VASSAR COLLEGE

COMBINED HEAT & POWER DATA MONITORING PLAN

for

NYSERDA PON 914
DEMONSTRATION OF A COMBINED HEAT & POWER SYSTEM

CHA PROJECT NO. 17102

January 2008

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1.0 PLAN OBJECTIVE

Vassar College (Vassar) is a liberal arts college located in Poughkeepsie, New York. The campus is an approximately 1,000 acre site with over 2.4 million square feet in buildings. Vassar has a student body of over 2,400, and 1,200 employees.

Vassar has recently completed the installation of a new 250 kW back pressure steam turbine that will operate in conjunction with an existing 750 kW back pressure steam turbine for optimizing steam turbine power generation. As part of an agreement between Vassar and NYSERDA, a data monitoring plan is required to collect and transfer key performance metrics on the systems operation to NYSERDA's data integration website.

This plan documents the requirements for developing and implementing a performance monitoring application for the system. The plan will outline the requirements for designing the application to import performance data from the monitoring equipment and process it for delivery to NYSERDA. Features include calculation of the annual overall efficiency based on higher heating value, as well as hourly electric, fuel, and recovered and beneficially used thermal energy load profiles.

The system will output the results in an electronic format conducive to a direct upload to NYSERDA's website by maintenance personnel.

2.0 INTRODUCTION

2.1 General Information

Vassar has just completed a project which included decommission and removal of two 1930 boilers that were replaced with two new 750 HP package steam boilers. Also one new 250 kW backpressure turbine generator rated for 12,000 lbs/hr was installed which will operate in parallel with an existing 750 kW single stage backpressure turbine generator.

The new 250 kW generator is intended to operate independently when steam demands are between 3,000 and 11,800 lbs per hour, and operate in parallel with the existing 750 kW unit when steam demand exceeds 32,900 lbs per hour.

The project scope and analysis were developed as part of a NYSERDA study conducted in 2004 and 2005. Several alternatives were investigated as part of the study which included:

Alternative	Description
Base Case	Install two 750 HP Steam Boilers
1	Install two 750 HP Steam Boilers and one 250 kW Backpressure Steam Turbine
2	Install one 750 HP Steam Boiler and one 1 MW Gas Turbine Generator with Heat Recovery Steam Generator
3	Install two 750 HP Steam Boilers and five 75 kW Engine Gensets in designated buildings around the campus

Vassar reviewed all of the alternatives provided and decided to move ahead with Alternative 1. The body of the NYSERDA report has been included in Appendix A. All of the appendices from the report have not been included but can be made available upon request.

2.2 System Overview

The existing 1930 decommissioned boilers were removed and replaced with two 750 HP packaged steam boilers bringing the total number of boilers to five. See Section 2.10 Boiler Name Plate Data for additional information regarding the five boilers currently used. The boilers operate up to 225 psig. An additional 250 kW steam backpressure turbine rated for 12,000 lbs/hr was installed with the existing 750 kW single-stage backpressure turbine generator and will operate in parallel with the existing 225/20 psig pressure reducing station (PRV). The two turbines are sized to meet a peak steam demand of 45,000 lbs/hr. A nominal isentropic efficiency of 53% results in a generator capacity of 1.0 MW under full flow. Electrically, the generators will be in parallel with the utility grid and displace approximately 13.3% of peak electric demand under rated steam flow.

A basic system schematic and floor plan is presented in Drawings SK-1 & M-3, located in Appendix C.

By establishing PRV set points 2 to 3 psig lower than the turbine exhaust pressure set point, uninterrupted steam flow is maintained with minimal external controls. When plant steam demand is less than full turbine flow, the turbine throttles will modulate to reduce steam flow with a corresponding reduction in output electric power. When steam demand rises above full flow or plant electric load is less than generator capacity, the turbine throttles modulate accordingly with excess steam demand causing campus pressure to drop below 20 psig. When plant pressure reaches PRV set point pressure, the reducing station supplements the necessary flow to maintain plant pressure at the PRV set point.

Steam is distributed to the campus underground at 20 psi. The steam plant operates from October to May at approximately 77% efficiency with a load of approximately 5,000 – 30,000 lbs/hr in the fall/spring and 30,000 – 52,000 lbs/hr in the winter. Approximately 135 million pounds of steam was produced annually from September 2002 to August 2004 over 5,600 operating hours.

2.3 Generator Size and Type

The new equipment is a skid-mounted package consisting of a turbine and 250 kW generator separated by a reducing gear, steam throttles, pressure and temperature sensors, lubrication oil system, and electronic (PLC) controls. The equipment is located in the main boiler plant adjacent to the existing 750 kW steam turbine. The control cabinet consisting of control system, protective relay devices, and generator breaker is located next to the equipment.

Historically the existing 750 kW backpressure steam turbine normally operates when ambient temperature is below 40°F. Approximately 1.1 million kWh was produced annually from this generation unit from September 2002 to August 2004.

2.4 Operation Analysis

An Operation Model was developed for the 2005 NYSERDA report previously discussed in Section 1.0. The model is based on the plant's historical hourly electric and steam demand data for the period of September 2002 to August 2004. The model predicted that plant electric generation will result in peak shaving 961 kW of the demand and displace approximately 13.3% or 2.8 million kWh of purchased power. Incremental fuel costs were estimated at $40,000 annually to convert the 225 psig steam to electricity and continue to provide the campus with the required 20 psig steam. Under the new arrangement, throttling will largely be accomplished by the backpressure turbines instead of the pressure reducing station. The thermal utilization is 100% and the fuel conversion efficiency (FCE) is 88.6%. See Appendix B Operating Models.

2.5 Electric, Gas, Oil and Steam Use

Total energy costs for the college are approximately $2.5 million annually, $0.6 million for natural gas, $0.7 million for No. 6 fuel oil, and $1.25 million for electricity.

Vassar currently purchases transmission and distribution of electric power from Central Hudson Gas & Electric Corporation (CHGE) under the SC-3 Service Classification. Total electric use at the facility for a two year period from September 2002 to August 2004 was approximately 40.4 million kWh (20.2 million kWh annually) with peak demands ranging from approximately 2700 - 4000 kW. Annual costs averaged $1.3 million at a blended rate of $0.0625/kWh. Primary service is provided to the site at 15 kV.

Vassar purchases commodity supply of natural gas from Amerada Hess with transportation from CHGE. Total natural gas consumption at the facility for a two year period from September 2002 to August 2004 was approximately 1.1 million Ccf (0.55 million Ccf annually) for the Main Campus & Boiler, Greenhouse, and Davison services. Annual natural gas costs averaged $370,000 at a blended rate of $0.68/Ccf.

Vassar also has the ability to burn No. 6 fuel oil as an alternate fuel with three 100,000 gallon tanks in place. For the same period, approximately 1.9 million gallons (0.9 million gallons annually) was purchased from Amerada Hess. Annual fuel oil costs averaged $860,000 at a blended rate of $0.92/gal.

Natural gas and fuel oil are both utilized for production of steam for building heating. A central heating plant houses five steam boilers, including two new Cleaver Brooks fire tube boilers that produce 24,996 lbs/hr of steam at 225 psi; one 1963 Springfield water tube boiler, which produces 50,000 lbs/hr of steam at 225 psi; and two supplemental boilers which are both 1989 Johnson fire tube boilers that produce 25,875 lbs/hr of steam each. At a minimum, one of the Cleaver Brooks boilers will operate as the lead with one of the other boilers lagging during the heating season. Three boilers are required during the highest steam demands.

2.6 Energy Profile

Temporal coincidence exists between electric demand and steam demand during the operation of the existing central heating plant from approximately October through April of each year. Total electric demand varies between 1.5 to 4 MW with peak loads in summer months due to air conditioning loads. Steam demand fluctuates primarily due to seasonal variation and fluctuates between 5,000 and 50,000 lbs/hr. Hot water is needed throughout the year for limited space humidity control and hot water use for laundry, showers, and food facilities. While the central heating plant is operational, this is provided by steam with hot water converters located in the affected buildings. When the central heating plant is shut down, this load is supplied by satellite hot water boilers.

2.7 Generator Power Usage

The generators are anticipated to be capable of handling 961 kW of the peak demand with an average annual generation anticipated to be 2.8 million kWh annually.

It should be noted at the time of the NYSERDA report, CHGE considered the 750 kW turbine exempt from the SC-14 tariff for standby service.

2.8 Tariff Impact

Currently approximately 87% of the campus' annual electric power, or 18.5 million kWh, is purchased through CHGE. On-site generation is under 1 MW but exceeds 15% of maximum demand.

Vassar currently purchases electricity under service classification SC-3 but after the turbines are online, the college will switch to SC-14.

2.9 Generator Name Plate Data

Following is a listing of name plate data for the back pressure turbine generators:

750 kW Generator	
Manufacturer	Coppus Turbine
Type	Back Pressure
Year Manufactured	1984
Maximum Steam Rating	32,000 lbs steam / hour at 20 psig
Pressure	225 psig in/ 20 psig our
Input	2.56 MMBTUH steam
Output	750 kW

250 kW Generator	
Manufacturer	Turbosteam
Type	Back Pressure
Year Manufactured	2007
Maximum Steam Rating	12,000 lbs steam / hour at 20 psig
Pressure	225 psig in/ 20 psig out
Input	0.853 MMBTUH steam
Output	250 kW

2.10 Boiler Name Plate Data

Following is a listing of name plate data for boilers #1 through #5:

<u>Boiler #1</u>

Manufacturer	Cleaver Brooks
Type	Fire Tube
Year Manufactured	2006
Horse Power	750 HP
Fuel	#6 Oil and Natural Gas
Design Pressure	250 lbs Steam
Steam Capacity	24,996 lbs steam / hour at 212°F

<u>Boiler #2</u>

Manufacturer	Cleaver Brooks
Type	Fire Tube
Year Manufactured	2006
Horse Power	750 HP
Fuel	#6 Oil and Natural Gas
Design Pressure	250 lbs Steam
Steam Capacity	24,996 lbs steam / hour at 212°F

<u>Boiler #3</u>

Manufacturer	Johnston
Type	Fire Tube
Year Manufactured	1989
Horse Power	HP 800
Fuel	#6 Oil and Natural Gas
Design Pressure	225 lbs Steam
Steam Capacity	25,875 lbs steam / hour

<u>Boiler #4</u>

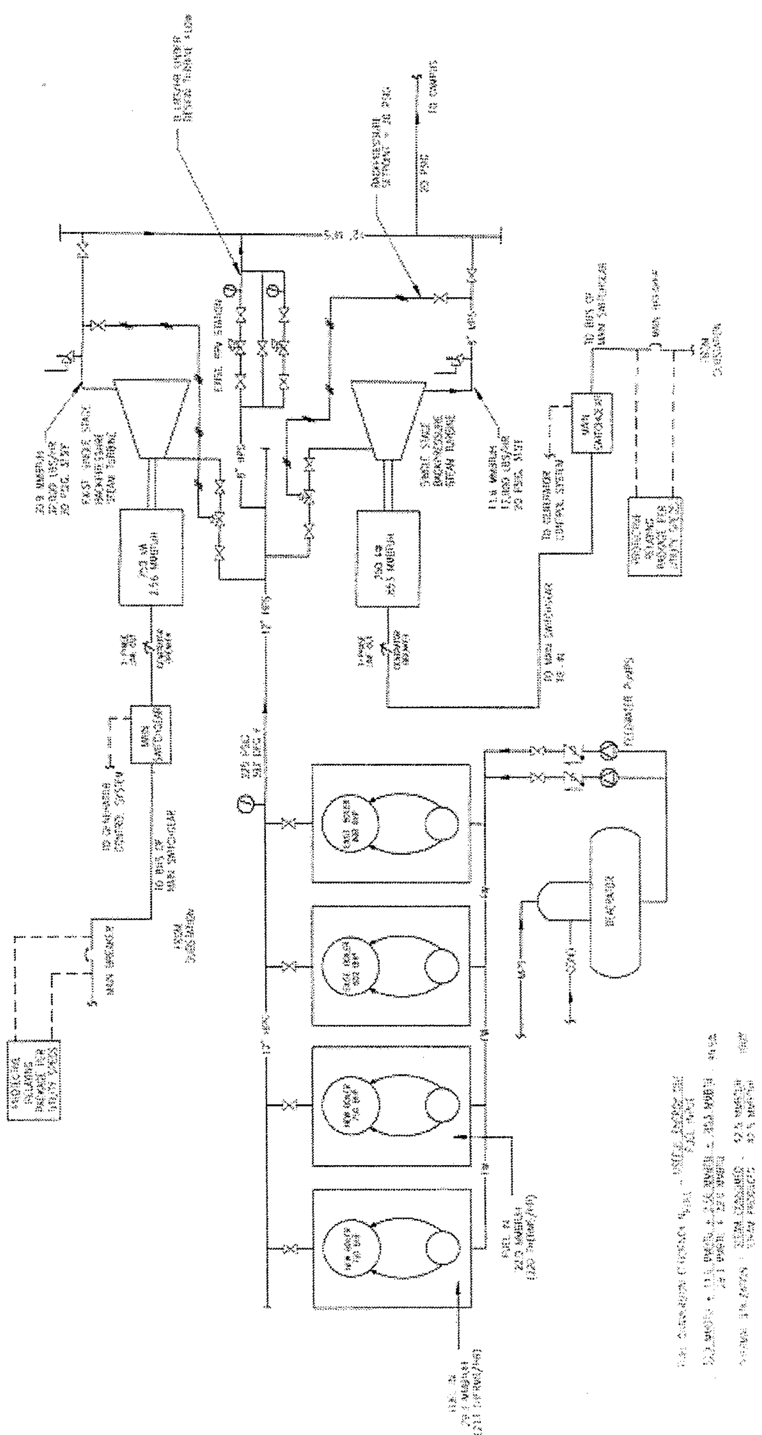
Manufacturer	Johnston
Type	Fire Tube
Year Manufactured	1989
Horse Power	HP 800
Fuel	#6 Oil and Natural Gas
Design Pressure	225 lbs Steam
Steam Capacity	25,875 lbs steam / hour

<u>Boiler #5</u>

Manufacturer	Springfield
Type	Water Tube
Year Manufactured	1963
Horse Power	HP
Fuel	#6 Oil and Natural Gas
Design Pressure	225 lbs Steam
Steam Capacity	50,000 lbs steam / hour

2.11 System Schematic Diagram

Following is a schematic diagram of the system piping showing the interface of the boilers with the steam generators. Note that the oldest boiler manufactured in 1963 is not shown. See Appendix C.



3.0 DATA MONITORING PLAN

One of the critical requirements of the monitoring system is the ability to communicate the readings and measurements collected at various monitoring points to NYSERDA on a consistent basis. The transmission of this data will enable NYSERDA to analyze the performance of the system and compare the results to expected values. The following report section outlines the process by which data from the monitoring points will be collected and transferred to NYSERDA.

3.1 Required Data Monitoring Points

Following is a listing of proposed data monitoring points:

No.	Tag	Description	Units	Type of Sensor	Purpose
1	WT1	Electrical Output from 250kW turbine/generator	kWh/kW	Read from turbine/generator control panel	Measure turbine/generator output - 250Kw
2	WT2	Electrical Output from 750kW turbine/generator	kWh/kW	Read from turbine/generator control panel	Measure turbine/generator output - 750kW
3	FS1	225# Steam Flow through 250kW turbine	lbs/hr	Orifice flow meter, read from Andover System	Calculate turbine/generator efficiency - 250kW
4	FS2	225# Steam Flow through 750kW turbine	lbs/hr	Orifice flow meter, read from Andover System	Calculate turbine/generator efficiency - 750kW
5	THPS	225# Steam Header Temperature	deg F	Temperature transducer	Determine entering steam enthalpy, **Optional**
6	PHPS	225# Steam Header Pressure	psig	Pressure transducer	Determine entering steam enthalpy
7	TLPS1	20# Steam Temperature after 250kW turbine	deg F	Temperature transducer	Determine leaving steam enthalpy - 250kW turbine, **Optional**
8	PLPS1	20# Steam Pressure after 250kW turbine	psig	Pressure transducer, read from turb/gen cntrl panel	Determine leaving steam enthalpy - 250kW turbine
9	TLPS2	20# Steam Temperature after 750kW turbine	deg F	Temperature transducer	Determine leaving steam enthalpy - 750kW turbine, **Optional**
10	PLPS2	20# Steam Pressure after 750kW turbine	psig	Pressure transducer, read from turb/gen cntrl panel	Determine leaving steam enthalpy - 750kW turbine
11	FSB1	Boiler #1 Steam Output	lbs/hr	Orifice flow meter, read from Andover	Determine total steam produced, boiler efficiency
12	FSB2	Boiler #2 Steam Output	lbs/hr	Orifice flow meter, read from Andover System	Determine total steam produced, boiler efficiency

No.	Tag	Description	Units	Type of Sensor	Purpose
13	FSB3	Boiler #3 Steam Output	lbs/hr	Orifice flow meter, read from Andover System	Determine total steam produced, boiler efficiency
14	FSB4	Boiler #4 Steam Output	lbs/hr	Orifice flow meter, read from Andover System	Determine total steam produced, boiler efficiency
15	FSB5	Boiler #5 Steam Output	lbs/hr	Orifice flow meter, read from Andover System	Determine total steam produced, boiler efficiency
16	NGB1	Boiler #1 Fuel Input - Natural Gas	cf/hr	Yokogawa gas meter, read from Andover System	Determine boiler input
17	NGB2	Boiler #2 Fuel Input - Natural Gas	cf/hr	Yokogawa gas meter, read from Andover System	Determine boiler input
18	NGB3	Boiler #3 Fuel Input - Natural Gas	cf/hr	Connect and read from Andover System	Determine boiler input
19	NGB4	Boiler #4 Fuel Input - Natural Gas	cf/hr	Connect and read from Andover System	Determine boiler input
20	NGB5	Boiler #5 Fuel Input - Natural Gas	cf/hr	Connect and read from Andover System	Determine boiler input
21	FOB1	Boiler #1 Fuel Input - #6 Fuel Oil	gal/hr	Amco oil meter, read from Andover System	Determine boiler input
22	FOB2	Boiler #2 Fuel Input - #6 Fuel Oil	gal/hr	Amco oil meter, read from Andover System	Determine boiler input
23	FOB3	Boiler #3 Fuel Input - #6 Fuel Oil	gal/hr	Connect and read from Andover System	Determine boiler input
24	FOB4	Boiler #4 Fuel Input - #6 Fuel Oil	gal/hr	Connect and read from Andover System	Determine boiler input
25	FOB5	Boiler #5 Fuel Input - #6 Fuel Oil	gal/hr	Connect and read from Andover System	Determine boiler input
26	OAT	Outside Air Temperature *	deg F	Temperature transducer, read from Andover System	Correlate to outside air temperature, **Optional**

* Outside Air Temperature readings is not required, as sufficient data on these conditions is available to NYSERDA through the National Weather Service and other existing resources, however Vassar may include this data if readily available.

Data Monitoring Points Sketch SK-01 is provided at the end of this section.

3.2 Data Collection and Formatting

In accordance with NYSERDA's reporting standards, readings from all required monitoring points should be recorded at 15 minute intervals. These readings should then be compiled into a log file and transmitted to NYSERDA on a daily basis. The daily log filed must be submitted electronically in a standardized database-friendly format.

Vassar already has instrumentation and software in place for capturing automated readings for a number of the required data points. These include monitoring points tied into the Colleges' Andover system:

- FS1 225# Steam Flow through 250kW turbine
- FS2 225# Steam Flow through 750kW turbine
- FSB3 Boiler #3 Steam Output
- FSB4 Boiler #4 Steam Output
- FSB5 Boiler #5 Steam Output
- NGB3 Boiler #3 Fuel Input - Natural Gas
- NGB4 Boiler #4 Fuel Input - Natural Gas
- NGB5 Boiler #5 Fuel Input - Natural Gas
- FOB3 Boiler #3 Fuel Input - #6 Fuel Oil
- FOB4 Boiler #4 Fuel Input - #6 Fuel Oil
- FOB5 Boiler #5 Fuel Input - #6 Fuel Oil

Readings from these devices are captured continuously and will be reported in intervals of 15 minutes using Vassar's Andover Continuum software. This application is currently accessible from networked PCs at both the Boiler Plant and the Buildings and Grounds Services Center.

The Andover Continuum software also features an option for exporting data directly to a comma separated text file (.CSV) format. It is recommended that Vassar College utilize this format for collecting and transferring all of its data to NYSERDA. The .CSV format is a simple, widely accepted text file format that can be imported directly into most database applications, as well read by Excel, Word or Notepad. Using this format will also allow data from the Andover system to be transmitted directly to NYSERDA without the need for conversion or reformatting.

Additional data points are currently being monitored through a Human Machine Interface (HMI) system linked to the Turbine Panel. These monitoring points include:

- WT1 Electrical Output from 250kW turbine/generator
- WT2 Electrical Output from 750kW turbine/generator
- PLPS1 20# Steam Pressure after 250kW turbine
- PLPS2 20# Steam Pressure after 750kW turbine

Data collected through the HMI is accessible from networked campus PCs using a Smart Service application which provides remote access capabilities. The HMI application also features the capacity to export data to a CSV format. Currently logged data is being saved to a memory card connected locally to the HMI. However, this process may be modified to allow data to be saved directly to a PC or network storage location. The CSV log files may then be appended to the daily log file generated by the Andover system, or sent as a second file to NYSERDA.

There are a number of additional data points that are not linked to Andover Continuum or the HMI. These points have visual gauges or meters installed, but that have not been linked to an electronic data gathering system. These include:

- FSB1 Boiler #1 Steam Output
- FSB2 Boiler #2 Steam Output
- NGB1 Boiler #1 Fuel Input - Natural Gas
- NGB2 Boiler #2 Fuel Input - Natural Gas
- FOB1 Boiler #1 Fuel Input - #6 Fuel Oil
- FOB2 Boiler #2 Fuel Input - #6 Fuel Oil

Gathering readings for these points manually is not practical or feasible due to the requirement for logging readings at 15 minute intervals. Therefore it is suggested that the existing instrumentation should be connected to the Andover control panel and logged using the Continuum software. This effort will require the installation of cabling to connect these devices, and possibly programming assistance from Andover to allow Continuum to begin monitoring additional readings.

For the first year of monitoring, saturated steam tables will be used to determine the steam enthalpy. During the next summer shutdown, temperature sensors will be added to the steam piping to allow enthalpy to be determined directly.

3.3 Data Transmission and Communications

A separate .CSV log file of monitoring data shall be created for each calendar day. All log files should be named consistently and include information referencing the time periods associated with the data stored within the file. (i.e. Vassar_CHP_010408). The log files may then be transmitted to NYSERDA on a nightly basis. The process of packaging and transmitting the data offers several opportunities for automation to help minimize the effort that will be required of system operators. As noted earlier, the Andover Continuum software offers the capacity for a direct export to CSV files. It may also be possible to develop a mechanism for scheduling these exports in an automated fashion. In addition, a batch file or script may be developed to automate the nightly upload of log files to NYSERDA's FTP site.

3.4 Additional Monthly Reporting Requirements

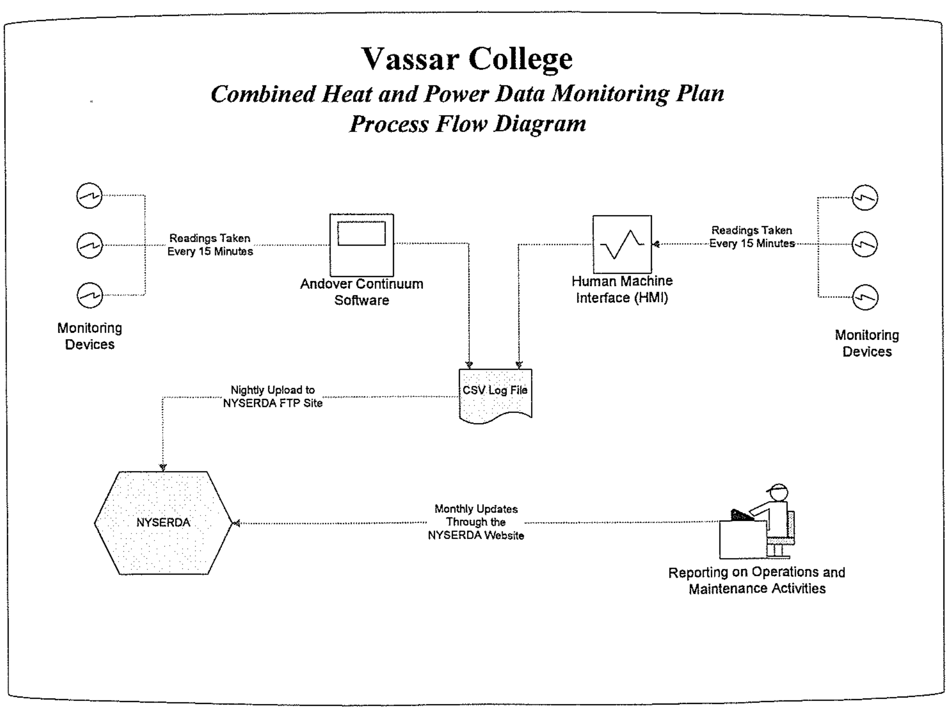
Along with the detailed data to be collected at each monitoring point, supplemental information on operations and maintenance activities will also need to be reported to NYSERDA on a monthly basis. This will include information on any scheduled or unscheduled equipment outages, including the time and date of the outage, cause and resolution. Operation reliability data will be reported and made available on NYSERDA's web base (http://chp.nyserda.org). NYSERDA will provide a user account and password for logging in to this form as well as step-by-step instructions on how to enter the time, date, and reason of each outage event.

3.5 Hardware, Software and Networking Requirements

Vassar currently has networked computers available at both the Boiler Plant and the Buildings and Grounds Services Center with the capacity for transferring monitoring data to NYSERDA. These PCs have access to the Andover Continuum application, high speed Internet connectivity and email capabilities. Recorded data and historic copies of log files should be stored on a network drive with regularly scheduled backups to avoid potential data loss.

3.6 Data Monitoring Data Flow Diagram

Following is a flow chart showing the process by which monitoring data will be collected and transferred to NYSERDA.



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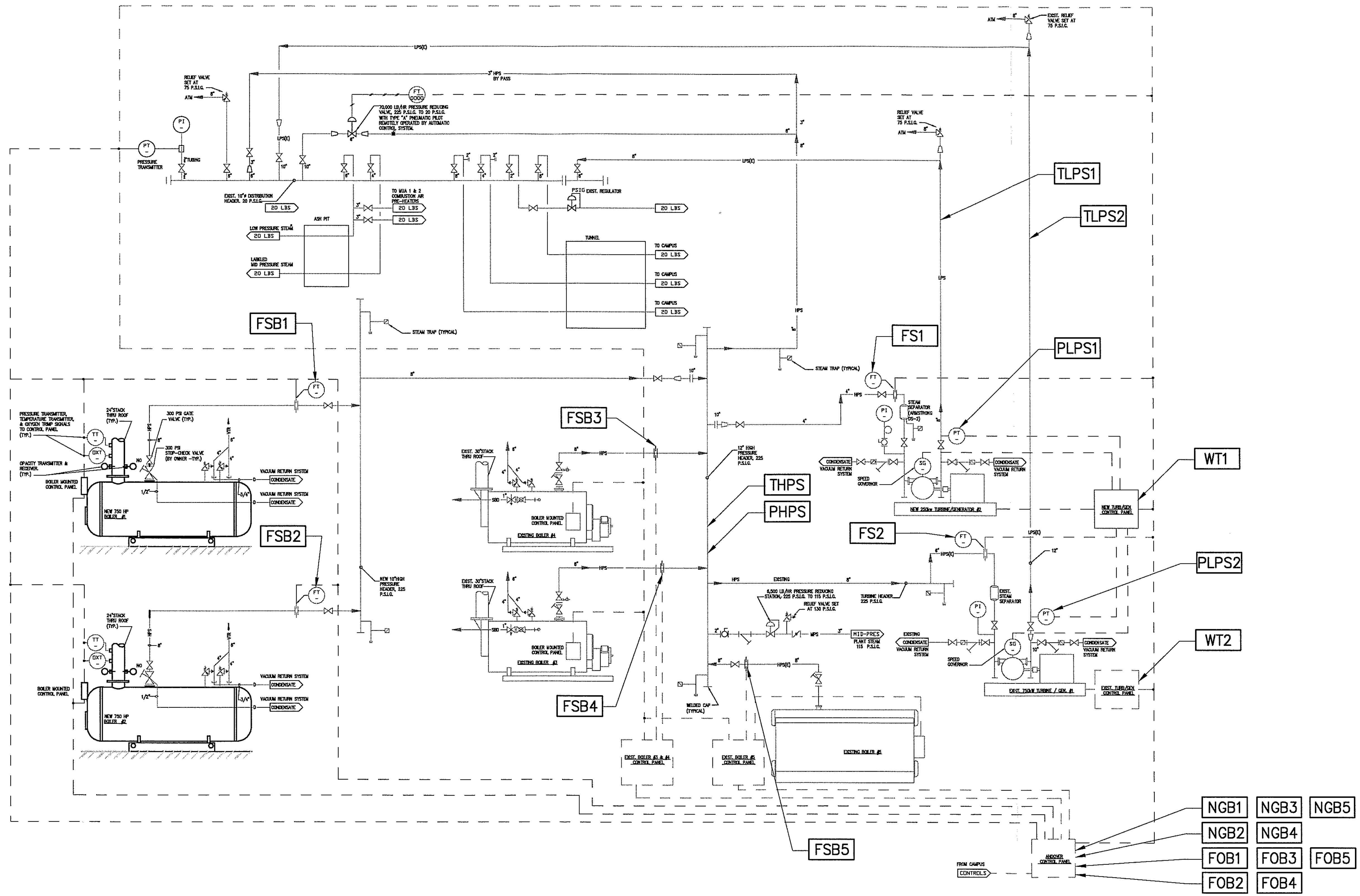

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NYSERDA – VASSAR COLLEGE
DATA MONITORING POINTS

PROJECT NO. 17102

11/12/07

SK–01

APPENDIX A

2005 NYSERDA Report (Text Only)

VASSAR COLLEGE

COMBINED HEAT & POWER FEASIBILITY STUDY

for

NYSERDA PON 795-02
COMBINED HEAT & POWER TECHNICAL ASSISTANCE

CHA PROJECT NO. 13632

May 2005

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1.0 EXECUTIVE SUMMARY

1.1. Study Overview

Vassar College (Vassar), located in Poughkeepsie, New York, is one of the nation's leading liberal arts colleges. The college first opened its doors in 1865 and was a pioneer in women's and liberal arts education in the United States. In 1969, Vassar became coeducational and today remains at the forefront of liberal arts' institutions. The campus is an approximately 1,000 acre site with over 2.4 million square feet in buildings. Vassar has a student body of over 2,400, and 1,200 employees.

Total energy costs for the college are approximately $2.5 million annually, $0.6 million for natural gas, $0.7 million for No. 6 fuel oil, and $1.25 million for electricity.

Vassar purchases transmission and distribution of electric power from Central Hudson Gas & Electric Corporation (CHGE) under SC-3 Service Classification. Total electric use at the facility for a two year period from September 2002 to August 2004 was approximately 40.4 million kWh (20.2 million kWh annually) with peak demands ranging from approximately 2700 - 4000 kW. Annual costs averaged $1.3 million at a blended rate of $0.0625/kWh. Primary service is provided to the site at 15 kV.

Vassar purchases commodity supply of natural gas from Amerada Hess with transportation from CHGE. Total natural gas consumption at the facility from September 2002 to August 2004 was approximately 1.1 million Ccf (0.55 million Ccf annually) for the main campus and boiler, greenhouse, and Davison services. Annual natural gas costs averaged $370,000 at a blended rate of $0.68/Ccf. Vassar also has the ability to burn No. 6 fuel oil as an alternate fuel with three 100,000 gallon tanks in place. For the same period, approximately 1.9 million gallons (0.9 million gallons annually) were purchased from Amerada Hess were consumed. Annual fuel oil costs averaged $860,000 at a blended rate of $0.92/gal.

Natural gas and fuel oil is utilized for production of steam for building heating. A central heating plant houses five steam boilers, three of which are operable. The two decommissioned boilers were installed in 1930 and are non-operable. A 1963 Springfield water tube boiler, which produces 40,000 lbs/hr of steam at 225 psi, is the primary unit during the heating season. The two supplemental boilers are both 1989 Johnson fire tube boilers that produce 27,600 lbs/hr of steam each. At a minimum, one of the supplemental boilers operates in conjunction with the primary unit during the majority of the heating season. All three boilers are required during the highest steam demands.

Steam is distributed to the campus underground at 20 psi. The steam plant operates from October to May at approximately 77% efficiency with a load of approximately 5,000 – 30,000 lbs/hr in the fall/spring and 30,000 – 52,000 lbs/hr in the winter. Approximately 135 million pounds of steam was produced annually from September 2002 to August 2004 over 5,600 operating hours.

Natural gas is also utilized for packaged hot water boilers and heaters (approx. 13,500 MBH of capacity) located in various buildings throughout the campus. During the heating season, the central heating plant is utilized to produce hot water in these buildings, with the packaged units operating primarily during the non-heating season.

Also located in the central heating plant is a 750 kW backpressure steam turbine that normally operates when ambient temperature is below 40°F. Approximately 1.1 million kWh was produced annually from this generation unit from September 2002 to August 2004.

Two 1,000 ton chillers were installed in 2001 in a new facility near the Building & Grounds building to meet air conditioning requirements on campus. One chiller is a Trane electric centrifugal unit, the other a Trane gas-fired absorption unit. The gas-fired absorption unit was installed with the help of the **NYSERDA New York Energy $mart Program**.

The primary steam boiler (40+ years' old) in the central heating plant is reaching the end of its useful life. If this boiler fails during the heating season, the two remaining boilers would not be able to meet demand during periods of high steam usage. Vassar is considering a plan to install two new 750 HP steam fire tube boilers to replace the Springfield boiler. As an alternative, Vassar was interested in Clough, Harbour & Associates LLP (CHA) investigating options to install a Combined Heat and Power (CHP) plant as an efficient method of producing both electric and steam needs, and perform a detailed technical and economical feasibility analysis for installing a CHP plant at the Poughkeepsie campus.

The following three alternatives were considered as part of the feasibility analysis and compared to replacing the primary boiler with two new 750 HP boilers:

- Install two new 750 HP steam fire tube boilers and optimize use of backpressure steam turbines to produce electricity; this may include adding another turbine that would operate during lower steam demand and in parallel with the existing turbine during higher steam demand
- Evaluate a gas turbine generator sized to most cost effectively match the continuous thermal demands of the campus
- Evaluate small satellite gas-fired induction generators that will be sized to most cost effectively match the thermal demands of various buildings or groups of buildings on campus

1.2. Energy Profile (reference Appendix A)

Temporal coincidence exists between electric demand and steam demand during the operation of the existing central heating plant from approximately October through April of each year. Total electric demand varies between 1.5 to 4 MW with peak loads in summer months due to air conditioning loads. It should be noted that this load could increase if the 1000 ton electric chiller is operated in lieu of the gas absorption chiller which was operating during the period evaluated. Steam demand fluctuates primarily due to seasonal variation and fluctuates between 5,000 and 50,000 lbs/hr. Hot water is needed throughout the year for limited space humidity control and hot water use for laundry, showers, and food facilities. While the central heating plant is operational, this is provided by steam with hot water converters located in the affected buildings. When the central heating plant is shut down, this load is supplied by satellite hot water boilers.

1.3. Base Energy Costs

Vassar purchases transmission and distribution of electric power from Central Hudson Gas & Electric Corporation (CHGE) under the SC-3 Service Classification. During the period from September 2002 to August 2004, this included a customer refund for a one-time distribution for the sale of a fossil fuel plant. For the base case analysis and to compare the site's on-going costs to the proposed alternatives, the refund was excluded, and the exclusion results in an average annual cost of $1,372,000 for 20.2 million kWh at a peak demand of 3,970 kW for a blended rate of $0.068/kwh. This includes the average annual generation of 1.1 million kWh from the existing 750 kW backpressure steam turbine which would result in an overall electric consumption of 21.3 million kWh. It should be noted the CHGE considers the existing turbine exempt from the SC-14 tariff for standby service.

Natural gas and No. 6 fuel oil pricing for the base case is calculated from September 2002 to August 2004 for the services to the main campus and boiler, greenhouse, and Davison meters. For the base case analysis, an average natural gas/fuel consumption of 1,973,000 Ccf was used for an annual cost of $1,236,000 or $0.626/Ccf. This was based on 44% of the fuel needed being satisfied by natural gas, and the remaining 56% by No. 6 fuel oil. The amount of No. 6 fuel oil is driven by the permitted level of the facility. For all alternatives evaluated the fuel oil used remained constant with natural gas usage adjusted accordingly. Details of the base case annual electric and gas costs are located in Appendix B.

1.4. CHP Analysis

Three potentially viable system alternatives for providing different levels of combined heat and power for the campus were examined in detail and are summarized below:

Alternative	Description
Base Case	Install two 750 HP Steam Boilers
1	Install two 750 HP Steam Boilers and one 250 kW Backpressure Steam Turbine
2	Install one 750 HP Steam Boiler and one 1 MW Gas Turbine Generator with Heat Recovery Steam Generator
3	Install two 750 HP Steam Boilers and five 75 kW Engine Gensets in designated buildings around the campus

These alternatives were evaluated compared to the existing operation, and the central heating plant operating year round. Vassar is considering operating year round due to an increasing demand for steam as more building around campus are upgraded to include humidity control. Each alternative was evaluated based on actual hourly electric demand for a two year period from September 2002 through August 2004 and actual average daily steam demand for the same period.

For Alternatives 1 and 3, two new 750 HP boilers would be installed in the existing central heating plant in the space presently occupied by the two 1930 decommissioned boilers. The existing single-stage 750 kW backpressure turbine generator will continue to be used in parallel with the 225/20 psig pressure reducing station (PRV), but its operation will be optimized by operating when steam demand is greater than 11,800 lbs per hour.

In Alternative 1, a new 250 kW backpressure turbine generator will be added in parallel with existing equipment. It will operate independently when steam demands are between 3,000 and 11,800 lbs per hour, and operate in parallel with the existing unit when steam demand exceeds 32,900 lbs per hour.

In Alternative 3, five 75 kW gas-fired induction generators would be installed at the Athletic & Fitness Center, Student's Building, and Center for Drama & Film and run in parallel with the electric service. Heat rejected form these units would be used to satisfy thermal demand for these buildings year round.

For Alternative 2, a 1 MW natural gas or fuel fired combustion turbine generator with a heat recovery steam generator package and supplemental gas-fired duct burner is evaluated as the primary mover. In Alternative 2, the turbine generator and one new 750 HP boiler would be installed in the space presently occupied by the two 1930 decommissioned boilers. The new turbine would run in parallel with the electric service. The existing backpressure turbine generator would not be utilized in this alternative. For Alternatives 2, whenever the gas turbine is on-line, steam will be supplied by the HRSG using exhaust gases as primary heat source supplemented by the duct burners as necessary, with supplemental steam being supplied by the new 750 HP boiler when necessary. When the combustion turbine is shut down, plant steam demand will be met by new 750 HP boiler.

Annual operating performance of these alternatives as compared to the base case is as follows:

CHP OPERATING ANALYSIS (without Summer Operation of Central Heating Plant)							
	CHP		Electricity (000 kwh)		Steam (000 pounds)		Natural Gas/Fuel
	Thermal Util.	FCE*	CHP Produced	Procured	CHP Produced	Boiler Produced	Procured (000 therms)
Base Case	100%	86.8%	1,124	20,171	0	134,988	1,973
Alternative 1	100%	88.6%	2,826	18,470	0	137,856	2,040
Alternative 2	100%	67.4%	5,551	15,745	111,737	23,252	2,276
Alternative 3	74%	87.2%	5,349	15,947	15,852	121,954	2,166

* - FCE = Fuel Conversion Efficiency (Average Annually)

CHP OPERATING ANALYSIS (with Summer Operation of Central Heating Plant)							
	CHP		Electricity (000 kwh)		Steam (000 pounds)		Natural Gas/Fuel
	Thermal Util.	FCE*	CHP Produced	Procured	CHP Produced	Boiler Produced	Procured (000 therms)
Base Case	100%	86.1%	1,124	20,171	0	165,764	2,211
Alternative 1	100%	88.6%	3,484	17,812	0	169,771	2,292
Alternative 2	100%	71.4%	9,022	12,273	142,510	23,254	2,688
Alternative 3	74%	86.6%	5,349	15,947	15,852	152,343	2,403

* - FCE = Fuel Conversion Efficiency (Average Annually)

Investment and annual operating costs of these alternatives as compared to the base case (without summer operation of central heating plant) are as follows:

CHP INVESTMENT/OPERATING COST ANALYSIS (without Summer Operation of Central Heating Plant)						
	Investment* ($000)	Gas Costs ($000)	Electric Costs ($000)	Incremental Maintenance Costs ($000)	Annual Savings ($000)	Simple Payback (yrs)
Base Case	961	1,236	1,372	NA	NA	NA
Alternative 1	1,466	1,276	1,268	10	54	9.4
Alternative 2	4,930	1,424	1,102	24	58	68
Alternative 3	2,038	1,349	1,112	35	112	9.6

* - Funding incentives are not included

CHP INVESTMENT/OPERATING COST ANALYSIS (with Summer Operation of Central Heating Plant)						
	Investment* ($000)	Gas Costs ($000)	Electric Costs ($000)	Incremental Maintenance Costs ($000)	Annual Savings ($000)	Simple Payback (yrs)
Base Case	961	1,411	1,372	NA	NA	NA
Alternative 1	1,466	1,462	1,226	8	87	5.8
Alternative 2	4,930	1,718	863	48	154	26
Alternative 3	2,038	1,534	1,112	39	98	11.0

* - Funding incentives are not included

Twenty-year life cycle analysis for these alternatives is as follows:

CHP LIFE CYCLE ANALYSIS (without Summer Operation of Central Heating Plant)		
	IRR	NPV ($000)
Base Case	NA	NA
Alternative 1	13.6%	663
Alternative 2	-5.1%	724
Alternative 3	13.3%	1,387

Sensitivity analyses were conducted on key variables to determine their impact on the life cycle analyses of the CHP alternatives. A summary is as follows:

CHP LIFE CYCLE SENSITIVITY ANALYSIS (IRR/NPV - $000)						
	w/Summer Operation	Funding Incentive*	Investment + 20%	Investment - 20%	Gas Cost + 20%	Gas Cost - 20%
Alternative 1	21.4% 1,061	19.2% 663	11.1% 663	16.9% 663	11.4% 566	15.6% 760
Alternative 2	2.4% 1,907	-3.1% 724	NA 724	NA 724	NA 263	-1.6% 1,184
Alternative 3	11.6% 1,221	18.8% 1,387	10.9% 1,387	16.6% 1,387	10.4% 1,109	16.0% 1,666

* 30%; capped at $1 million

CHP LIFE CYCLE SENSITIVITY ANALYSIS (IRR/NPV - $000)						
	Electric Cost + 20%	Electric Cost - 20%	Maintenance + 20%	Maintenance - 20%	Utility Inflation @ 7.5%	Utility Inflation @ 2.5%
Alternative 1	18.4% 905	7.9% 420	13.1% 640	14.1% 685	16.3% 831	10.8% 533
Alternative 2	-0.4% 1,378	NA 69	-5.7% 667	-4.7% 780	-3.1% 724	NA 557
Alternative 3	19.2% 2,017	6.1% 757	12.5% 1,308	14.1% 1,466	16.2% 1,774	10.2% 1,089

1.5. Tariff Impact

Depending on the alternative, approximately 74% - 87% of the campus' annual electric power, or 15.7 - 18.5 million kWh, will still need to be purchased through CHGE. The addition of on-site generation that exceeds 15% of maximum demand, or in the case of Vassar approximately 600 kW, typically results in procurement of electric falling under the SC-14 tariff for standby service. Under the SC-14 tariff, a CHGE client can apply for exemption of up to 1 MW of on-site generation if it is operational by May 31, 2006. In discussions with Sam Rossenberry of CHGE, it was noted that the existing turbine generator is not "significant" and SC-14 would not be applicable. For all the alternatives, an exemption would need to be applied for to not to fall under SC-14, therefore no standby charges have been included in the analysis.

If exemption to SC-14 is granted, all electricity purchased would be under the SC-3 Service Classification. Effective April 1, 2005, an hourly pricing provision came into effect for SC-3 CHGE clients which is based on the Day Ahead Location Based Market Price (DAM) set forth by the New York State Independent System Operator (NYISO) for the Central Hudson region. This revision may affect the overall electrical costs to Vassar and could vary from this analysis. The sensitivity analysis for electric cost illustrates how this could affect the financial performance of each alternative.

1.6. Environmental Issues & Permitting

Vassar College previously applied for a State Facility Permit for air emissions. Potential emissions (based on maximum operating conditions) indicated that the facility could exceed the Title V thresholds for SO_2 and NO_x. The application included a request for emission limits for SO_2 and NO_x, in order to cap emissions of these contaminants below the thresholds required for a Title V Permit. The caps for the Central Heating Plant were set at 94 tons/yr for SO_2 and 84 tons/yr for NO_x. These limits also capped the facility out of New Source Review (NSR) and NO_x RACT requirements. Actual fuel usage data for the existing units in the Central Heating Plant indicate that the facility could operate well below the proposed caps and that emission increases of approximately 35 tons/yr SO_2 and 61 tons/yr NO_x can be made at the facility before a Title V permit will be required.

Once an alternative has been chosen, the facility-wide emissions must be calculated and an appropriate permit modification or application applied for as necessary. Emission increases due to equipment installed under the base case, Alternate 1 or Alternate 2 will most likely result in actual emission increases of less than 35 tons/yr SO_2 and 61 tons/yr NO_x. This assumes that modest increases of fuel usage, especially No. 6 fuel oil, are planned. Under these conditions, the facility should be able to continue to operate with the existing SO_2 and NO_x caps in place for the Central Heating Plant. The State Facility Permit will need to be modified to add the new equipment and delete equipment to be removed for each case/alternate.

In addition, depending upon the size of the gas turbine generator to be installed under Alternate 2, the requirements of 40 CFR 60, Subpart GG 'Standards of Performance for Stationary Gas Turbines' may also be applicable. Subpart GG is applicable to any stationary gas turbine with a heat input at maximum load greater than 10 MMBtu/hr. Under this standard, SO_2 emissions are limited to 0.015 percent by volume at 15 percent oxygen on a dry basis. The NO_x emission limit is variable and is calculated using a formula based on the heat rate and fuel bound nitrogen allowance. Emissions from any Subpart GG applicable unit will need to be verified through both the manufacturer's specifications and initial performance testing after start-up. Test results, as well as notifications of installation and start-up, will need to be submitted to EPA. If applicable, these requirements would need to be addressed in the permit modification.

Alternate 3 is likely to produce the largest increase in emissions, particularly emissions of NO_x. Without controls, five 75 kw co-generators have the potential to increase facility-wide NO_x emissions by approximately 52 tons/yr. Depending upon the planned increases for fuel use, the facility could exceed the current NO_x cap and be required to apply for a Title V permit. Such an increase could also trigger NO_x RACT and NSR requirements. However, if appropriate NO_x controls are specified for the co-generators, emissions may stay below the 84 ton/yr cap. Many co-generators are available with controls that reduce NO_x emissions to 0.75 g/bhp-hr. If units with controls of this type are chosen, the use of five 75 kw co-generators would result in less than 4 tons/yr of increased NO_x emissions. In this case, the facility would be able to maintain a State Facility Permit with the current emission caps, modified to include the new sources and emission points.

Regardless of which case/alternate is chosen, the facility's State Facility Air permit will need to be modified. The extent of the required modification, and possibility that a Title V permit will be required, will depend on the specifications/ratings of the particular equipment chosen and planned level of fuel use. For this analysis, the fuel oil usage has been kept constant with the natural gas usage adjusted accordingly.

1.7. Schedule

Lead time for implementing Alternatives 1 and 3 is approximately 34 weeks, and approximately 66 weeks for Alternatives 2. Milestones are summarized as follows:

Implementation Schedule		
Alternative	**1 & 3**	**2**
Milestone	**Week**	**Week**
Notice To Proceed	0	0
Final System Sizing/Specification	6	10
Equipment Procurement/Fabrication	22	48
Equipment Installation	30	58
Start-Up/Commissioning	34	66

1.8. Recommendations

Due to current operation of the Central Heating Plant from October to April, or approximately seven months of the year, the relatively favorable utility rates as compared to other parts of the state makes justification for on-site generation economically difficult. The alternatives evaluated have simple paybacks ranging from 9.3 years and higher, not including funding incentives.

Since high pressure steam (225 psi) is currently generated at the facility, peak electric shaving can be accomplished with minimal investment. By optimizing backpressure turbine output and operation, and applying for exemption from the SC-14 tariff, an additional 1.7 million kWh can be generated, saving approximately $54,000 annually with a payback of 9.4 years.

Distributed generation also has similar economic benefits for buildings that have continuous thermal (hot water) loads throughout the year. Outfitting three buildings, the Avery Center for Drama and Arts, Student's Center, and Walker Athletic Facilities with induction generator sets, while optimizing the operation of the existing backpressure turbine, an additional 4.2 million kWh can be generated, saving approximately $112,000 annually with a payback of 9.6 years. This will also require an exemption from the SC-14 tariff. A drawback of this alternative, from an aesthetics and noise standpoint, is locating the equipment in or near the existing facilities.

Key factors that would impact overall economic performance include the following:

- If Vassar intends to begin year round operation of the Central Heating Plant, it will improve the overall economics of these alternatives
- Securing potential funding incentives for CHP will improve overall economics

- Rising gas/fuel costs will negatively impact the economics, while rising electric costs will positively impact the economics
- For simplicity, downtime for the generation equipment has not been included in the utility cost analyses (maintenance costs have been included):
  - For the cases that evaluated non-summer operation, this should have minimal impact on economics since maintenance could be conducted during summer months when the system is shut down and high uptime should be achieved during operation
  - For the cases that evaluated summer operation the economics would be impacted for system downtime; one week of downtime for Alternate 1would reduce annual savings by approximately $4,900 or $29/hr, for Alternate 2 by approximately $9,600 or $57/hr, and for Alternate 3 by approximately $7,000 or $42/hr.

If Vassar College elects to proceed with one of the recommendations, a meeting should be held with Central Hudson Gas & Electric's rate department to confirm that exemption from the SC-14 tariff will be granted.

New York State Energy Research and Development Authority's support of this project through Program Opportunity Notice 795-02, "CHP and Renewable Generation Technical Assistance" made it possible for Vassar College to evaluate these alternatives that can potentially allow them to maintain a competitive facility operating budget.

2.0 BACKGROUND

Vassar College (Vassar), located in Poughkeepsie, New York, is a leading liberal arts college. The college first opened its doors in 1865 and was a pioneer in women's and liberal arts education in the United States. In 1969, Vassar became coeducational and today remains at the forefront of liberal arts institutions. The campus is an approximately 1,000 acre site with over 2.4 million square feet in buildings. Vassar has a student body of over 2,400, and 1,200 employees.

Total energy costs for the college are approximately $2.5 million annually, $0.6 million for natural gas, $0.7 million for No. 6 fuel oil, and $1.25 million for electricity.

Vassar purchases transmission and distribution of electric power from Central Hudson Gas & Electric Corporation (CHGE) under the SC-3 Service Classification. Total electric use at the facility for a two year period from September 2002 to August 2004 was approximately 40.4 million kWh (20.2 million kWh annually) with peak demands ranging from approximately 2700 - 4000 kW. Annual costs averaged $1.3 million at a blended rate of $0.0625/kWh. Primary service is provided to the site at 15 kV.

Vassar purchases commodity supply of natural gas from Amerada Hess with transportation from CHGE. Total natural gas consumption at the facility for a two year period from September 2002 to August 2004 was approximately 1.1 million Ccf (0.55 million Ccf annually) for the Main Campus & Boiler, Greenhouse, and Davison services. Annual natural gas costs averaged $370,000 at a blended rate of $0.68/Ccf. Vassar also has the ability to burn No. 6 fuel oil as an alternate fuel with three 100,000 gallon tanks in place. For the same period, approximately 1.9 million gallons (0.9 million gallons annually) were purchased from Amerada Hess were consumed. Annual fuel oil costs averaged $860,000 at a blended rate of $0.92/gal.

Natural gas and fuel oil is utilized for production of steam for building heating. A central heating plant houses five steam boilers, three of which are operable. The two decommissioned boilers were installed in 1930 and are non-operable. A 1963 Springfield water tube boiler, which produces 40,000 lbs/hr of steam at 225 psi, is the primary unit during the heating season. The two supplemental boilers are both 1989 Johnson fire tube boilers that produce 27,600 lbs/hr of steam each. At a minimum, one of the supplemental boilers operates in conjunction with the primary unit during the majority of the heating season. All three boilers are required during the highest steam demands.

Steam is distributed to the campus underground at 20 psi. The steam plant operates from October to May at approximately 77% efficiency with a load of approximately 5,000 – 30,000 lbs/hr in the fall/spring and 30,000 – 52,000 lbs/hr in the winter. Approximately 135 million pounds of steam was produced annually from September 2002 to August 2004 over 5,600 operating hours.

Natural gas is also utilized for packaged hot water boilers and heaters (approx. 13,500 MBH of capacity) located in various buildings throughout the campus. During the heating season, the central heating plant is utilized to produce hot water in these buildings, with the packaged units operating primarily during the non-heating season.

Also located in the central heating plant is a 750 kW back pressure steam turbine that normally operates when ambient temperature is below 40°F. Approximately 1.1 million kWh was produced annually from this generation unit from September 2002 to August 2004.

Two 1,000 ton chillers were installed in 2001 in a new facility near the Building & Grounds building to meet air conditioning requirements on campus. One chiller is a Trane electric centrifugal unit, the other a Trane gas-fired absorption unit. The gas-fired absorption unit was installed with the help of the **NYSERDA New York Energy $mart Program**.

The primary steam boiler (40+ years' old) in the central heating plant is reaching the end of its useful life. If this boiler fails during the heating season, the two remaining boilers would not be able to meet demand during periods of high steam usage. Vassar is considering a plan to install two new 750 HP steam fire tube boilers to replace the Springfield boiler. As an alternative, Vassar was interested in having Clough, Harbour & Associates LLP (CHA) investigate options to install a Combined Heat and Power (CHP) plant as an efficient method of producing both electric and steam needs and perform a detailed technical and economical feasibility analysis for installing a CHP plant at the Poughkeepsie campus.

3.0 PROJECT DESCRIPTION

3.1 Summary Description of Alternatives

Three potentially viable system alternatives for providing different levels of combined heat and power for the campus plant were examined in detail and are summarized below:

Alternative	Description
Base Case	Install two 750 HP Steam Boilers
1	Install two 750 HP Steam Boilers and one 250 kW Backpressure Steam Turbine
2	Install one 750 HP Steam Boiler and one 1 MW Gas Turbine Generator with Heat Recovery Steam Generator
3	Install two 750 HP Steam Boilers and five 75 kW Engine Gensets in designated buildings around the campus

3.2 Analysis Methodology and Assumptions

3.2.1 Temporal Coincidence

The viability of any combined heat and power system is proportional to the level of temporal coincidence between the thermal and electrical loads to be satisfied by the system. At Vassar College, hourly electric interval metering data (kW) was available for a two year period from September 2002 through August 2004 along with daily central steam plant production rates (lbs/day) and this data was used for each analysis. Data analysis involved evaluating the temporal coincidence between electric demand and steam demand on a daily and seasonal basis throughout a typical year, and over the course of a typical day for each season. Days were chosen to reflect demand when school was in session and not in session. Energy profiles for Vassar College are located in Appendix A.

Electric demand varies from 3 MW to 4.5 MW and typically peaks around midday. When school is not in session, the demand profile is much flatter, only varying between 3 and 3.5 MW.

Steam demand depends highly on seasonal conditions. The central plant operates from October through April. A test was performed by CHA and Vassar's maintenance personnel to determine the base load. With loads valved shut for approximately one hour, the base load for distribution line losses was determined to be 6,500 lbs/hr. Daily peaks in steam flow occur in the morning hours due to building warmup, which can require steam flows in excess of 50,000 lbs/hr. Steam flow then drops off until the early evening hours when another lower peak typically occurs.

Site electric demand remains relatively constant throughout the year except for lower peak demands when school is not in session and higher demand in the summer for air conditioning loads.

3.2.2 Base Case Energy Analysis and Annual Cost

Vassar purchases transmission and distribution of electric power from Central Hudson Gas & Electric Corporation (CHGE) under the SC-3 Service Classification. During the period from September 2002 to August 2004, this included a customer refund for a one time distribution for the sale of a fossil fuel plant. For the base case analysis and to compare the site's on-going costs to the proposed alternatives, this refund was excluded and results in an average annual cost of $1,372,000 for 20.2 million kWh at a peak demand of 3,970 kW for a blended rate of $0.068/kwh. This includes the average annual generation of 1.1 million kWh from the existing 750 kW backpressure steam turbine which would result in an overall electric consumption of 21.3 million kWh. It should be noted the CHGE considers the existing turbine exempt from the SC-14 tariff for standby service.

A summary of the impact of this customer refund for Vassar College based on the 2002/2004 electric consumption is as follows:

CHGE SC-3	Peak Demand (kW)	Total Usage (000 kWH)	Annual Electric Cost	Cost per kwh
Actual	3,990	20,216	$1,263,000	$0.0625
Base	3,970	20,171	$1,372,000	$0.0680

Natural gas and No. 6 fuel oil pricing for the base case is calculated for September 2002 to August 2004 for the services to the main campus and boiler, greenhouse, and Davison meters. For the base case analysis, an average natural gas/fuel consumption of 1,973,000 Ccf was used for an annual cost of $1,236,000 or $0.626/Ccf. This was based on 44% of the fuel needed being satisfied by natural gas and the remaining 56% by No. 6 fuel oil. The amount of No. 6 fuel oil is driven by the permitted level of the facility. For all alternatives evaluated the fuel oil used remained constant with natural gas usage adjusted accordingly. A summary of the natural gas and fuel oil consumption and costs for the 2002/2004 period is as follows:

Service	Gas Usage (000 Ccf)	Annual Gas Cost	Fuel Oil Usage (000 gal)	Annual Fuel Oil Cost	Total Usage (000 Ccf)	Total Cost	Cost per Ccf
Main Campus/Boiler	338	$190,500	944	$864,000	1,762	$1,054,500	$0.598
Greenhouse	75	$64,500	0	$0	75	$64,500	$0.860
Davison	136	$117,000	0	$0	136	$117,000	$0.860
TOTAL	549	$372,000	943	$864,000	1,973	$1,236,000	$0.626

Details of the base case annual electric and gas costs are located in Appendix B.

For the alternatives analyses, the hourly interval electric data was used to develop a spreadsheet model. Daily steam demand was averaged over the course of one day and used in the hourly spreadsheet model. The campus steam demand experiences only minor daily variations.

3.2.3 Thermal Load

For the base case and all alternatives examined under this study, the thermal load is the 20 psig steam load to the campus. Presently, the majority of plant steam is generated at 225 psig by the Springfield boiler and a Johnston boiler. The third boiler, another Johnston boiler, is used to meet demand on the coldest days. There is no backup boiler. High pressure steam is generated for use in the existing 750 kW backpressure steam turbine. Steam not expanded through the turbine passes through a pressure reducing station in parallel with the turbine. The main consumer of steam is space heating.

3.2.4 Fuel Sources

Presently, the central plant operates the boilers under a dual fuel arrangement using #6 fuel oil as the primary fuel, with natural gas as a backup. Vassar's central boiler plant is under an interruptible gas service contract with Amerada Hess.

For this analysis, it is assumed that dual fuel capability will be maintained for the boilers and combustion turbine option, however, the amount of fuel oil used will remain constant with the natural gas usage adjusted accordingly. For Alternative 3, the induction generators will be gas-fired only, since this is a distributed generation option and fuel oil distribution is not practical.

Gas service brought into the facility is adequate to meet the requirements of the alternatives; however, a compressor will be required for the combustion turbine alternatives.

3.2.5 Electrical Service

Vassar College receives power from Central Hudson Gas & Electric at 115 kV service voltage to the substation located on the north side of the main campus. The utility metering takes place at this service voltage. The service voltage is then distributed underground in a radial distribution loop at 13.8 kV where it is stepped down through local substation transformers to 480 V for distribution in the facilities.

The existing cogeneration unit in the Central Heating Plant is a steam driven induction generator rated 750 kW, 480/277 volts, 3 phase. It is connected to a 1200 amp, 480 volt switchboard with electrically operated circuit breaker and protective relaying located in the Central Heating Plant. The unit feeds an outdoor pad-mounted 1,000 kVA, 480 volt – 13.8 kV transformer with 15 kV fused load break switch and then connects into the campus' 13.8 kV distribution loop at pad mounted sectionalizing switch SS#13 located outside the Central Heating Plant.

All CHP alternatives evaluated assume power generated at 480V and tied into the plant distribution system. Each of the alternatives requires a main circuit breaker to be installed ahead of the main switchgear lineup and modifications to the main switchgear for power, protection, and control connections. Additionally, during the design, a detailed coordination with Central Hudson will be needed to ascertain the extent of their protection requirements.

3.2.6. Financial Assumptions

For the financial analysis of each alternative the following base assumptions have been made:

- Life Cycle – 20 years
- Tax Rate – 0% (Vassar is tax exempt)
- NPV Discount Rate – 10%
- Tax Depreciation – 15 years, straight line
- Material inflation factor – 4%
- Labor & services inflation factor – 4%
- Utilities inflation factor – 5%
- Funding incentives – 0%

Sensitivity analyses were performed and included the following:

- Summer Central Heating Plant operation
- Funding incentives: 30% capped at $1 million
- Investment cost: ± 20%
- Gas costs: ± 20%
- Electric costs: ± 20%
- Maintenance costs: ± 20%
- Utility Inflation Factor: ± 2.5%

3.3 CHP Alternatives

3.3.1 Alternative 1: Two 750 HP packaged steam boilers with one 250 kW backpressure steam turbine

3.3.1.1 System Description

For this option, the existing 1930 decommissioned boilers will be removed and replaced with two 750 HP packaged steam boilers, which will bring the total number to five. These boilers shall operate at 225 psig. An additional steam backpressure turbine rated for 12,000 lbs/hr will be installed with a 250 kW generator. The existing 750 kW single-stage backpressure turbine generator will continue to be operated in parallel with the new turbine and the existing 225/20 psig pressure reducing station (PRV). The two turbines are sized to meet a peak steam demand of 45,000 lbs/hr. A nominal isentropic efficiency of 53% results in a generator capacity of 1.0 MW under full flow. Electrically, the generators will be in parallel with the utility grid and displace approximately 13.3% of peak electric demand under rated steam flow. A basic system schematic and floor plan is presented in Drawings SK-1 & M-3, located in Appendix F.

By establishing PRV set points 2 to 3 psig lower than the turbine exhaust pressure set point, uninterrupted steam flow is maintained with minimal external controls. When plant steam demand is less than full turbine flow, the turbine throttles will modulate to reduce steam flow with a corresponding reduction in output electric power. When steam demand rises above full flow or plant electric load is less than generator capacity, the turbine throttles modulate accordingly with excess steam demand causing plant pressure to drop below 120 psig. When plant pressure reaches PRV set point pressure, the reducing station supplements the necessary flow to maintain plant pressure at the PRV set point.

The proposed unit is a skid-mounted package consisting of a turbine and 250 kW generator separated by a reducing gear, steam throttles, pressure and temperature sensors, lubrication oil system, and electronic (PLC) controls. The best location in the main boiler plant will be adjacent to the existing steam turbine. The control cabinet consisting of control system, protective relay devices, and generator breaker will be mounted locally.

3.3.1.2 Operational Analysis

The system operations model is presented in Appendix F and is based on the plant's historical hourly electric and steam demand data for the period of September 2002 to August 2004. The model predicts that Alternative 1 will result in peak shaving 961 kW of plant demand and displace approximately 13.3% or 2.8 million kWh of purchased power. Incremental fuel costs are estimated at $40,000 annually to convert the 225 psig steam to electricity and continue to provide the campus with the required 20 psig steam. Under the new arrangement, throttling will largely be accomplished by the backpressure turbines instead of the pressure reducing station. The thermal utilization of this alternative is 100% and the fuel conversion efficiency (FCE) is 88.6%.

3.3.1.3 Tariff Impact

Approximately 87% of the campus' annual electric power, or 18.5 million kWh, will still need to be purchased through CHGE. The addition of on-site generation that exceeds 15% of maximum demand, or in the case of Vassar approximately 600 kW, typically results in procurement of electric falling under the SC-14 tariff for standby service. Under the SC-14 tariff, a CHGE client can apply for exemption of up to 1 MW of on-site generation if it is operational by May 31, 2006. In discussions with Sam Rossenberry of CHGE, it was noted that the existing turbine generator is not "significant" and SC-14 would not be applicable. With the combination of this turbine generator and the proposed 250 kW generator, an exemption would need to be applied for to not to fall under SC-14. Total electric costs for this alternative are estimated at $1.3 million at $0.0686/kWh based on this exemption. Details are provided in Appendix B.

3.3.1.4 Electrical Power

The most cost effective method to connect an additional 279 kW/310 kVA steam driven induction generator would be to provide a similar connection arrangement as the existing unit. A 480 volt switchboard with electrically operated 800AF/400AT circuit breaker and associated protective relaying would be provided to connect the generator. The unit would then feed an outdoor pad mounted 500 kVA, 480 volt – 13.8 kV transformer and 15 kV fused load break switch. A proposed one line connection diagram is shown in Drawing E-1 located in Appendix F.

This generator would require two types of protective relaying. The first set of relaying is for generator protection which typically consists of short circuit protection and protection from abnormal operating conditions (reverse power, unbalanced currents, etc.). The second set of protective relaying is the interconnection protective relaying, which is designed to allow the generator to operate in parallel with the utility and typically includes protection against over/under voltage, over/under frequency, etc.

3.3.1.5 Maintenance Impact

A steam turbine driven generator requires maintenance, and most of the tasks are not out of the ordinary and require minimal time on a daily basis. A regular maintenance schedule should be followed to ensure dependable operation. A list of recommended tasks is as follows:

Frequency	Task	Time Required
Daily	Visual inspection for leaks, unusual noises or vibrations, proper temperatures and pressures	5 minutes
Weekly	Check operation of shutdown controls, examine electrical components	20 minutes
Monthly	Test lubricating oil and filter, check air breather, pump seals, and foundation bolts	30 minutes
3000 hours	Grease generator bearings	30 minutes
6 months	Check gear tooth wear, coupling alignment, and zinc anodes	2 hours
Yearly	Clean steam separator and strainer;, inspect bearing and end play and carbon gland seals; check throttle valve and sentinel warning valve, foundation, tooth wear pattern, coupling alignment, and tuning parameters or control loops; flush lube system; clean generator; recalibrate gauges and governor	30 hours
5 years	Complete disassembly and inspection	5 days

Availability of this type of equipment is high and should be expected to exceed 98%. Vassar has labor on site to maintain and operate the existing boilers and turbine generator; therefore, no additional labor is anticipated for the additional steam turbine. Typical incremental cost to perform the necessary maintenance on the steam turbine generator is estimated to be approximately $0.006 per kWh; therefore, overall incremental annual maintenance costs are estimated to be $10,000. Since the equipment will be not operating during summer months, maintenance can be scheduled during this period allowing for 100% uptime during the operating months.

3.3.1.6 Financial Analysis

Total investment costs and life cycle analysis for this alternative are included in Appendix G and summarized as follows:

	Investment * ($000)	Gas Costs ($000)	Electric Costs ($000)	Incremental Maintenance Costs ($000)	Annual Savings ($000)	Simple Payback (yrs)
Base	961	1,236	1,372	NA	NA	NA
Alternative 1	1,466	1,276	1,268	10	54	9.4

* - Funding incentives are not included

	IRR	NPV ($000)
Alternative 1	13.6%	663

3.3.1.7 Schedule

Lead time for implementing this alternative is approximately 34 weeks. Milestones are summarized as follows:

Milestone	Week
Notice To Proceed	0
Final System Sizing/Specification	6
Equipment Procurement/Fabrication	22
Equipment Installation	30
Start-Up/Commissioning	34

3.3.2 Alternative 2: One 750 HP packaged steam boiler with one 1 MW gas turbine generator with heat recovery steam generator

3.3.2.1 System Description

The system would install one 750 HP boiler with one dual fuel turbine generator. The heat recovery steam generator with supplemental duct burner operates using the exhaust from the turbine and can generate steam approximately equal to one 750 HP boiler. The heat recovery steam generator would produce 20-psig steam. The existing boilers and the new 750 HP boiler would be operated at 225 psig. The system will be located in the area presently occupied by the two 1930 decommissioned boilers. A basic system schematic and floor plan is presented in Drawings SK-2 & M-4, and located in Appendix H.

The major equipment for the turbine generator system include the following:

- One natural gas compressor required to boost the existing service to approximately 212 psig
- One turbine generator set, skid mounted, including compressor, combustor, turbine, and generator
- One heat recovery steam generator with supplemental duct burners
- SCR emissions control package
- Continuous emissions monitoring system
- Power management system including PLC controller, synchronizing system, and protective relay package
- Switchgear
- Motor control center
- Auxiliary power transformer
- Generator grounding resistor

Utilities that will be required to be routed to the system include the following:

- Natural gas and fuel to combustion turbine and HRSG duct burners
- Plant compressed air
- Feedwater piping from existing feed system to HRSG
- 10" steam piping from HRSG to boiler room distribution tie-in
- 2000A feeder to plant electrical tie-in location
- Sanitary drains
- Condensate returns from drip traps

The system will be operated whenever site demand is equal to or exceeds 50% of the electric generator's rated output. Below this point, system efficiency begins to degrade significantly and most manufacturers will not guarantee system emission rates. Historically, Vassar's site demand does not drop this low.

Whenever the turbine is on-line, steam loads will be supplied by the HRSG using exhaust gases as primary heat source supplemented by the duct burners and additional boilers as necessary. When the combustion turbine is shut down, plant steam demand will be met by the three 750 HP, 225 psig boilers.

3.3.2.2 Operational Analysis

The system operations model is presented in Appendix H and is based on the campus' historical hourly electric and steam demand data for September 2002 to August 2004.

The model predicts that Alternative 2 will result in peak shaving 1,069 kW of plant demand and displace approximately 26.1%, or 5.5 million kWh, of purchased power. Incremental fuel costs are estimated at $188,000 annually. The thermal utilization of this alternative is 100% and the fuel conversion efficiency (FCE) is 71.4%.

3.3.2.3 Tariff Impact

Approximately 74% of the campus' annual electric power, or 15.7, million kWh will still need to be purchased through CHGE. The addition of on-site generation that exceeds 15% of maximum demand, or in the case of Vassar approximately 600 kW, typically results in procurement of electric falling under the SC-14 tariff for standby service. Under the SC-14 tariff, a client of CHGE can apply for exemption of up to 1 MW of on-site generation if it is operational by May 31, 2006. In discussions with Sam Rossenberry of CHGE, it was stated that an exemption could be applied for so as not to fall under SC-14. Total electric costs for this alternative are estimated at $1.1 million at $0.0700/kWh based on this exemption. Details are provided in Appendix B.

3.3.2.4 Electrical Power

If a new 1 MW dual fuel turbine cogeneration unit is installed, it would operate instead of the existing 750 kW steam driven induction generator. The new turbine unit would be a synchronous generator and, therefore, require automatic synchronization equipment to connect in parallel with the utility. The generator would require a new transformer, 480 volt switchgear located in the Central Heating Plant with electrically operated 1600AF/1600AT circuit breaker, and associated protective relaying and automatic synchronizing equipment would be provided to connect the generator. The switchgear would feed an outdoor pad mounted 1500 kVA, 480 volt – 13.8 kV transformer which would then feed into the existing 13.8 kV distribution loop at pad mounted sectionalizing switch SS#13. A proposed one line connection diagram is shown in Drawing E-1, located in Appendix H.

This generator would require two types of protective relaying. A set for generator protection typically consists of short circuit protection and protection from abnormal operating conditions (reverse power, unbalanced currents, etc.). The set for interconnection protective relaying is designed to allow the generator to operate in parallel with the utility, and typically includes protection against over/under voltage, over/under frequency, etc.

3.3.2.5 Maintenance Impact

A dual fuel turbine system will require many of the same daily and weekly checks as steam turbines, mostly visual checks to verify the system is operating properly. Regular maintenance is scheduled twice per year and requires about seven days' total downtime per year. System overhauls should be performed every 30,000 operating hours and include a complete disassembly and inspection of the turbine and generator. Availability of this type of equipment is high and should be expected to exceed 98%. Vassar has existing labor on site to maintain and operate the existing boilers; therefore, no additional labor is anticipated for the turbine system. Maintenance contracts for this size system are estimated at $0.007 per kWh which would be offset by one less boiler estimated at $0.125 per Mlbs of steam, for a total net incremental maintenance cost of $24,000 per year. Since the equipment will be not operating during summer months, maintenance can be scheduled during this period allowing for 100% uptime during the operating months.

3.3.2.6 Financial Analysis

Total investment costs and life cycle analysis for this alternative are included in Appendix I and summarized as follows:

	Investment* ($000)	Gas Costs ($000)	Electric Costs ($000)	Incremental Maintenance Costs ($000)	Annual Savings ($000)	Simple Payback (yrs)
Base	961	1,236	1,372	NA	NA	NA
Alternative 2	4,930	1,424	1,102	24	58	68

* - Funding incentives are not included

	IRR	NPV ($000)
Alternative 2	-5.1%	724

3.3.2.7 Schedule

Lead time for implementing this alternative is approximately 66 weeks. Milestones are summarized as follows:

Milestone	**Week**
Notice To Proceed	0
Final System Sizing/Specification	10
Equipment Procurement/Fabrication	48
Equipment Installation	58
Start-Up/Commissioning	66

3.3.3 Alternative 3: Two 750 HP Packaged Steam Boilers with Distributed Cogeneration Units

3.3.3.1 System Description

Alternative 3 incorporates two 750 HP packaged steam boilers installed in the central plant with distributed cogeneration units at individual buildings, while maintaining the operation of the existing 750 kW backpressure turbine generator. The cogeneration units would be engine gensets with hot water heat recovery. It is only practical to install these gensets in buildings with hot water heat and a year-round heat requirement. A basic system schematic is presented in Drawings SK-3 & SK-4 located in Appendix J.

3.3.3.2 Site Selection

CHA used several criteria factors to evaluate each building's potential as a viable candidate for a distributed cogeneration unit. The building should be heated primarily by hot water heat. Generating hot water with cogeneration units is more easily accomplished than generating steam. The building needs to have a significant electrical load; therefore, only buildings on the campus grid were viable. Power not required by the connected building could be fed back to the campus grid. In addition, the building should have a significant summer time heat requirement. Building reheat, cafeterias, and domestic hot water heaters require year round heat that helps to maximize the cogeneration unit's energy saving potential.

Other characteristics that are important in evaluating a potential cogeneration site is aesthetics and space requirements. Each cogeneration unit will require an outdoor "dump" radiator to reject unused heat. For some buildings that lack suitable interior space, the cogeneration units themselves will need to be located outside. This could have an effect on the architecture and landscaping of the campus' buildings. Along with the visual effects, these units include internal combustion engines that generate considerable noise when operating. Interior space for pumps, heat exchangers, and electrical equipment is also required.

The following buildings were evaluated as potential distributed cogeneration sites:

- Walker Athletic Center – The swimming pool is a good year-round heat load. There is adequate site space around the mechanical room for cogen units although no indoor space is available; a building addition would be required. The building uses hydronic heating.
- Mudd Chemistry – This building has very little summer load, mostly lab steam. There is a steam to hot water converter in the basement used for space heating during the heating season. The building has adequate flat roof space.
- Olmstead Hall – There is considerable flat roof space with a high parapet, and six stories between roof and basement steam-to-hot water converters. Summer heating loads include lab steam and summer reheat. The building utilizes hydronic heating.
- Loeb Art Gallery – The building utilizes summer reheat for the art gallery. There is no indoor space for a cogen unit. The flat roof is visible from adjacent road and installation would be architecturally challenging. The hydronic heating system is kept hot year round.
- Blodgett Hall – This is an old stone building with a steeply sloped roof. There are very light summer loads from reheat and cage washing. There is little space in the basement's mechanical room for additional equipment.

- Student's Center – There are flat roofs on the wings of the building and adequate space in the second floor's mechanical room. Although no reheat, there is a considerable summer DHW load associated with the cafeteria. The building also has hydronic baseboard heating.
- Noyes Dorm – This building has a flat roof with no parapet. The summer DHW load is considerably lower due to a lack of students and associated laundry loads. The building utilizes hydronic heating. There is adequate space available in the mechanical room.
- Cushing Dorm – This building has a steeply pitched roof. The mechanical room is located in a crawl space that does not have additional space and would not be viable for an installation.
- Jewett Dorm – This building has a very high flat roof with space. There is considerable space in the mechanical room. The building has some summer DHW load and utilizes hydronic heat.
- Davison/Raymond/Strong/Lathrop/ Josselyn – All of these buildings use steam heat and do not have any summer load.
- Main Building – This building utilizes steam heating. The equipment space is very tight.
- Avery Center for Drama and Arts – This building has reheat coils that are used in conjunction with the cooling system for dehumidification. A water-source heat pump is used to make hot water for the reheat loop. Some parts of the building utilize hydronic heating.

Based on this analysis, the following buildings were considered viable candidates for distributed generation:

- Avery Center for Drama and Arts
- Student's Center
- Walker Athletic Center

3.3.3.3 Operations Analysis

The system operations model is presented in Appendix J and is based on individual building's heating demand data estimated from September 2002 to August 2004. The analysis assumes that the cogeneration units will run at 100% to supply full electrical capacity to the campus. Where multiple units exist, only units needed to meet thermal demand would be run. Any unneeded heat would be rejected using an outdoor cooler. The model predicts that Alternative 3 will result in peak shaving 375 kW as a result of the distributed generation units which would be combined with the 710 kW of the existing backpressure turbine. This will displace approximately 25% of electrical energy purchased, or 5.3 million kWh of purchased power. Incremental fuel costs are estimated at $133,000. The thermal utilization of this alternative is 74% and the fuel conversion efficiency (FCE) is 87.2%.

3.3.3.4. Tariff Impact

Approximately 75% of the campus's annual electric power, or 15.9 million kWh, will still need to be purchased through CHGE. The addition of on-site generation that exceeds 15% of maximum demand, approximately 600 kW in the case of Vassar, typically results in procurement of electricity falling under the SC-14 tariff for standby service. Under the SC-14 tariff, a client of CHGE can apply for exemption of up to 1 MW of on-site generation if it is operational by May 31, 2006. In discussions with Sam Rossenberry of CHGE, it was stated that the existing turbine generator is not "significant" and SC-14 would not be applicable. With the combination of this turbine generator and proposed 375 kW of gensets, an exemption would need to be applied in order to not fall under SC-14. Total electric costs for this alternative are estimated at $1.1 million at $0.0697/kWh based on this exemption. Details are provided in Appendix B.

3.3.3.5. Electrical Power

This option looks at electrical requirements for providing satellite gas fired induction generators at three locations:

- Avery Center for Drama and Arts
- Student's Center
- Walker Athletic Center

The units would be rated 75 kW, 480/277 volt or 120/208 volt, depending on location. Each unit would be connected into the existing 480 volt or 208 volt main distribution gear for each building. Generator protective relaying would be provided integral to the cogeneration unit. A new switchboard with an electrically operated circuit breaker would be provided at each building and inter-tie protective relaying provided to allow the units to be connected in parallel with the utility.

One line diagram showing typical connection for a facility is shown in Drawing E-2 located in Appendix J.

3.3.3.6. Maintenance Impact

Maintenance required for the reciprocating engine generators would include lube oil and filter inspection, air filter and breather inspection, and foundation inspection. Availability of this type of equipment is high and should be expected to exceed 98%. Vassar has existing labor on site to maintain and operate the existing boilers; therefore, no additional labor is anticipated for the genset systems. Maintenance costs for this system are estimated at $0.007 per kWh, offset by a reduction in steam production, resulting in a net incremental maintenance cost of $35,000 per year. The impact of individual unit downtime is considered negligible as the unit maintenance can be scheduled so only one 75kW unit would be down at any one time.

3.3.3.7. Financial Analysis

Total investment costs and life cycle analysis for this alternative are included in Appendix K and summarized as follows:

	Investment* ($000)	Gas Costs ($000)	Electric Costs ($000)	Incremental Maintenance Costs ($000)	Annual Savings ($000)	Simple Payback (yrs)
Base	961	1,236	1,372	NA	NA	NA
Alternative 3	2,038	1,349	1,112	35	112	9.6

* - Funding incentives are not included

	IRR	NPV ($000)
Alternative 3	13.3%	1,387

3.3.3.7. Schedule

Lead time for implementing this alternative is approximately 34 weeks. Milestones are summarized as follows:

Milestone	Week
Notice To Proceed	0
Final System Sizing/Specification	6
Equipment Procurement/Fabrication	22
Equipment Installation	30
Start-Up/Commissioning	34

3.4 Sensitivity Analysis

The following tables indicate the impact of several variables on the financial payback of each alternative. Detail life cycle analyses can be referenced in Appendix L.

	Base		**Summer Operation of CHP**	
Alternative	**IRR**	**NPV ($000)**	**IRR**	**NPV ($000)**
1	13.6%	663	21.4%	1,061
2	-5.1%	724	2.4%	1,907
3	13.3%	1,387	11.6%	1,221

	Base		**Funding Incentive ***	
Alternative	**IRR**	**NPV ($000)**	**IRR**	**NPV ($000)**
1	13.6%	663	19.2%	663
2	-5.1%	724	-2.5%	724
3	13.3%	1,387	18.8%	1,387

* 30% incentive capped at $1 million

	Base		Gas Costs *	
Alternative	IRR	NPV ($000)	IRR	NPV ($000)
1	13.6%	663	11.4% / 15.6%	566 / 760
2	-5.1%	724	NA / -1.6%	263 / 1,184
3	13.3%	1,387	10.4% / 16.0%	1,109 / 1,666

* ± 20%

	Base		Electric Costs *	
Alternative	IRR	NPV ($000)	IRR	NPV ($000)
1	13.6%	663	7.9% / 18.4%	420 / 905
2	-5.1%	724	NA / -0.4%	69 / 1,378
3	13.3%	1,387	6.1% / 19.2%	757 / 2,017

* ± 20%

	Base		Maintenance Costs *	
Alternative	IRR	NPV ($000)	IRR	NPV ($000)
1	13.6%	663	13.1% / 14.1%	640 / 685
2	-5.1%	724	-5.7% / -4.7%	667 / 780
3	13.3%	1,387	12.5% / 14.1%	1,308 / 1,466

* ± 20%

	Base		Investment *	
Alternative	IRR	NPV ($000)	IRR	NPV ($000)
1	13.6%	663	11.1% / 16.9%	663 / 663
2	-5.1%	724	NA / NA	724 / 724
3	13.3%	1,387	10.9% / 16.6%	1,387 / 1,387

* ± 20%

	Base		Utility Inflation Factor *	
Alternative	IRR	NPV ($000)	IRR	NPV ($000)
1	13.6%	663	10.8% / 16.3%	533 / 831
2	-5.1%	724	NA / -2.5%	557 / 939
3	13.3%	1,387	10.2% / 16.2%	1,089 / 1,774

* ± 2.5%

3.5 Environmental Issues and Permitting

Vassar College previously applied for a State Facility Permit for air emissions. Potential emissions (based on maximum operating conditions) indicated that the facility could exceed the Title V thresholds for SO_2 and NO_x. The application included a request for emission limits for SO_2 and NO_x, in order to cap emissions of these contaminants below the thresholds required for a Title V Permit. The caps for the Central Heating Plant were set at 94 tons/yr for SO_2 and 84 tons/yr for NO_x. These limits also capped the facility out of New Source Review (NSR) and NO_x RACT requirements. As noted in Table 1, actual fuel usage data for the existing units in the Central Heating Plant indicated that the facility could operate well below the proposed caps. Table 1 also indicates that emission increases of approximately 35 tons/yr SO_2 and 61 tons/yr NO_x can be made at the facility before a Title V permit will be required.

Table 1

Contaminant	Title V Permit Threshold (tons/yr)	State Facility Permit Cap (tons/yr)	Maximum Actual Emissions (tons/yr)	Increase Possible Before Current Cap is Exceeded (tons/yr)
PM	100	None	5	na
SO_2	100	94	59	35
NO_x	100	84	23	61
CO	100	None	8	na
VOC	50	None	1	na

Once an alternative has been chosen, the facility-wide emissions must be calculated and an appropriate permit modification or application applied for as necessary. Emission increases due to equipment installed under Alternate 1 or Alternate 2 will most likely result in actual emission increases of less than 35 tons/yr SO_2 and 61 tons/yr NO_x. This assumes that modest increases of fuel usage, especially No. 6 fuel oil, are planned. Under these conditions, the facility should be able to continue to operate with the existing SO_2 and NO_x caps that are in place for the Central Heating Plant. The State Facility Permit will need to be modified to add the new equipment and delete equipment to be removed for each case/alternate.

In addition, depending upon the size of the turbine generator to be installed under Alternate 2, the requirements of 40 CFR 60, Subpart GG 'Standards of Performance for Stationary Gas Turbines' may also be applicable. Subpart GG is applicable to any stationary gas turbine with a heat input at maximum load of greater than 10 MMBtu/hr. Under this standard, SO_2 emissions are limited to 0.015 percent by volume at 15 percent oxygen on a dry basis. The NO_x emission limit is variable and calculated using a formula based on the heat rate and fuel bound nitrogen allowance. Emissions from any Subpart GG applicable unit will need to be verified through both the manufacturer's specifications and initial performance testing after start-up. Test results, as well as notifications of installation and start-up, will need to be submitted to EPA. If applicable, these requirements would need to be addressed in the permit modification.

Alternate 3 is likely to produce the largest increase in emissions, particularly of NO_x. Without controls, five 75 kw co-generators have the potential to increase facility-wide NO_x emissions by approximately 52 tons/yr. Depending upon the planned increases for fuel use, the facility could exceed the current NO_x cap and be required to apply for a Title V permit. Such an increase could also trigger NO_x RACT and NSR requirements. However, if appropriate NO_x controls are specified for the co-generators, emissions may stay below the 84 ton/yr cap. Many co-generators are available with controls that reduce NO_x emissions to 0.75 g/bhp-hr. If units with controls of this type are chosen, the use of five 75 kw co-generators would result in less than 4 tons/yr of increased NO_x emissions. In this case, the facility would be able to maintain a State Facility Permit with the current emission caps, modified to include the new sources and emission points.

Regardless of which case/alternate is chosen, the facility's State Facility Air Permit will need to be modified. The extent of the required modification, and the possibility that a Title V permit will be required, will depend on the specifications/ratings of the particular equipment that is chosen and the planned level of fuel use. For this analysis, the fuel oil usage has been kept constant with the natural gas usage adjusted accordingly.

4.0 RECOMMENDATIONS

Due to the current operation of the Central Heating Plant, from October to April or approximately seven months out of the year, the relatively favorable utility rates as compared to other parts of the state, justification for on-site generation is economically difficult. The alternatives evaluated have simple paybacks ranging from 9.3 years and higher, not including any funding incentives.

Due to the fact that high pressure steam (225 psi) is currently generated at the facility, peak electric shaving can be accomplished with minimal investment. By optimizing backpressure turbine output and operation and applying for exemption from the SC-14 tariff, an additional 1.7 million kWh can be generated, saving approximately $54,000 annually with a payback of 9.4 years.

Distributed generation also has similar economic benefits for buildings that have continuous thermal (hot water) loads throughout the year. Outfitting three buildings, the Avery Center for Drama and Arts, the Student's Center, and Walker Athletic Center with induction generator sets, while optimizing the operation of the existing backpressure turbine will result in an additional 4.2 million kWh that can be generated, saving approximately $112,000 annually with a payback of 9.6 years. This will also require an exemption from the SC-14 tariff. The one drawback with this alternative is locating this equipment in or near the existing facilities, from an aesthetics and noise standpoint.

Key factors in this study that would impact overall economic performance, include the following:

- If Vassar College intends to begin year round operation of the Central Heating Plant, it will improve the overall economics of these alternatives
- Securing potential funding incentives for CHP will improve overall economics
- Rising gas/fuel costs will negatively impact the economics, while rising electric costs will positively impact the economics
- For simplicity, downtime for the generation equipment has not been included in the utility cost analyses (maintenance costs have been included):
  - For the cases that evaluated non-summer operation, this should have minimal impact on economics since maintenance could be conducted during summer months when the system is shut down and high uptime should be achieved during operation
  - For the cases that evaluated summer operation the economics would be impacted for system downtime; one week of downtime for Alternate 1would reduce annual savings by approximately $4,900 or $29/hr, for Alternate 2 by approximately $9,600 or $57/hr, and for Alternate 3 by approximately $7,000 or $42/hr.

If Vassar College elects to proceed with one of these recommendations, it is recommended that a meeting be held with Central Hudson Gas & Electric's rate department to confirm that exemption from the SC-14 tariff will be granted.

New York State Energy Research and Development Authority support of this project through Program Opportunity Notice 795-02, "CHP and Renewable Generation Technical Assistance" made it possible for Vassar College to evaluate these alternatives that can potentially allow them to maintain a competitive facility operating budget.

APPENDIX B

Operating Model

VASSAR COLLEGE NYSERDA COGENERATION STUDY
Cogen Alternative #1 - 2 Parallel Turbines (300 & 750 kW)
Backpressure Steam Turbine Generators (T.G.)

Description: Two single stage backpressure turbines, one sized for 32,000 lbs/hr steam flow, the second for 12,000 lbs/hr, thermal following

Steam inlet conditions:	225 psig / 397 F	
Turbine exhaust pressure:	15	psig
Large Turbine Gen. Size	750	kW
Small Turbine Gen. Size	255	
Existing boiler efficiency	77%	
Annual kWh used	21,295,351	kWh/yr
Annual kWh produced	2,825,741	kWh/yr
	13.3%	of consumption
Supplemental kWh purch.	18,469,610	
Annual Steam Produced	137,855,684	lbs
Annual Fuel Used	1,828,826	therms/yr
Peak demand avoided	961	kW

Flows

Small turbine min	3,000	lbs/hr
Small turbine max	11,845	lbs/hr
Large turbine min	11,845	lbs/hr
Large turbine max	32,940	lbs/hr
Small Turbine hours	1,428	hrs/yr
Large Turbine hours	4,956	hrs/yr

test 0

Date	Campus Thermal Demand (Btu/hr)	Req'd HP Boiler Steam Flow (lbs/hr)	Average Electric Demand (kW)	Small Turbine Operation (oper)	Large Turbine Operation (oper)	Small Turbine Flow (lbs/hr)	Large Turbine Flow (lbs/hr)	Small Turbine Output (kW)	Large Turbine Output (kW)	Total T.G. Power (kW)	Average T.G. Power (% of avg. dmd)	Purchased Electric (kW)	Turbine Steam Flow (lbs/hr)	PRV flow (lbs/hr)	Iteration Info: Thermal Load Covered (Btu/hr)	Additional Load Required (Btu/hr)	Additional HP Steam (Btu/hr)	Total Steam Req'd (lbs/hr)	Boiler Fuel Used (therms)
9/1/02 0:00	0	0	1,774	0	0	0	0	0	0	0	0%	1,774	0	0	0	0	0	0	0
9/1/02 1:00	0	0	1,729	0	0	0	0	0	0	0	0%	1,729	0	0	0	0	0	0	0
9/1/02 2:00	0	0	1,653	0	0	0	0	0	0	0	0%	1,653	0	0	0	0	0	0	0
9/1/02 3:00	0	0	1,604	0	0	0	0	0	0	0	0%	1,604	0	0	0	0	0	0	0
9/1/02 4:00	0	0	1,579	0	0	0	0	0	0	0	0%	1,579	0	0	0	0	0	0	0
9/1/02 5:00	0	0	1,607	0	0	0	0	0	0	0	0%	1,607	0	0	0	0	0	0	0
9/1/02 6:00	0	0	1,676	0	0	0	0	0	0	0	0%	1,676	0	0	0	0	0	0	0
9/1/02 7:00	0	0	1,611	0	0	0	0	0	0	0	0%	1,611	0	0	0	0	0	0	0
9/1/02 8:00	0	0	1,665	0	0	0	0	0	0	0	0%	1,665	0	0	0	0	0	0	0
9/1/02 9:00	0	0	2,010	0	0	0	0	0	0	0	0%	2,010	0	0	0	0	0	0	0
9/1/02 10:00	0	0	2,100	0	0	0	0	0	0	0	0%	2,100	0	0	0	0	0	0	0
9/1/02 11:00	0	0	2,317	0	0	0	0	0	0	0	0%	2,317	0	0	0	0	0	0	0
9/1/02 12:00	0	0	2,385	0	0	0	0	0	0	0	0%	2,385	0	0	0	0	0	0	0
9/1/02 13:00	0	0	2,405	0	0	0	0	0	0	0	0%	2,405	0	0	0	0	0	0	0
9/1/02 14:00	0	0	2,416	0	0	0	0	0	0	0	0%	2,416	0	0	0	0	0	0	0
9/1/02 15:00	0	0	2,511	0	0	0	0	0	0	0	0%	2,511	0	0	0	0	0	0	0
9/1/02 16:00	0	0	2,511	0	0	0	0	0	0	0	0%	2,511	0	0	0	0	0	0	0
9/1/02 17:00	0	0	2,503	0	0	0	0	0	0	0	0%	2,503	0	0	0	0	0	0	0
9/1/02 18:00	0	0	2,512	0	0	0	0	0	0	0	0%	2,512	0	0	0	0	0	0	0
9/1/02 19:00	0	0	2,519	0	0	0	0	0	0	0	0%	2,519	0	0	0	0	0	0	0
9/1/02 20:00	0	0	2,492	0	0	0	0	0	0	0	0%	2,492	0	0	0	0	0	0	0
9/1/02 21:00	0	0	2,303	0	0	0	0	0	0	0	0%	2,303	0	0	0	0	0	0	0
9/1/02 22:00	0	0	2,261	0	0	0	0	0	0	0	0%	2,261	0	0	0	0	0	0	0
9/1/02 23:00	0	0	2,163	0	0	0	0	0	0	0	0%	2,163	0	0	0	0	0	0	0
9/2/02 0:00	0	0	2,080	0	0	0	0	0	0	0	0%	2,080	0	0	0	0	0	0	0
9/2/02 1:00	0	0	1,962	0	0	0	0	0	0	0	0%	1,962	0	0	0	0	0	0	0
9/2/02 2:00	0	0	1,818	0	0	0	0	0	0	0	0%	1,818	0	0	0	0	0	0	0
9/2/02 3:00	0	0	1,781	0	0	0	0	0	0	0	0%	1,781	0	0	0	0	0	0	0
9/2/02 4:00	0	0	1,766	0	0	0	0	0	0	0	0%	1,766	0	0	0	0	0	0	0
9/2/02 5:00	0	0	1,807	0	0	0	0	0	0	0	0%	1,807	0	0	0	0	0	0	0
9/2/02 6:00	0	0	2,032	0	0	0	0	0	0	0	0%	2,032	0	0	0	0	0	0	0
9/2/02 7:00	0	0	2,080	0	0	0	0	0	0	0	0%	2,080	0	0	0	0	0	0	0
9/2/02 8:00	0	0	2,310	0	0	0	0	0	0	0	0%	2,310	0	0	0	0	0	0	0
9/2/02 9:00	0	0	2,539	0	0	0	0	0	0	0	0%	2,539	0	0	0	0	0	0	0
9/2/02 10:00	0	0	2,747	0	0	0	0	0	0	0	0%	2,747	0	0	0	0	0	0	0
9/2/02 11:00	0	0	2,722	0	0	0	0	0	0	0	0%	2,722	0	0	0	0	0	0	0
9/2/02 12:00	0	0	2,747	0	0	0	0	0	0	0	0%	2,747	0	0	0	0	0	0	0
9/2/02 13:00	0	0	2,824	0	0	0	0	0	0	0	0%	2,824	0	0	0	0	0	0	0
9/2/02 14:00	0	0	2,827	0	0	0	0	0	0	0	0%	2,827	0	0	0	0	0	0	0
9/2/02 15:00	0	0	2,836	0	0	0	0	0	0	0	0%	2,836	0	0	0	0	0	0	0
9/2/02 16:00	0	0	2,808	0	0	0	0	0	0	0	0%	2,808	0	0	0	0	0	0	0
9/2/02 17:00	0	0	2,704	0	0	0	0	0	0	0	0%	2,704	0	0	0	0	0	0	0
9/2/02 18:00	0	0	2,709	0	0	0	0	0	0	0	0%	2,709	0	0	0	0	0	0	0
9/2/02 19:00	0	0	2,801	0	0	0	0	0	0	0	0%	2,801	0	0	0	0	0	0	0

VASSAR COLLEGE NYSERDA COGENERATION STUDY
Cogen Alternative #1a - 2 Parallel Turbines (250 & 750 kW) w/ Summer CHP Operation
Backpressure Steam Turbine Generators (T.G.)

Description: Two single stage backpressure turbines, one sized for 32,000 lbs/hr steam flow, the second for 12,000 lbs/hr, thermal following

Steam inlet conditions:	225 psig / 397 F	
Turbine exhaust pressure:	15	psig
Large Turbine Gen. Size	750	kW
Small Turbine Gen. Size	250	
Existing boiler efficiency	77%	
Annual kWh used	21,295,351	kWh/yr
Annual kWh produced	3,483,703	kWh/yr
	16.4%	of consumption
Supplemental kWh purch.	17,811,648	
Annual Steam Produced	169,770,988	lbs
Annual Fuel Used	2,252,222	therms/yr
Peak demand avoided	961	kW

Flows		
Small turbine min	3,000	lbs/hr
Small turbine max	11,845	lbs/hr
Large turbine min	11,845	lbs/hr
Large turbine max	32,940	lbs/hr
Small Turbine hours	4,809	hrs/yr
Large Turbine hours	4,956	hrs/yr

test 0

																Iteration Info				
Date	Campus Thermal Demand	Req'd HP Boiler Steam Flow	Average Electric Demand	Small Turbine Operation	Large Turbine Operation	Small Turbine Flow	Large Turbine Flow	Small Turbine Output	Large Turbine Output	Total T.G. Power	Average T.G. Power	Purchased Electric	Turbine Steam Flow	PRV flow	Thermal Load Covered	Additional Load Required	Additional HP Steam	Total Steam Req'd	Boiler Fuel Used
	(Btu/hr)	(lbs/hr)	(kW)	(oper)	(oper)	(lbs/hr)	(lbs/hr)	(kW)	(kW)	(kW)	(% of avg. dmd)	(kW)	(lbs/hr)	(lbs/hr)	(Btu/hr)	(Btu/hr)	(lbs/hr)	(lbs/hr)	(therms)
9/1/02 0:00	9,088,610	9,233	1,774	1	0	9,233	0	189	0	189	11%	1,585	9,233	0	9,088,171	439	0	9,234	122
9/1/02 1:00	9,088,610	9,233	1,729	1	0	9,233	0	189	0	189	11%	1,540	9,233	0	9,088,171	439	0	9,234	122
9/1/02 2:00	9,088,610	9,233	1,653	1	0	9,233	0	189	0	189	11%	1,464	9,233	0	9,088,171	439	0	9,234	122
9/1/02 3:00	9,088,610	9,233	1,604	1	0	9,233	0	189	0	189	12%	1,415	9,233	0	9,088,171	439	0	9,234	122
9/1/02 4:00	9,088,610	9,233	1,579	1	0	9,233	0	189	0	189	12%	1,390	9,233	0	9,088,171	439	0	9,234	122
9/1/02 5:00	9,088,610	9,233	1,607	1	0	9,233	0	189	0	189	12%	1,419	9,233	0	9,088,171	439	0	9,234	122
9/1/02 6:00	9,088,610	9,233	1,676	1	0	9,233	0	189	0	189	11%	1,487	9,233	0	9,088,171	439	0	9,234	122
9/1/02 7:00	9,088,610	9,233	1,611	1	0	9,233	0	189	0	189	12%	1,422	9,233	0	9,088,171	439	0	9,234	122
9/1/02 8:00	9,088,610	9,233	1,665	1	0	9,233	0	189	0	189	11%	1,476	9,233	0	9,088,171	439	0	9,234	122
9/1/02 9:00	9,088,610	9,233	2,010	1	0	9,233	0	189	0	189	9%	1,822	9,233	0	9,088,171	439	0	9,234	122
9/1/02 10:00	9,088,610	9,233	2,100	1	0	9,233	0	189	0	189	9%	1,911	9,233	0	9,088,171	439	0	9,234	122
9/1/02 11:00	9,088,610	9,233	2,317	1	0	9,233	0	189	0	189	8%	2,129	9,233	0	9,088,171	439	0	9,234	122
9/1/02 12:00	9,088,610	9,233	2,385	1	0	9,233	0	189	0	189	8%	2,196	9,233	0	9,088,171	439	0	9,234	122
9/1/02 13:00	9,088,610	9,233	2,405	1	0	9,233	0	189	0	189	8%	2,216	9,233	0	9,088,171	439	0	9,234	122
9/1/02 14:00	9,088,610	9,233	2,416	1	0	9,233	0	189	0	189	8%	2,228	9,233	0	9,088,171	439	0	9,234	122
9/1/02 15:00	9,088,610	9,233	2,511	1	0	9,233	0	189	0	189	8%	2,322	9,233	0	9,088,171	439	0	9,234	122
9/1/02 16:00	9,088,610	9,233	2,511	1	0	9,233	0	189	0	189	8%	2,322	9,233	0	9,088,171	439	0	9,234	122
9/1/02 17:00	9,088,610	9,233	2,503	1	0	9,233	0	189	0	189	8%	2,314	9,233	0	9,088,171	439	0	9,234	122
9/1/02 18:00	9,088,610	9,233	2,512	1	0	9,233	0	189	0	189	8%	2,323	9,233	0	9,088,171	439	0	9,234	122
9/1/02 19:00	9,088,610	9,233	2,519	1	0	9,233	0	189	0	189	7%	2,330	9,233	0	9,088,171	439	0	9,234	122
9/1/02 20:00	9,088,610	9,233	2,492	1	0	9,233	0	189	0	189	8%	2,303	9,233	0	9,088,171	439	0	9,234	122
9/1/02 21:00	9,088,610	9,233	2,303	1	0	9,233	0	189	0	189	8%	2,114	9,233	0	9,088,171	439	0	9,234	122
9/1/02 22:00	9,088,610	9,233	2,261	1	0	9,233	0	189	0	189	8%	2,072	9,233	0	9,088,171	439	0	9,234	122
9/1/02 23:00	9,088,610	9,233	2,163	1	0	9,233	0	189	0	189	9%	1,974	9,233	0	9,088,171	439	0	9,234	122
9/2/02 0:00	9,088,610	9,233	2,080	1	0	9,233	0	189	0	189	9%	1,891	9,233	0	9,088,171	439	0	9,234	122
9/2/02 1:00	9,088,610	9,233	1,962	1	0	9,233	0	189	0	189	10%	1,774	9,233	0	9,088,171	439	0	9,234	122
9/2/02 2:00	9,088,610	9,233	1,818	1	0	9,233	0	189	0	189	10%	1,629	9,233	0	9,088,171	439	0	9,234	122
9/2/02 3:00	9,088,610	9,233	1,781	1	0	9,233	0	189	0	189	11%	1,592	9,233	0	9,088,171	439	0	9,234	122
9/2/02 4:00	9,088,610	9,233	1,766	1	0	9,233	0	189	0	189	11%	1,577	9,233	0	9,088,171	439	0	9,234	122
9/2/02 5:00	9,088,610	9,233	1,807	1	0	9,233	0	189	0	189	10%	1,618	9,233	0	9,088,171	439	0	9,234	122
9/2/02 6:00	9,088,610	9,233	2,032	1	0	9,233	0	189	0	189	9%	1,844	9,233	0	9,088,171	439	0	9,234	122
9/2/02 7:00	9,088,610	9,233	2,080	1	0	9,233	0	189	0	189	9%	1,891	9,233	0	9,088,171	439	0	9,234	122
9/2/02 8:00	9,088,610	9,233	2,310	1	0	9,233	0	189	0	189	8%	2,121	9,233	0	9,088,171	439	0	9,234	122
9/2/02 9:00	9,088,610	9,233	2,539	1	0	9,233	0	189	0	189	7%	2,350	9,233	0	9,088,171	439	0	9,234	122
9/2/02 10:00	9,088,610	9,233	2,747	1	0	9,233	0	189	0	189	7%	2,559	9,233	0	9,088,171	439	0	9,234	122
9/2/02 11:00	9,088,610	9,233	2,722	1	0	9,233	0	189	0	189	7%	2,533	9,233	0	9,088,171	439	0	9,234	122
9/2/02 12:00	9,088,610	9,233	2,747	1	0	9,233	0	189	0	189	7%	2,558	9,233	0	9,088,171	439	0	9,234	122
9/2/02 13:00	9,088,610	9,233	2,824	1	0	9,233	0	189	0	189	7%	2,635	9,233	0	9,088,171	439	0	9,234	122
9/2/02 14:00	9,088,610	9,233	2,827	1	0	9,233	0	189	0	189	7%	2,639	9,233	0	9,088,171	439	0	9,234	122
9/2/02 15:00	9,088,610	9,233	2,836	1	0	9,233	0	189	0	189	7%	2,648	9,233	0	9,088,171	439	0	9,234	122
9/2/02 16:00	9,088,610	9,233	2,808	1	0	9,233	0	189	0	189	7%	2,619	9,233	0	9,088,171	439	0	9,234	122
9/2/02 17:00	9,088,610	9,233	2,704	1	0	9,233	0	189	0	189	7%	2,515	9,233	0	9,088,171	439	0	9,234	122
9/2/02 18:00	9,088,610	9,233	2,709	1	0	9,233	0	189	0	189	7%	2,520	9,233	0	9,088,171	439	0	9,234	122
9/2/02 19:00	9,088,610	9,233	2,801	1	0	9,233	0	189	0	189	7%	2,612	9,233	0	9,088,171	439	0	9,234	122

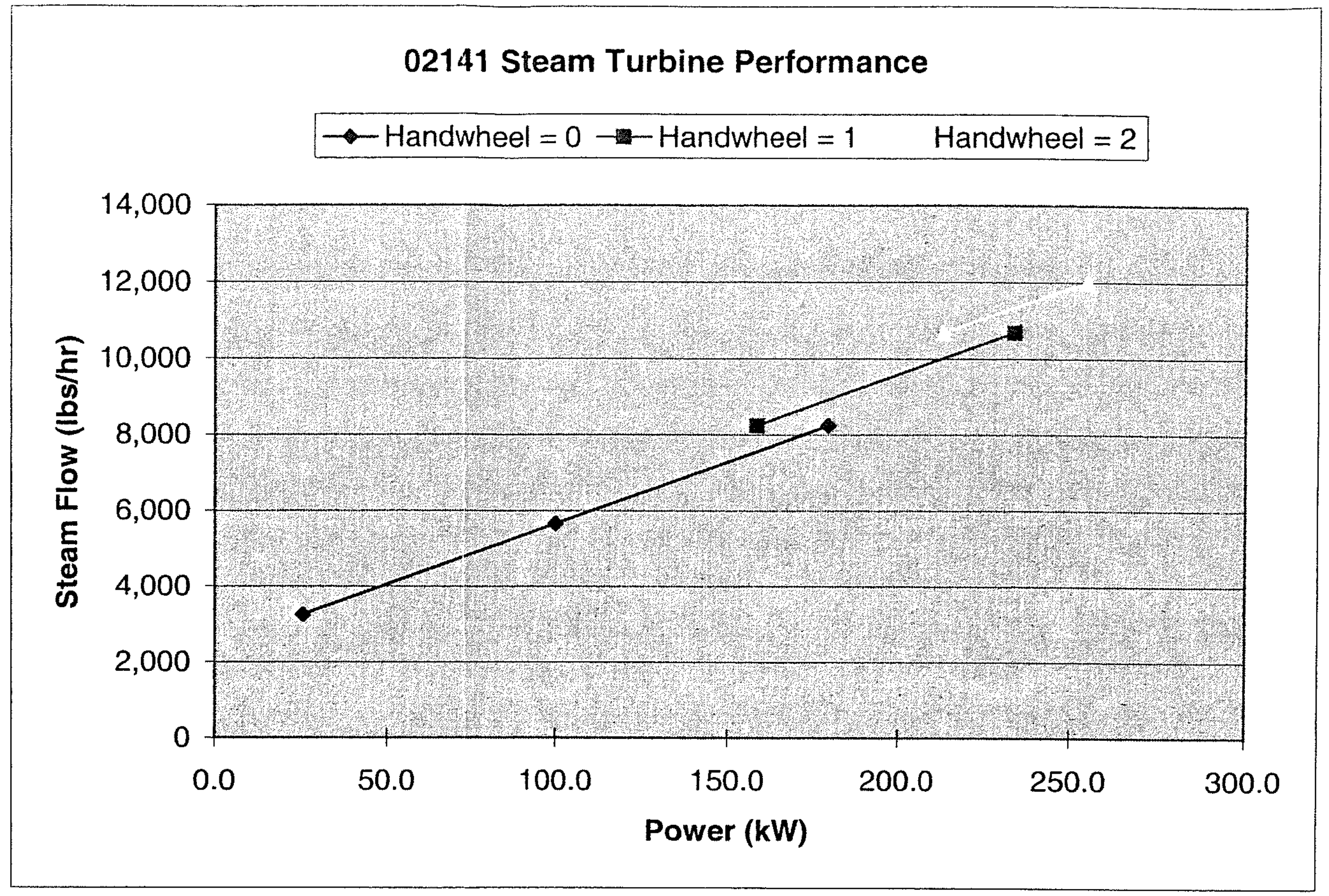
Vassar College
CHA #13632
250 kW Steam Back Pressure Turbine

Generator Efficiency 0.948

lbs/hr	horsepower	kw	EQ1	EQ2	
Handwheel = 0					
3,250	25	25.0	0.0309	32.38	slope
5,650	150	100.0	-75.1	2431	intercept
8,249	260	179.4			
1,000 <= steam <= 7,500					
Handwheel = 1					
8,250	250	158.1	0.0311	32.18	slope
10,686	340	233.8	-98.3	3162	intercept
7,500 < steam <= 10,000					
Handwheel = 2					
10,687	330	213.2	0.0318	31.49	slope
12,000	400	254.9	-126.2	3974.01	intercept
10,000 < steam <= 12,000					

*EQ1 slope and intercepts are for the following formula:
kW = (slope*lbs/hr) + intercept

**EQ2 slope and intercepts are for the following formula:
lbs/hr = (slope*kW) + intercept



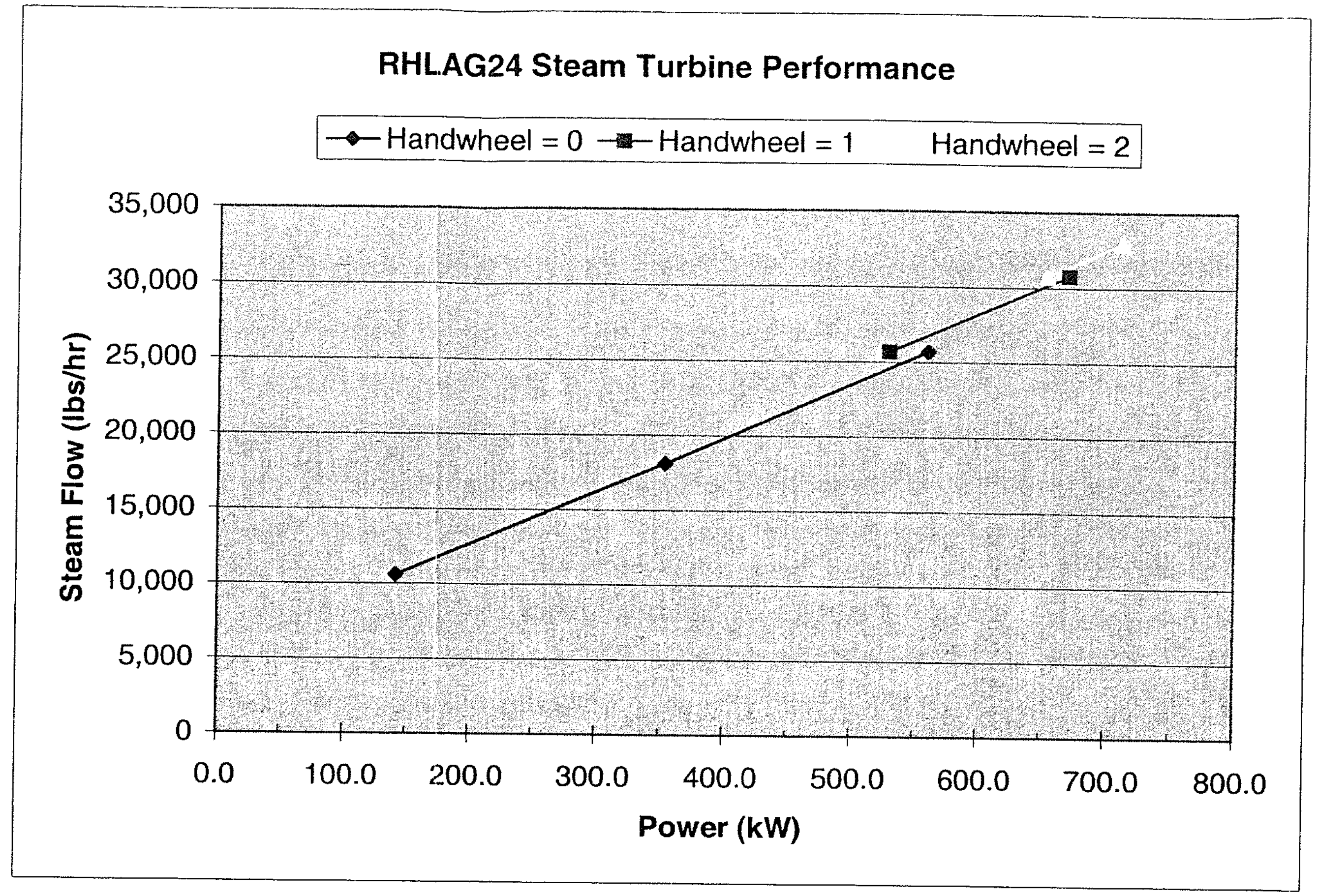
Vassar College
CHA #13632
750 kW Steam Back Pressure Turbine

Generator Efficiency 0.948

lbs/hr	horsepower	kw	EQ1	EQ2	
Handwheel = 0					
10,588	200	141.4	0.0277	36.10	slope
18,136	500	353.6	-150.8	5446	intercept
25,686	791.4	559.7			
11,135 <= steam <= 28,405					
Handwheel = 1					
25,687	748.3	529.2	0.0277	36.04	slope
30,784	948.3	670.6	-183.6	6617	intercept
25,784 < steam <= 30,780					
Handwheel = 2					
30,785	924.1	653.5	0.0269	37.21	slope
32,940	1006	711.5	-173.9	6470	intercept
30,780 < steam <= 32,940					

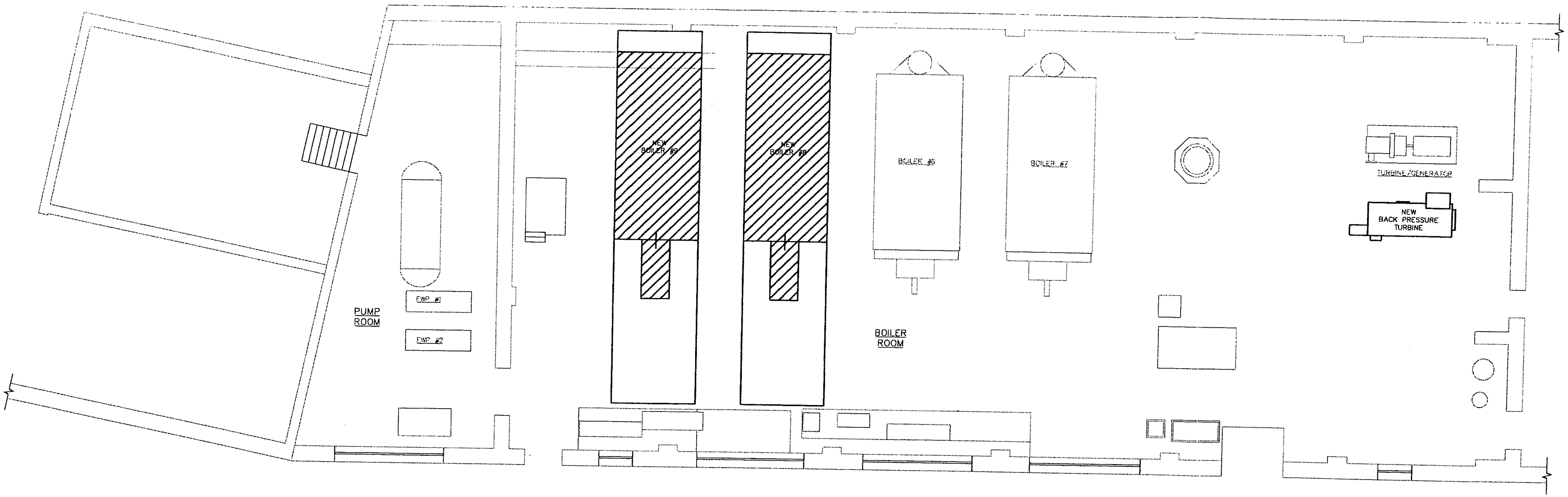
*EQ1 slope and intercepts are for the following formula:
kW = (slope*lbs/hr) + intercept

**EQ2 slope and intercepts are for the following formula:
lbs/hr = (slope*kW) + intercept



APPENDIX C

Layout and System Schematic



PUMP AND BOILER ROOM PLAN
SCALE: N.T.S.

Revisions:	Drawn By:	App'd. By:	Date:

Designed By:	Date:
MJC	2/05
Drawn By:	Date:
KHO	2/05
Checked By:	Date:
AWL	2/05

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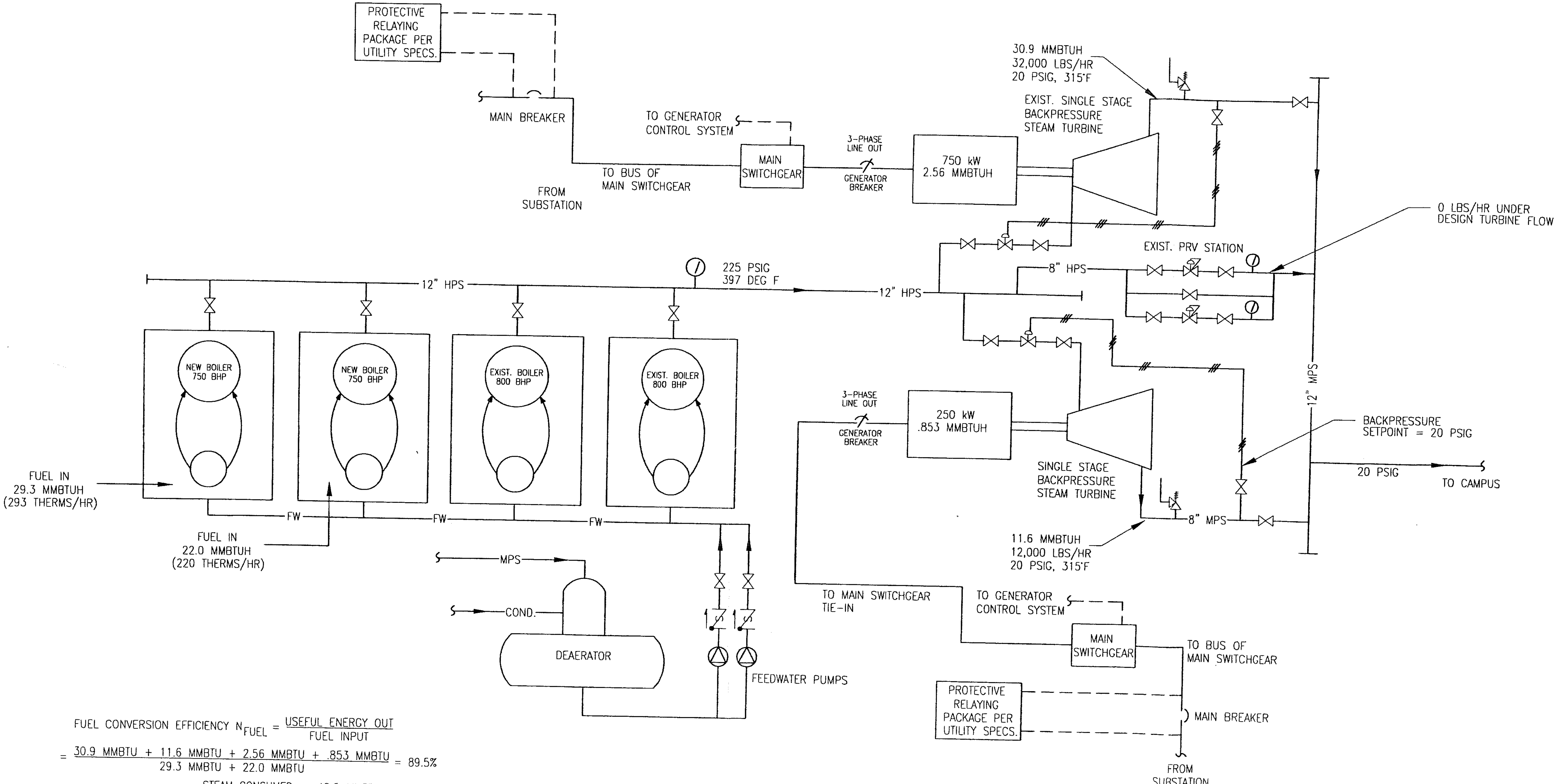
www.cloughharbour.com

VASSAR
POUGHEEPIE, NY

VASSAR COLLEGE
CENTRAL HEATING PLANT
FLOOR PLANS
ALTERNATE 1
2 – NEW 750 BHP STEAM BOILERS
1 – NEW BACK PRESSURE TURBINE

Drawing No.
M-3



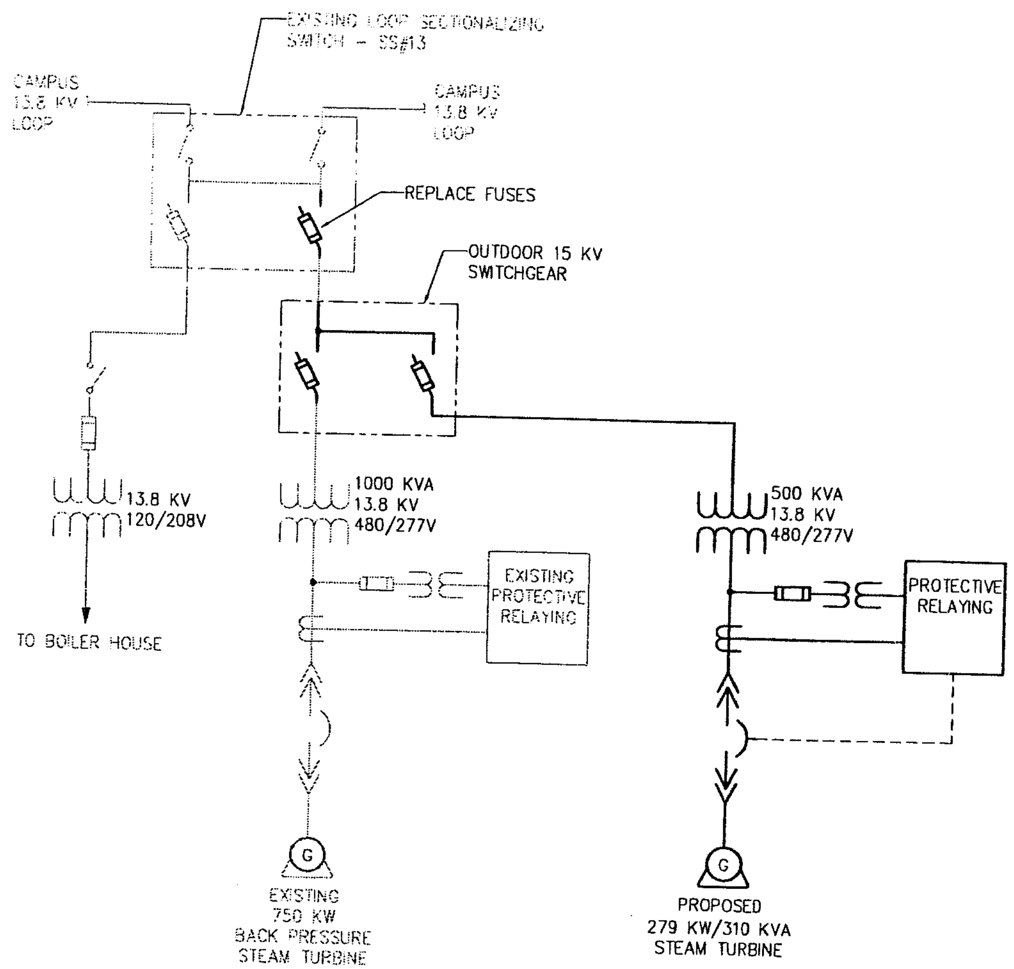
FUEL CONVERSION EFFICIENCY $N_{FUEL} = \frac{\text{USEFUL ENERGY OUT}}{\text{FUEL INPUT}}$

$$= \frac{30.9 \text{ MMBTU} + 11.6 \text{ MMBTU} + 2.56 \text{ MMBTU} + .853 \text{ MMBTU}}{29.3 \text{ MMBTU} + 22.0 \text{ MMBTU}} = 89.5\%$$

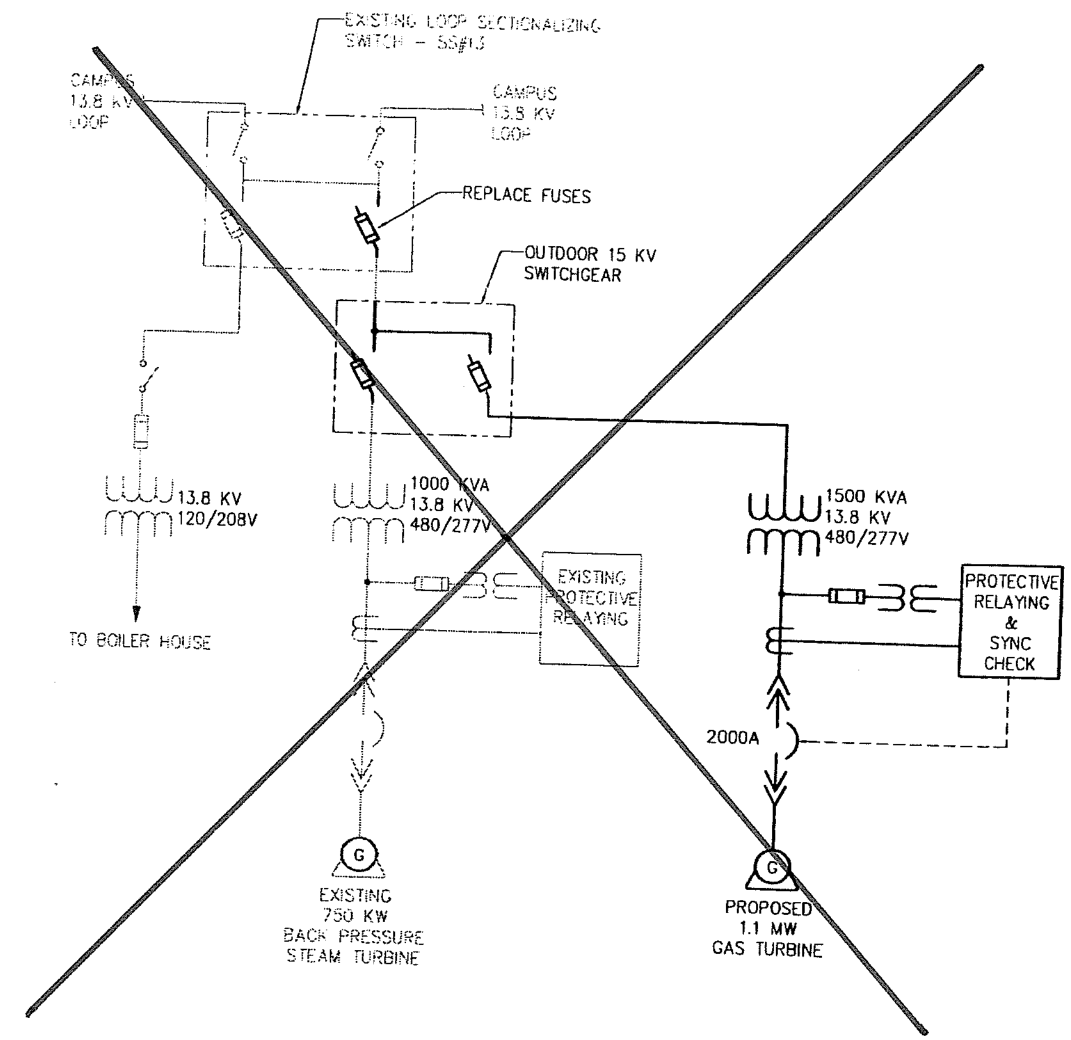
$$\text{THERMAL UTILIZATION} \equiv \frac{\text{STEAM CONSUMED}}{\text{STEAM PRODUCED}} = \frac{42.5 \text{ MMBTUH}}{42.5 \text{ MMBTUH}} = 100\%$$

CHA
CLOUGH HARBOUR & ASSOCIATES LLP

COGENERATION ALTERNATIVE 1 DUAL STEAM TURBINES	Date: 2/05	Project No.: 13632
VASSAR COLLEGE CHA #13632 COMBINED HEAT AND POWER STUDY	Scale: NTS	Sheet No.: SK-1
	Drawn By:	Checked By:



ALTERNATE #1
SCALE: N.T.S.



~~ALTERNATE #2~~
~~SCALE: N.T.S.~~

Revisions:	Drawn By:	App'd. By:	Date:

Designed By:	Date:
JBF	2/05
Drawn By:	Date:
KHO	2/05
Checked By:	Date:
JBF	2/05

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VASSAR
POUGHEEPIE, NY

VASSAR COLLEGE
CENTRAL HEATING PLANT
FLOOR PLANS

ALTERNATE 1 & 2
1 - NEW 750 BHP STEAM BOILER OR

Drawing No.
E-1