kwh	71,569,000 kwh	$501,000
	$25.80/installed kw	8,600 kw	$222,000
Labor	$45,000/employee	5 employees	$225,000
TOTAL FIRST YEAR O&M COST			$948,000
FIRST YEAR COST / KWH			1.32 cents/kwh

Table 5 -3 Break Even Power Costs

Interest Rate	Capital Recovery Period	Annual Capital Recovery Cost	First Year O&M Cost	Total First Year Cost	Break Even Power Cost
5%	7 years	$3,918,000	$948,000	$4,866,000	$0.068/kwh
6%	7 years	$4,049,000	$948,000	$4,997,000	$0.070/kwh
5%	15 years	$2,192,000	$948,000	$3,140,000	$0.040/kwh
6%	15 years	$2,339,000	$948,000	$3,278,000	$0.046/kwh

6.0 POTENTIAL CUSTOMERS

6.1 Overview

In general, customers for the electrical output from a project such as this would include conventional municipal, rural electric and investor-owned utilities. An independent power producer may also find a project such as this to have value. Another alternative would be for the developer to contract with a power marketing firm to sell the plant's output into the regional electricity market.

Marketing electrical output from a project such as this requires a degree of understanding and sophistication typically not available in wood processing and char manufacturing firms. Therefore, the most likely customers would be an established utility that would bring an understanding of power marketing and transmission to the project. Partnering with an independent power producer is also viable, but in our opinion riskier for the developer. Retaining ownership of the project and using a power marketing firm to sell its electrical output offers some potential benefits, but we believe it is much riskier with sales and cash flows subject to the vagaries the electricity market.

For a typical wood processing firm considering a heat recovery project, we believe a firm power purchase agreement (PPA) with an established electric utility is the best option. A PPA defines and limits the financial risk for the period of the agreement. A similar option in this regard would be some sort of parterning or joint ownership agreement with an established power company.

One other consideration in identifying potential customers is the fact that this type of project is considered renewable and would generate certified renewable energy credits (RECs). Potential customers that have renewable portfolio standard requirements would likely have a greater interest in this type of project.

6.2 Challenges and Impediments

There are at least three specific challenges in identifying and engaging customers for the electrical output from this type of heat recovery project. First is the lack of electric utility experience in the firms that would typically develop a project such as this. Engaging a consultant or partner with utility experience to negotiate and develop contracts with electricity producers is needed. A second and larger challenge is the price for which the power must be sold to make the project economically viable. Due to their relatively small size, these projects, < 9 MW for the subject of this study, economies of scale work against them even considering the essentially free fuel source. This requires customers that might have a specific capacity need which can be met by this type of project; could have need of RECs; or possibly one expecting electricity prices to increase in the next several years. While not a fatal flaw, the cost of electricity produced from this type of project presents a challenge in the current power market.

Finally, we believe the largest impediment to identifying and engaging potential customers is access to a regional transmission system. As described in the Transmission Constraints Section (7.0), the process of obtaining approval to connect a project of this size to a regional transmission system is complex, time-consuming and expensive. While certainly not impossible, obtaining approval to interconnect a project such as this with the regional system, which is necessary to access a larger potential customer base, would be a significant challenge. We believe a more likely scenario would be to connect this project to a local distribution system or directly to the customer's system. This would, however, restrict the potential customer base for a heat recovery project.

6.3 Specific Customers

As part of this feasibility study we did identify potential customers for the electrical output from the project that is the subject of this study. We investigated their interest in participating in the project or purchasing its electrical output. Independent power producers and utilizing a power marketing firm to sell the project's output were considered too risky and not viable.

Contacts were made with rural electric, municipal and investor-owned utilities. All of the utilities we contacted expressed interest in and support for such a project, but had different needs and objectives. The cooperatives are not subject to the State's Renewable Portfolio Standard and have no need for RECs. Neither do they have capacity needs at this time.

The investor-owned utility in the area has a general interest in renewable projects and a specific need for RECs several years in the future. They have expressed an interest in the project and additional discussions are likely.

There are several municipal utilities in the area that will have capacity and energy requirements within the next few years. They are looking at various options available to them and are likely to consider this project relative to those options. Follow up discussions in this regard are expected within the next few months.

6.4 Summary

Obviously a project such as this is only feasible if there is a customer to purchase the electrical output. Identifying such customers in the current energy market is challenging. As electric demand and prices increase with a recovering economy these projects should become more attractive to potential customers. Access to customers through a regional transmission system is expected to remain challenging.

7.0 TRANSMISSION CONSTRAINTS

We anticipate heat recovery projects such as this would typically be in the range of 7 to 15 MW. Interconnecting projects of this size to a regional transmission system can be complex and expensive.

With the advent of open-access electric transmission in this country, a process to control how the systems are used has been implemented. Before a generating source can be interconnected to the transmission system, its impact on the stability of that system must be evaluated by the utility and/or the Regional Transmission Coordinator. Each new generating source must be approved before it can connect to the regional transmission system. An example of this process was provided by Associated Electric and is summarized below.

A Pre-queue Informational meeting is the first step. A valid Interconnection Request is then prepared. This requires a non-refundable fee of $5,000 and, for projects >5 MW, a $30,000 study deposit. The process then proceeds to a System Impact Study Phase and then to the Facility Study Phase.

There are specific milestones to complete the Facility Study including an executed study agreement, demonstration of 100% site control, detailed stability model and one-line drawings, and possibly an executed Power Purchase Agreement (PPA). For projects between 5 and 50 MW a study deposit of $100,000 is required.

The final step is to enter into a Generator Interconnection Agreement (GIA) that must be negotiated. This involves recertification of 100% site control, a non-refundable deposit of up to $500,000 applied to future material and construction costs and something proving the viability of the project such as a PPA, execution of major design or construction contracts or issued environmental permits such as an air construction permit. It must also be considered that at any point in this process it could be determined that the system cannot support the new generation and approval to interconnect would not be granted.

A firm or individual with expertise in this area would have to be retained to represent the developer at each stage of this process, through negotiating the final GIA. This is critical as the Associated process includes specific time lines that must be met or the entire application is withdrawn. The time required to complete this process and have a final GIA could easily be a year or longer.

The process described above is specific to Associated Electric, but is likely representative. Obtaining approval to interconnect a project such as this to a regional transmission system is complex, expensive and lengthy. Getting the power out of a heat recovery generating project will be challenging and, for some projects, could adversely affect their viability.

Connecting a project such as this to a more local distribution system, while not necessarily providing regional access to customers, can expand the customer base and gaining approval is a much less onerous process. For example, we contacted the local distribution cooperative regarding interconnecting this project to their system. They were able to perform an assessment of adding the project to their system and determined that the additional generation does not cause any negative impact. Furthermore, it is possible that a project such as this would provide some minimal system support and benefits.

For this project, the result of being able to connect to the cooperative's distribution system would be access to additional municipal utilities that may have a need for generating capacity in the future. Whether there would be a similar benefit for other projects is location dependent.

As noted, access to customers for the electrical output of a heat recovery project can be a significant challenge. Further assessment of the process to interconnect to a regional transmission system would be helpful and would likely be necessary as part of the feasibility assessment for specific projects.

8.0 NON-ENERGY BENEFITS

The non-energy benefits of the proposed multi-hearth furnace and heat recovery power generation project are both socio-economic and environmental. The socio-economic benefits fall into two categories; new jobs created with the wages and benefits paid for those jobs and real and personal property taxes paid to the county on plant and equipment. The environmental benefits are related to reduced emissions and the renewable nature of the project.

While the feasibility study is primarily evaluating the addition of heat recovery electrical generation to a rotary hearth furnace, the socio-economic and environmental benefits would accrue to both the furnace and the power generation unit. Therefore the following discussion includes jobs created, taxes paid and environmental benefits from the combined project.

8.1 Jobs and Wages

For the rotary hearth furnace, the minimum staffing requirements to cover 24-hour per day 7 day per week (24/7) operation, including routine maintenance, would be one supervisor and 12 operators. The operators would have a base wage of $13.00 per hour plus an average $0.75 per hour attendance and safety bonuses. Typically the operators would average 10 hours per week of overtime at $20.25 per hour including the attendance and safety bonuses. The supervisor's annual salary would be $42,000 per year. The total annual payroll for the operation and maintenance of the furnace is estimated to be $512,000.

It is estimated that five additional people will be required to operate the power generating plant on a 24/7 basis. This assumes some shared operator duties between the furnace and generating plant and that most of the maintenance will be contracted. The same supervisor would be responsible for both systems and the operating staff would be paid the same wages and also average the same 10 hours of overtime per week. This would add approximately $196,000 per year to the plant's payroll.

For the combined furnace and generating plant, 17 high quality operation and maintenance jobs plus one supervisory position would be created. Those 18 jobs are estimated to generate an annual payroll of $708,000 in Howell County.

Additionally, the increased demand for wood to supply the furnace would result in the creation of additional jobs for in-woods chipping crews. Assuming a 50/50 blend of sawdust and wood chips, about 1350 tons of wood chips would be required each week. A good 6-man chipping crew can produce about 330 tons of chips per week. This additional demand for wood would result in four new crews or 24 new jobs. The average wage for a chipper crew is $12.00 per hour and they can be expected to average 8 to 10 hours of overtime per week paid at time and a half. These jobs would result in an annual payroll of about $801,000. Although we are unable to quantify it, an additional benefit would be the added profit earned by the logging companies for supplying wood chips to this project.

Typically the wood supply for the furnace would come from within a 50-mile radius of the plant. As such the chipping crew wages would be distributed among Howell, Oregon, Douglas, Texas and Shannon Counties.

To estimate the total wage impact of these new jobs in the Howell County area, we relied on a wage multiplier of 2.2 provided by the Missouri Department of Natural Resources. Therefore, with first year wages of $1,509,000 the estimated economic benefit to the area from the new plant and wood chipping jobs would be about $3,320,000.

8.2 Property Taxes

The total value of real property improvements resulting from the combined rotary hearth furnace and power generation plant is estimated to be $28,500,000. These improvements would be made in Howell County which currently has an Enhanced Enterprise Zone Abatement Program. This program provides a 50 percent property tax abatement for economic development. The enterprise zone expires in October 2032.

Based on 2010 levies, the Howell County assessor has estimated the real property tax liability for the proposed improvement to be $230,600 annually. After the expiration of the enterprise zone in October 2032 the estimated real property tax liability would double to $461,200, again based on 2010 levies.
Additionally, there would be increased personal property valued at about $2,300,000. At 2010 levies this would result in additional tax revenue for the county of about $22,000.

8.3 Environmental Benefits

The environmental benefits of the project stem primarily form the fact it is a renewable resource with zero net carbon emissions and virtually no SO_2 or CH_4 emissions. Additionally, approximately half of the raw wood supply for the project would be waste or slash from logging operations, removing over 66,000 tons of this material annually from area forests. Removing this material not only converts a waste material to useful products with the additional benefit of heat recovery for electrical generation, it also promotes forest regrowth and reduces potential fire hazards.

Emissions of CO_2, SO_2, and CH_4 from this plant will be virtually zero and would displace emissions from other regional generation. The EPA's eGRID 2010 Version 1.0 Year 2007 Annual Output Emission Rates data set (eGRID) was used to estimate emissions offset from this project. eGRID provides output based average emission rates for identified reliability sub regions. For this version of eGRID the project would be located in the SRMW (SERC Region Midwest) sub region. Using a net capacity of 8.6 megawatts for this project with an annual design capacity factor of 95 percent, the annual generation would be 71,569 megawatt-hours. Assuming 71,569 megawatt-hours of regional generation is replaced by generation from the proposed project, the following emission offsets would then be expected.

Table 8.1 Estimated Emission Offsets from Renewable Generation

Pollutant	eGRID Regional Emission Rate	Emission Offset
CO_2	1779 lbs/mw -hr	63,660 Tons
CH_4	20.6 lbs/mw -hr	737 Tons
SO_2	5.43 lbs/mw -hr	194 Tons

It is likely that NOx emission rates will also be lower since less fuel bound nitrogen is expected. However, we do not have NOx emissions data for a 7-hearth furnace so we could not quantify any benefits.

8.4 Summary of Non-Energy Benefits

The combined rotary hearth furnace and power generation project would result in an estimated capital investment of $28,500,000 in Howell County. The project will generate an estimated 18 additional jobs in Howell County plus another 24 logging related jobs in the six-county area. Additionally there will be temporary economic benefits during the construction phase and annual maintenance activities which we have not attempted to quantify.

The new real property improvements and additional personal property will result in estimated additional taxes for Howell County of $252,000 the first year.

The 42 new jobs that are expected to be created will result in a total estimated annual payroll of $1,509.000. With a reasonable wage multiplier in the local economy of 2.2, the economic benefit of these jobs would be about $3,320,000 in the six-county area, the bulk of which will accrue to Howell County.

The proposed project would also result in significant environmental benefits. Over 66,000 tons of logging wastes would be reclaimed for beneficial use, with the added benefit of improvements to logged areas. Since the project utilizes renewable wood as its raw input, reductions in regional emission of CO_2, CH_4, and SO_2 are expected.

Appendix A

LD& B Study

ENGINEERING FEASIBILITY AND PROJECT COST ASSESSMENT OF RENEWABLE ELECTRIC GENERATION AS A BYPRODUCT OF CHAR PRODUCTION FROM A MULTI HEARTH WOOD FURNACE

GARNETT WOOD PRODUCTS

Quality Products and Customer Satisfaction!

STATE OF MISSOURI
5/11/2011
FRED J. LUTZ
NUMBER
E-11636
REGISTERED PROFESSIONAL ENGINEER

LUTZ, DAILY & BRAIN, LLC
CONSULTING ENGINEERS

TABLE OF CONTENTS

1.0 INTRODUCTION

Garnett Wood Products (GWP) was founded in 1965 with the purpose of providing quality products and superior service. GWP is a full service wood products company.

Currently, GWP operates a 4-hearth rotary furnace to produce various char products from wood stock ranging from green wood chips to dry sawdust. Due to increasing demand for its char products, GWP is considering increasing its char production capacity by adding a 7-hearth furnace. As part of planning for this increased production, consideration is being given to the implementation of combined cycle technology. Combined cycle technology as applied in the electric production industry converts unutilized process heat into electricity.

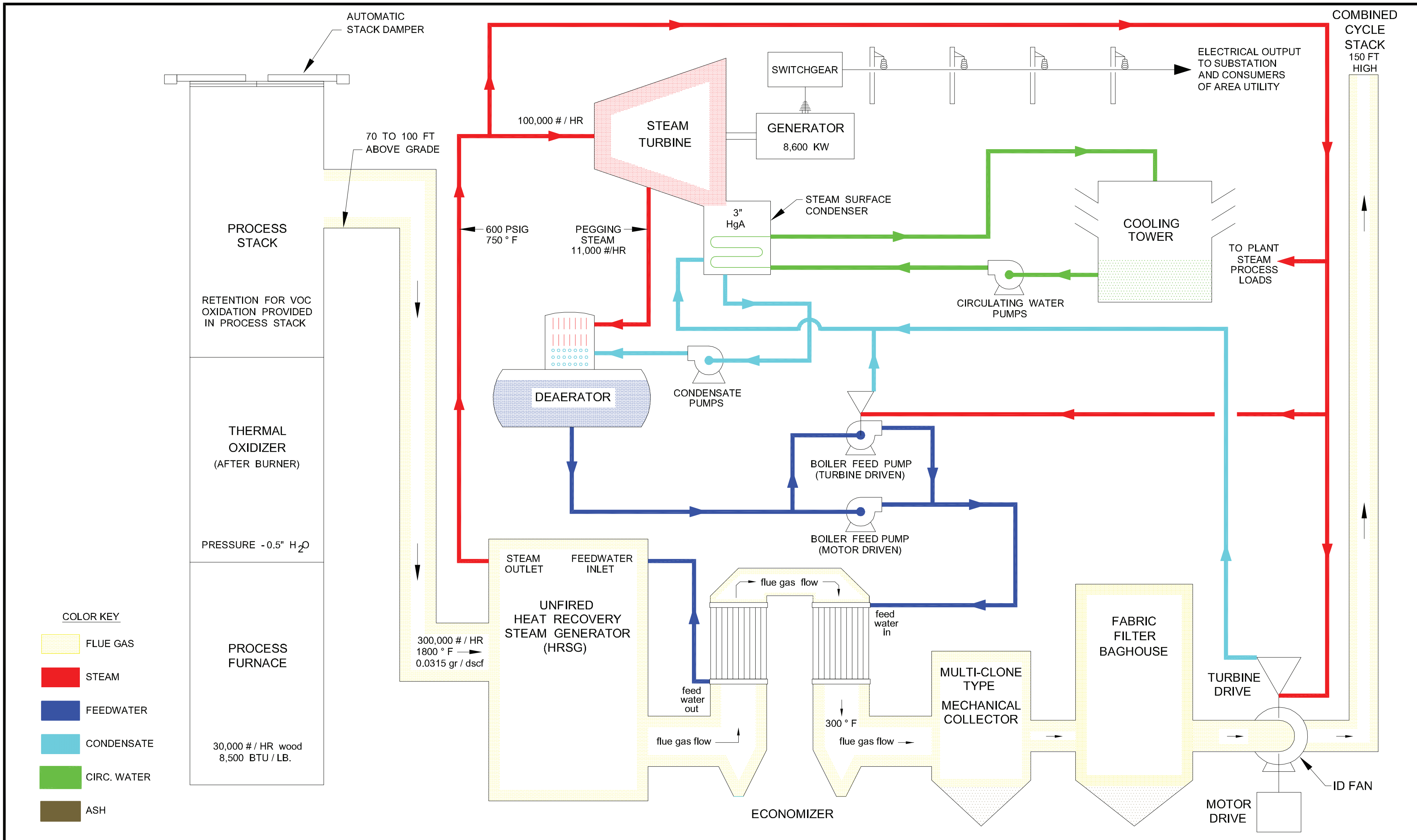
Char is produced by the utilization of wood products which are classified as "**biomass**". Combined cycle technology when incorporated into the char furnace production and manufacturing process can make available a "**renewable electric generation resource**". This renewable generation resource can be used to supplement the "**required renewable energy portfolio**" of area utilities as mandated by the "**Missouri Renewable Portfolio Standards"** and various other local ordinances.

This report is part of a feasibility study assessing the addition of a combined cycle heat recovery electrical generation system to a conventional multi-hearth rotary wood fired furnace. The study was funded in part by a grant from the Missouri Department of Natural Resources.

2.0 OVERVIEW OF PROCESS

An overview of the process is illustrated in Figure No. 1, Multi–Hearth Wood Char Process Flow Diagram. Wood for the process will be a combination of dry sawdust and green wood chips recovered from logging slash, normally a forest waste product. This material is supplied to the process furnace in which the volatiles are driven off and oxidized in a thermal oxidizer. The effluent flue gas from the process stack is ducted to an unfired heat recovery steam generator (HRSG) to recover waste heat from the flue gas. The flue gas from the HRSG then passes through an economizer to recover additional waste heat, and through a mechanical dust collector and fabric filter baghouse to remove ash (particulate matter). The flue gas, with constituents in compliance with environmental emission regulations, is drawn by an induced draft fan to the combined cycle stack for discharge to the atmosphere.

Steam is produced by the HRSG as a result of the heat being exchanged from the flue gas to the boiler feedwater. This high pressure superheated steam is used to drive a steam turbine generator which produces electricity. The resulting electrical output is available to supplement the loads of a participating area utility. Electric resources of this type are frequently referred to as **"distributed generation"** although this would be a relatively large distributed generation project. The proposed generator, when interconnected within the service area of the participating utility, will not only supply electricity to meet demand, but can also serve to support electric system voltage.



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MULTI-HEARTH
WOOD CHAR & COGENERATION PROCESS
FLOW DIAGRAM

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The net generating capacity of the proposed unit is about 8,600 KW. Redundant auxiliary equipment, of high reliability, has been selected to provide for continuity of service. Essential components of equipment such as boiler feed pumps and induced draft (ID) fan are equipped with alternate electric motor and steam turbine drives. These design features are expected to result in a capacity factor of 95%. To assure safe operations of the combined furnace and heat recovery system an automatic stack damper on the process stack is set to maintain negative pressure at that point.

3.0 PROCESS TECHNICAL FEASIBILITY

3.1 Safety and Operability

The combination of a multi hearth char production unit with combined cycle heat recovery technology is a logical step in the optimization of the overall cycle economics. This analysis has been conducted to adapt the cogeneration process to the 7-hearth furnace under consideration for addition by GWP.

It must be understood that there are operational and safety concerns that result from combining these technologies. The dissipation of the stored heat in the furnace must be provided for upon loss of power. The other critical consideration is the explosive nature of the volatile gases leaving the furnace. These characteristics of the char production facility must be recognized and accounted for in combining the technologies.

We carefully analyzed these operating characteristics and believe properly engineered systems can address the operational and safety concerns. The dissipation of stored heat during a loss of power can be addressed by using steam driven auxiliary equipment. Specifically, a steam driven boiler feed pump and an ID fan with a steam turbine drive would allow the process to extract residual heat from the furnace on a loss of electrical power as the steam side of the plant coasts to shut down. A parallel electric motor driven boiler feed pump and an electric motor drive on the ID fan would provide for plant startup. These features, while adding some cost to the project, will satisfactorily address the residual heat concern.

The second issue is of greater concern and was more difficult to resolve. Char is produced in a low oxygen negative pressure process. The resulting flue gas is rich in combustibles (volatiles from the wood) at a high temperature but very low in oxygen content. Any disturbance downstream in the heat recovery process that would pressurize the furnace could lead to introduction of large amounts of oxygen thereby creating the potential for explosive conditions.

We have investigated the experience in the industry to deal with the high temperatures and the volatile gases. Specifically we looked at high temperature dampers and cupola vents similar to those used in the steel industry. We have found that there are several HRSG's operating under similar conditions with high temperature dampers, and one HRSG manufacturer has recently signed a contract for a new unit significantly larger than the proposed HRSG, also utilizing high temperature dampers. It is therefore anticipated negative pressures can be safely maintained with a high temperature bypass damper on the furnace stack outlet.

3.2 Scalability

The heat recovery technology used in this type of project has a long successful history and can be applied to essentially any waste heat source. However, there are definitely economies of scale to be considered. Although the technology could be applied to furnaces smaller than the 7-hearth that is the basis for this study, the cost would likely not be competitive. Heat recovery systems could easily be scaled up to larger furnaces and heat sources, and the economics for a larger project would be expected to improve.

3.3 Unknowns

This was not a detailed engineering design study and it is understood that there are unknowns beyond the scope of this feasibility and cost study that could affect the feasibility of a project. Such unknowns would include how the power would be exported from the project and the availability and delivery times for key project components. Specific air permit requirements are not know and could adversely affect project costs and feasibility. Another unknown is the water supply for the project. Such supplies are project and location specific relative to availability and quality. The costs of obtaining and treating water for a project could affect its feasibility. Unknowns such as these would be addressed in a detailed engineering phase.

3.4 Conclusion

The process of combining a multi-hearth wood char furnace and a heat recovery electric generation plant is sound from an engineering standpoint and can provide a renewable electric generation resource by utilizing saw dust, wood chips and logging waste, normally a forest waste product.

4.0 ELECTRICAL SYSTEMS

The electrical system is shown in Figure No. 2, Single Line Electrical Diagram.

The electrical single line diagram shows the estimated electrical loads for the heat recovery portion of the facility. These loads would be served from the power produced or from the utility grid system if the facility is not producing electricity. The generator can be connected to different utility systems by the construction of a new electrical line to the interconnect point.

5.0 LOSS OF POWER TO THE FACILITY

The DC electrical system would provide an emergency source of power to the facility control system, device actuators, and protective devices. Although the feed of fuel to the process furnace would cease upon loss of power, heat would continue to be generated from the fuel charge already in the furnace. Water supply to the HRSG would be maintained by the turbine driven boiler feed pump as the system would safely coast down to rest. Flue gas would continue to be drawn through the system by the turbine driven ID fan. An automatic process stack damper at the outlet of the process stack would open as necessary to preclude the accumulation of positive pressure in the furnace. Upon restoration of the external AC power supply the system would be restarted utilizing the motor driven auxiliary pumps and ID fan.

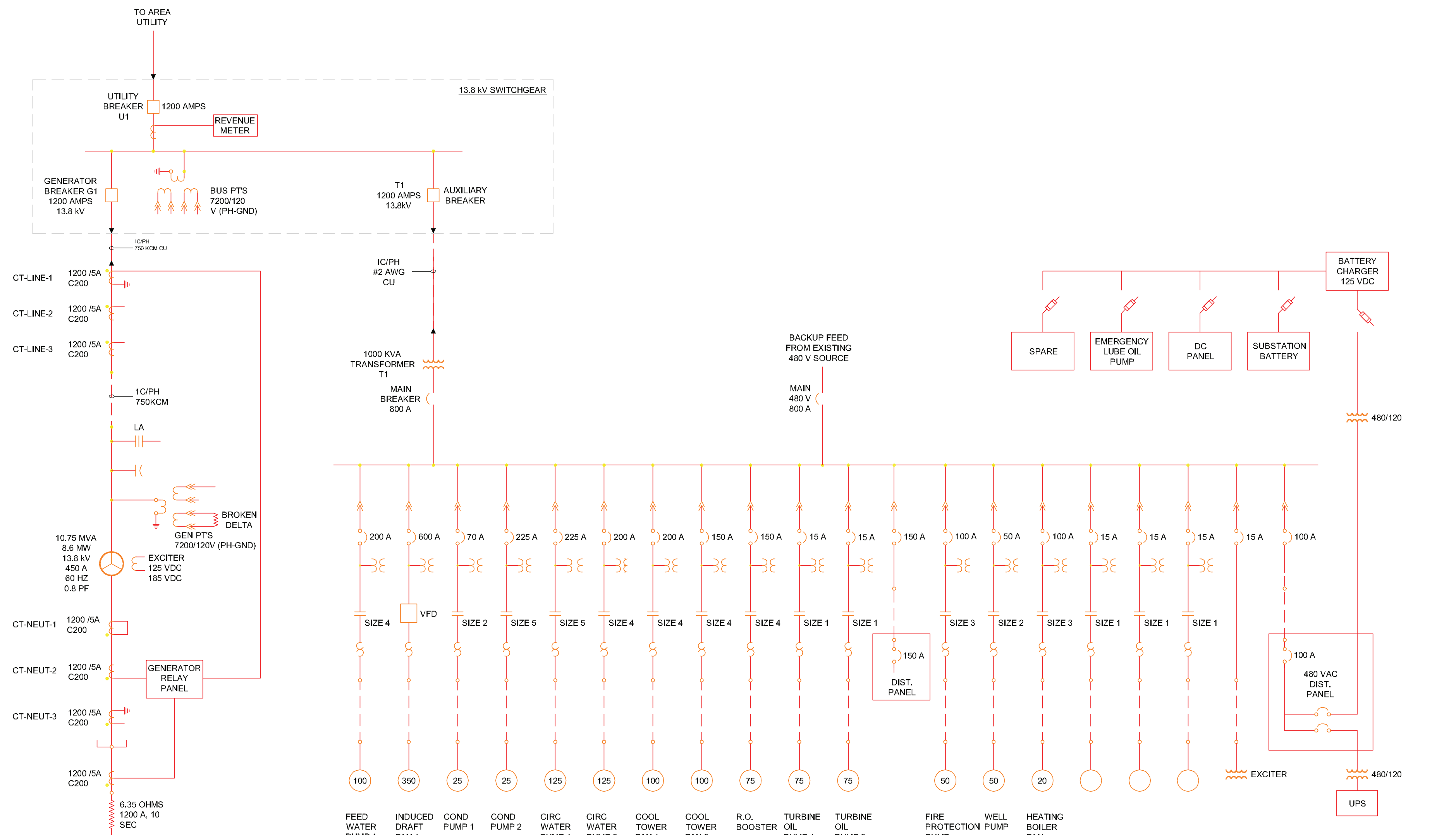
6.0 SITE PLAN

A tentative orientation of the Multi Hearth Char Production Unit has been outlined on Figure No. 3, Site Plan General Arrangement drawing of the existing Garnett Wood Products site which follows. The addition to an existing facility would take advantage of common facilities such as yard product storage, road and railroad access, office and maintenance facilities, water supply, waste disposal, fire protection, etc.

7.0 COGENERATION FACILITY CONSTRUCTION COST ESTIMATE

An estimate of the construction cost of the cogeneration portion of the facility is shown in Table 1, Cogeneration Facility Construction Cost Estimate. The cost estimate is based on the use of new equipment with the installation meeting the quality standards prevalent in the electric generation utility industry. Detailed quotations have been obtained from individual component vendors some of which are included in Appendix A, Summary of Detailed Equipment Vendor Quotations.

Used steam turbine generator and auxiliary equipment have been investigated while preparing the capital cost estimate. The components of equipment adaptable to the process are somewhat specialized. Suitable used equipment retired from utility or industrial installations occasionally becomes available in the market place at a favorable price. The complications introduced by the application of used equipment may easily outweigh any cost saving. The most adverse consequence of the application of used equipment would be the uncertainty as to the satisfactory performance and reliability of such equipment which would not be under warranty. This uncertainty would complicate the procurement of project funding.



	FEED WATER PUMP 1	INDUCED DRAFT FAN 1	COND PUMP 1	COND PUMP 2	CIRC WATER PUMP 1	CIRC WATER PUMP 2	COOL TOWER FAN 1	COOL TOWER FAN 2	R.O. BOOSTER	TURBINE OIL PUMP 1	TURBINE OIL PUMP 2		FIRE PROTECTION PUMP	WELL PUMP	HEATING BOILER FAN					
HP/KW/KVA	100	350	25	25	125	125	100	100	75	10	10		50	50	20					
BREAKER																				
STARTER SIZE																				

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DRAWN BY SEL APPROVED BY

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COGENERATION FACILITY
SINGLE LINE ELECTRICAL DIAGRAM

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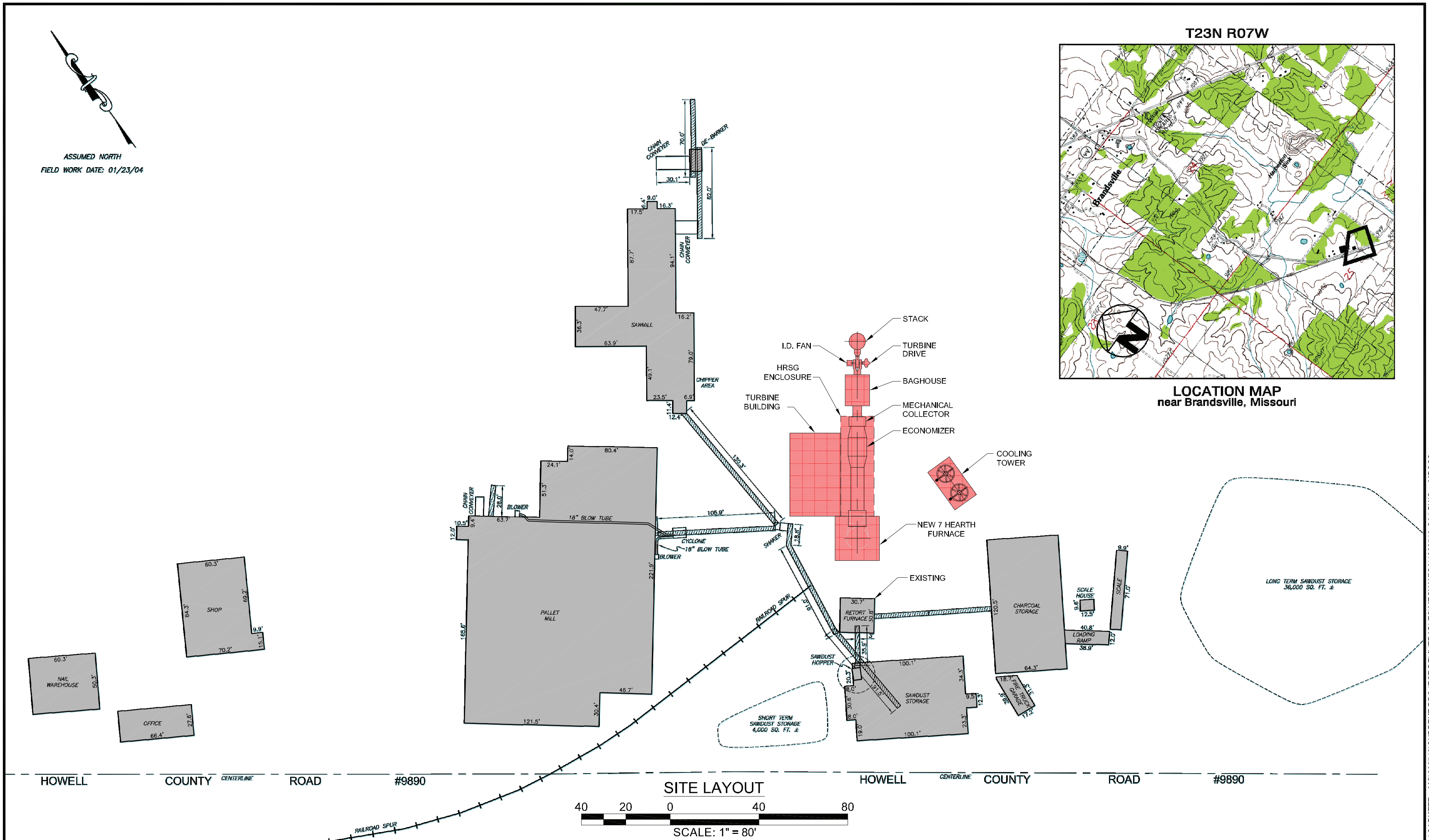

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SITE PLAN
GENERAL ARRANGEMENT

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FIGURE NUMBER 3
PAGE NUMBER 7

Lutz, Daily & Brain, LLC
Consulting Engineers

Table 1
GARNETT WOOD PRODUCTS
Brandsville, MO
COGENERATION FACILITY
CONSTRUCTION COST ESTIMATE
(Based on 2011 Cost Level)

				Item	Estimated Cost All New Equipment
I.	SITEWORK				$ 150,000
II.	BUILDING IMPROVEMENTS				
	A	Steam Turbine Generator Building 46 X 75 pre-insulated metal building			$ 320,000
	B.	HRSG Enclosure 30 x 90 x 45 H			$ 227,000
	C.	Foundations and Support Steel			
		1.	HRSG, Baghouse, Economizer, Multicone, and ID Fan with Motor and Turbine Drives, and Stack		$ 277,000
		2.	Steam Turbine Generator, Condenser, Boiler Feedwater Pumps, and Condensate Pumps		$ 167,000
		3.	Cooling Tower Basin and Circulating Water Pumps		$ 59,000
III.	MECHANICAL				
	A.	Equipment			
		1.	HRSG		$ 3,263,000
		2.	Stack Cap Damper		$ 200,000
		3.	Inlet Duct		$ 108,000
		4.	Outlet Duct		$ 54,000
		5.	Multicone Dust Collector		$ 150,000
		6.	Baghouse Fabric Filter System		$ 950,000
		7.	ID Fan with Motor Drive and Steam Turbine Drive		$ 221,900
		8.	Stack Steel 150 feet height		$ 150,000
		9	CEMS NOx, CO, O2, CO2, PM		$ 250,000
		10.	Steam Turbine Generator		$ 4,600,000
		11.	Condenser, Condensate Pumps & Circulating Water Pumps		$ 750,000
		12.	Cooling Tower two cell		$ 250,000
		13.	Boiler Feed Pumps - One Motor Drive and one Turbine Drive		$ 227,000
		14.	Deaerator including freight		$ 114,000
		15.	Heating Boiler		$ 350,000
		16.	Plant Service Well		$ 160,000
		17.	Boiler Water Makeup System Dual RO & Softener Trains		$ 150,000

Table 1 (Continued)
GARNETT WOOD PRODUCTS
Brandsville, MO
COGENERATION FACILITY
CONSTRUCTION COST ESTIMATE
(Based on 2011 Cost Level)

				Estimated Cost All New Equipment
			Item	
	B.	Equipment Erection		
		1.	HRSG & Economizer Including Assoc. Ductwork & Damper	$ 1,631,500
		2.	Multicone Dust Collector	$ 25,000
		3.	Steam Turbine Generator	$ 380,000
		4.	Condenser	$ 50,000
		5.	Cooling Tower	$ 30,000
		6.	Condensate Pumps	$ 15,000
		7.	Circulating Water Pumps	$ 25,000
		8.	Baghouse Fabric Filter System	$ 757,000
		9.	Start-up and Commissioning	$ 60,000
		10.	Training	Included with equipment
	C.	Piping Systems including Insulation and Lagging		$ 1,500,000
IV.	CONTROLS			$ 100,000
V.	ELECTRICAL			$ 757,000
VI.	TIE LINE TO UTILITY (TBD)			TBD
VII.	GRAND SUBTOTAL DIRECT CONSTRUCTION COST			$ 18,478,000
		(Nearest $1,000)		
VIII.	ENVIRONMENTAL PERMITTING, ENGINEERING & CONTINGENCIES			$ 4,620,000
		(Nearest $1,000)		
IX	**TOTAL ESTIMATED COST (TEC)**			**$ 23,098,000**
	(Nearest $1,000)			

8.0 COGENERATION FACILITY OPERATING & MAINTENANCE (O&M) COST ESTIMATE

An O&M cost for the cogeneration facility downstream from the process stack has been estimated based on other operating utility plants.

The operating labor cost component has been estimated using data that is based on a staff of five persons necessary to provide coverage for all shifts and the provision of some in-house staff maintenance activities using an average annual cost of $75,000 per staff member.

Based on an annual plant capacity factor of ninety-five percent (95%) and a net generating capacity of 8600 kW for export, the energy production would amount to 71.6 million kWhrs/yr.

Based on an estimated maintenance cost of 7mills/kWh of electric energy generated, supplies and miscellaneous items at $25.80/installed kW of generating capacity and operating labor at $375,000 per year, the estimated present day annual O & M costs would amount to $1,096,000.

APPENDIX A

SUMMARY OF DETAILED EQUIPMENT VENDOR QUOTATIONS

Heat Recovery Steam Generator (HRSG):
Victory Energy quoted two HRSGs

Victory A Type HRSG

1. Hoppers included
2. 600 PSIG, 750° F
3. Total Heat Input 150.318 mmBtu/hr
4. Total Heat Absorbed 132.1675 mmBtu/hr
5. Total Draft Loss 4.99 in. WC
6. Steam Flow at NRV Outlet 111,302 lb/hr

Victory O Type HRSG

1. Hoppers not included
2. 600 PSIG, 750° F
3. Total Heat Input 150.318 mmBtu/hr
4. Total Heat Absorbed 132.478 mmBtu/hr
5. Total Draft Loss 4.64 in. WC
6. Steam Flow at NRV Outlet 111,568 lb/hr

Steam Turbine Generator:
We received a quote from General Electric for $4.6 million. Delivery is expected to take 14 to 16 months.

Steam Turbine:

1. GE 5MC6 10,000 RPM suitable for 8800 kW
2. Structural steel base plate and anchor bolts
3. Cast steel construction with integral steam chest high pressure outer casing horizontally split
4. Gland condenser with exhauster system
5. Steam seal system with pneumatically operated regulating valve
6. Labyrinth style, interstage and gland packing made of stainless steel
7. Local instrumentation, wired up to junction boxes at baseplate
8. Local gauge board

Gearbox:

1. One single train horizontally offset , parallel shaft, speed reducing gear box
2. AGMA 421.06 standards, single reduction, horizontally offset design mounted on turbine baseplate and mechanically tested at rated speed, no load integral forged steel pinion and bull gear with through hardened nitride or carburized teeth
3. Pressure lubricated bearings
4. High speed flexible coupling with coupling guard
5. Low speed flanged coupling with coupling guard

Electric generator:

1. 8800 kW 3 phase 60 Hz 0.80 pf synchronous generator with side by side placed or integrated neutral and line cubicle
2. IEC or NEMA design totally enclosed water to air cooled (TEWAC)
3. Soleplates and anchor bolts for installation on foundation
4. Rotor and stator have resin impregnated Class F insulation with Class B Temperature rise
5. One 100% capacity air to water cooler
6. Brushless excitation system with rotating diode wheel
7. Automatic and manual voltage regulator
8. Line side cubicle or frame integrated
9. Neutral cubicle

Generator Control, protection measuring and synchronizing panel

1. One generator control panel
2. IP 31 protection degree suitable for local air conditioning control room
3. Generator control temperatures and vibrations managed by panel through use of a Modbus link

Boiler Feed Pumps

Goulds/ITT
1 Model 3600 3X4-8B with 7 stages with 150 HP 460V/ 3 phase / 60 Hz motor
1 Model 3600 3X4-8B with 7 stages with steam turbine drive

Pump Details

1. Capacity 187 GPM
2. Pump speed 3560 RPM
3. Specific Gravity 0.950
4. Head 1728 ft

Flowserve
The DMX pumps have a lead time of 52 weeks
1 Model DMX –B 3X8 with 6 stages with 200 HP 460 V / 3 phase motor
1 Model DMX –B 3X8 with 6 stages with steam turbine drive

Pump Details

1. Capacity 200 GPM
2. Pump speed 3560 RPM
3. Specific Gravity 0.955
4. Head 1723 ft

Flowserve Alternate
The 3WDXE pumps have a lead time of 30 weeks
1Model 3WDXE C with 6 stages with 200 HP 460 V / 3 phase motor
1Model 3WDXE C with 6 stages with steam turbine drive

Pump Details

1. Capacity 200 GPM
2. Pump speed 3565 RPM
3. Specific Gravity 0.955
4. Head 1723 ft

Deaerator
Kansas City Deaerator quoted a tray type deaerator with a lead time of 20 weeks.
Model BDS111-5511

Deaerator details:

1. Design pressure 50 psig
2. Design temperature 400 ° F
3. Heater diameter 4'-6"
4. Heater length 5'-0"
5. Tank diameter 5'-6"
6. Tank length 11'-0"
7. 4 spray valves
8. 24 trays 16 Gauge
9. 2 vent valves included
10. 1 relief valve included
11. 2 level switches included
12. 3 gauge glasses with valves included
13. 1 pressure gauge included
14. 1 inlet valve included
15. 1level transmitter included
16. 2 thermowells included
17. 2 thermometers included

ID Fan
Howden quoted an ID fan with a motor drive and a steam turbine drive; lead time is 26 to 30 weeks.

Fan details:

1. 100,000 ACFM
2. Air density 0.05 lb/cu ft
3. Inlet Static Press -17.0 in WG
4. Outlet Static Press -2 in WG
5. Power 303 BHP
6. Speed 900 RPM
7. Inlet Temperature 500° F
8. 85.25" diameter curved backward inclined blade

Fan Motor details:

1. Siemens
2. 350 HP
3. 900 RPM
4. 480 Volt 3 phase 60 Hz 1.0 SF
5. Lead Time 55 days

Steam Turbine Drive details:

1. Dresser Rand Model 503T with Lufkin Model NM1000C single reduction
2. Parallel shaft speed reducer to transmit 400 HP from steam turbine at 4050 RPM to ID fan input speed of 900 RPM
3. Lead time 32 to 34 weeks