FINAL REPORT

Demonstrating a Combined Heat and Power (CHP) System: V.I.P. Country Club Cogeneration Facility New Rochelle, New York

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NYSERDA Project #7306
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Submitted to:
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Notice

Project Summary

The V.I.P. Country Club Cogeneration Project involved the installation and demonstration of a combined cooling, heating and electric power system (CCHP). Unlike the majority of the electric power generation plants operating in the United States, the system installed at the V.I.P. Country Club utilizes a single combustion source for providing the majority of the facility's electric power, heating and cooling. The combustion source consists of three 60 kilowatt natural gas fired Capstone MicroTurbines capable of generating electric power in grid parallel and stand alone mode. Three heat exchangers are utilized to recover the thermal energy from the microturbine exhaust for producing hot water, and three 20 ton (minimum cooling capacity) hot water fired lithium bromide absorption chillers for producing chilled water. The cogeneration system is designed to remove 240 kW of electric load from the Con Edison grid during peak electric power demand. Typically this condition occurs during the summer when catering events are the most popular.

Site Description

The V.I.P. Country Club is a 70,000 square foot facility that specializes in catering services for weddings, conferences, and fund raising events. The majority of the catering services are provided on Friday, Saturday and Sunday for a period of 14 hours for each of these days. Weekdays including Monday through Thursday are typically used for showcasing the facility for attracting new business. The building has two ballrooms, one cocktail room, two large food preparation areas, and moderately sized office space. Cumulatively, the two ballrooms and cocktail room can accommodate approximately 850 people. The elevated human activity associated with catering functions produces an unusually large amount of latent heat which increases the humidity in the living space. The large latent cooling load combined with the typical sensible cooling load in this region increases the operating time and cycling of the existing roof-top air conditioning units. Continuous cycling of vapor compression air conditioning equipment can dramatically increase electric demand costs.

The water-front view of the Long Island Sound provides a very pleasant experience for clientele of the V.I.P. Country Club and numerous other similar catering facilities located on Davenport Avenue in New Rochelle. However, because these facilities are located within a few hundred feet of the Long Island Sound and on the outer perimeter of the electric grid, they are susceptible to frequent electric grid power failures caused by high winds and broken tree limbs.

Energy Consumption Characteristics

Electric and Natural Gas load profiles presenting consumption characteristics for a typical busy winter day are presented in the Appendix. Also included are monthly Electric Consumption, Electric Demand and Natural Gas Consumption charts.

System Description

A description of each major subsystem installed for this project is identified as follows:

Subsystem	Specifications
Electric Power Generators	Manufacturer: Capstone Turbine Corporation Model: C60 Number of Units: 3 Maximum Power Rating: 60 kW each Fuel: Natural Gas Minimum Fuel Inlet Pressure: 75 psi Operating Modes: Grid Connect and Stand Alone
Natural Gas Compressors	Manufacturer: Copeland Corporation Model: 03AA1594 Number of Units: 3 Minimum Fuel Inlet Pressure: 2 inches WG Maximum Fuel Outlet Pressure: 100 psi
Dual Mode Controller	Manufacturer: Capstone Turbine Corporation Model: 208 VAC, 600 Amp Number of Units: 1
Protective Relays	Manufacturer: Schweitzer Model: SEL-547 Manufacturer: Basler Model: BE1-32R
Heat Recovery Units	Manufacturer: Super Radiator Corporation Model: Custom Built Number of Units: 3
Absorption Chillers	Manufacturer: Yazaki Model: Hot Water Fired Lithium Bromide Absorption Chiller Number of Units: 3 Maximum Chilling Rating: 20 Tons each
Chilled/Hot Water Coils	Manufacturer: Super Radiator Corporation Model: Custom Built Number of Units: 8
Computer Control and Data Acquisition System	Manufacturers: Agilent VeePro (DAQ Software) and Measurement Computing (DAQ Boards)

The electric power and natural gas for the V.I.P. Country Club are supplied by Consolidated Edison of New York, Inc. The electric service is rated for 208 VAC, 3 Phase, and 2,500 Amps and enters at the Northwest corner of the facility. The natural gas supplied at the service entrance is 5 psi (referred to as medium pressure) and is delivered via a 2 inch steel pipe (and also enters at the Northwest corner of the facility). The only available space for the gas compressors and the microturbines was the Southeast corner of the facility, and because the maximum allowable natural gas pressure within a building is 4 inches of WG (water gauge), as required by the local building code, a 160 foot 4 inch pipe had to be installed to deliver the gas to the compressors. The three Copeland compressors raise the gas pressure from 4 inches of WG to approximately 80 psi. Three Capstone MicroTurbines, each rated at 60 kW, use the 80 psi natural gas to generate electricity, and the thermal energy recovered from the exhaust is used to produce hot water. The hot water is then either used for comfort space heating, or used to provide the thermal energy for three lithium bromide absorption chillers; which produce chilled water for comfort space cooling. The system can provide either comfort heating, or comfort cooling, depending on seasonal requirements, but not both simultaneously.

Grid Connect (GC) Mode

When operating in Grid Connect (GC) Mode, the three 60 kW microturbines are used to supplement the electric power provided by Consolidated Edison of New York, Inc. In this mode of operation, the protective relays installed as part of the objectives of this project, prohibit the export of electric power.

Load Following and GC Operation

The Capstone MicroTurbine is equipped with an electric load following power management feature when operating in GC Mode. To enable this feature the installation of a utility grade power meter which transmits a pulsed 5 VDC signal to the master microturbine is required. The procurement and installation of the power meter, along with the additional control wiring is well worth the cost. When the load following power management feature is enabled, the microturbines will follow the electric power demand of the facility. The quantity of power supplied by the utility can be programmed by adjusting the “Utility Power Set Point” and the “Minimum Power Shutoff” parameters, each of which are field adjustable.

Stand Alone (SA) Mode

The Capstone MicroTurbine can be manufactured to generate electric power in GC, SA or GC and SA Modes. When operating in SA Mode the microturbine does not require the utility voltage and frequency as a reference. Hence, the microturbine is essentially the same as an emergency back-up generator when operating in SA Mode. The microturbines will produce up to their maximum rated electric output of 180 kW, and will load follow the facility's electric power requirements.

Dual Mode Operating Features

When equipped with GC and SA capabilities, the proper operation of the equipment requires the installation of a Dual Mode Controller (DMC). The operating mode transition sequence is described below:

GC to SA

- The microturbines are operating in GC mode.
- A utility power abnormality is detected (typically a voltage or frequency excursion).
- The electrically operated circuit breaker located in the DMC opens, isolating the microturbines and protected electric loads from the utility.
- The microturbine output contactors open.
- The microturbines initiate a warm shutdown. In contrast to a normal shutdown (cooldown), which involves a motor assisted self cooling process, a warm shutdown causes the microturbines to utilize the available thermal energy to achieve a controlled shutdown.
- The microturbines start in Stand Alone Mode using the internal batteries for achieving the necessary rotational speed.
- The microturbine output contactors close.
- Electric power is supplied to the protected loads.

SA to GC

- Utility power is restored.
- The microturbine output contactors open.
- The electrically operated circuit breaker located in the DMC closes, allowing the utility to supply electric power to the facility.
- The microturbines initiate an internal battery recharge cycle.
- When the batteries are sufficiently charged, the microturbine initiates a normal shutdown (cooldown).
- After 1 minute (minimum), the microturbines re-start in GC Mode.

Multi-Pac Operation

The three microturbines installed at the V.I.P. Country Club are configured in a multi-pac arrangement, whereby one unit acts as the master and the other two units act as slaves and follow the instruction of the master. The Multi-Pac feature offered by

Capstone Turbine Corporation enables the three 60 kW Capstone MicroTurbines to operate as one 180 kW unit. If the operating parameters for each microturbine are the same, the electric load will be shared equally. However, microturbine number 1 (identified as the master for this system) will supply a greater amount of electric power than microturbine number 2, if the combustion air temperature entering microturbine number 1 is lower. An attractive feature of the multi-pac configuration is that power can be delivered by two or even one microturbine should one or two of the other microturbines experience a problem. In fact, even if the master microturbine experiences a problem, the two slaves will continue to operate, and will provide an equivalent amount of electric power as if three microturbines were operating, limited of course by the maximum power output of each microturbine (for this situation the maximum total power output of the two slaves would be 120 kW).

Observations, Findings and Recommendations

Manufacturers Participating in Projects Co-Funded by NYSERDA. All of the major equipment procured for the V.I.P. Country Club Cogeneration Project is covered by a manufacturer's warranty. Typically the manufacturers warranty will cover the material and labor cost to replace the defective component. However, there was a case where the manufacturer, Copeland Corporation, initially was not willing to supply a replacement for the defective component. In fact, Copeland Corporation eventually decided to replace the defective component only after being contacted by NYSERDA's Project Manager. In addition, Copeland Corporation has not made payment for the labor required to replace the defective component. The commencement of the warrantee period should be referenced as commencing upon activation of an installed component, not upon receipt of delivery of a component at the job site (in order to avoid having a warrantee period expire while a component is being staged at a job site prior to its installation – otherwise, a defect might not be detectable during the warrantee period).

Recommendation: NYSERDA might consider establishing a Preferred Equipment Supplier List that provides Contractors with the ability to determine if an equipment supplier has a credible record for adhering to published warranty documents.

Interconnection Requirements. The Standard Interconnection Requirements (SIR) established by the New York State Public Service Commission is a general document describing the responsibilities of the electric utility and the customer for distributed generation systems. For situations where the SIR document does not address the precise technical features for the required equipment, reference is made to review the electric utility's distributed generation documents. For the V.I.P. Country Club Cogeneration Project, the electrical relay protection system was designed to comply with the requirements of Specification EO-2115, as published by Consolidated Edison of New York, Inc (Con Edison). However, during an inspection of the equipment and subsequent relay testing, employees of Con Edison requested additional items not identified in Specification

EO-2115. A few of these items include screw-mounted stamped metal plates identifying each relay (as opposed to adhesive-mounted laminated labels), and multi-colored lamps indicating intertie breaker position.

Recommendation: The New York State Public Service Commission should require the electric utility to adhere to their published specifications.

Payments from NYSERDA. The completion of a cogeneration or CHP Project is time critical. That is, the sooner the system becomes operational, the sooner the building owner can benefit from the economic projections anticipated for the system.

Recommendation: NYSERDA might consider establishing a payment schedule that provides more funding during the initial phase of the project to offset the late deliveries usually experienced with state-of-the-art equipment.

Contingent Funding. Contractors engaged in the design and installation of cogeneration projects typically experience a series of problems which are very difficult to anticipate. For example, a Micogen Heat Recovery component was originally specified for the V.I.P. Country Club Cogeneration Project; however, since this unit is no longer being produced, a custom designed heat exchanger had to be manufactured. This change substantially increased the cost of the project.

Recommendation: NYSERDA might consider providing a 5% to 10% contingency payment added to the grant. After acquiring the knowledge required to install a cogeneration system, it would be tragic if a contractor could not survive the unexpected financial burdens often encountered with this type of technology.

Project Results and Lessons Learned

Although the V.I.P. Country Club Cogeneration Facility is currently performing admirably, there were a few issues that could have potentially inhibited the success of the project. These issues resulted from a combination of carelessness and lack of attention to detail on the part of the licensed electrical and plumbing contractors who served as subcontractors on the job. The possession of a license issued by a government organization is an important requirement; however, a conscientious workforce is equally as important.

Noteworthy lessons learned during the construction of the V.I.P. Country Club Cogeneration Facility include:
1) Avoid the custom design of a major system component, regardless of the attractive engineering challenge. The resulting financial and installation hardships associated with custom designed components are exorbitant.
2) Whenever possible, reduce the amount of labor required at the work site. That is, purchase equipment pre-assembled by a reputable manufacturer.

3) During project scoping, expend sufficient time evaluating the benefits and disadvantages of: a) installing the equipment outside of the building (environmental consequences for reliable equipment operation may not be that consequential), b) pumping and electric distribution losses associated with long distances between subsystems, and c) the cost of labor and material associated with the items a and b.

Anticipated Energy, Environmental, and Economic Benefits

The three 60 kW Capstone MicroTurbines installed as part of V.I.P. Country Club Cogeneration Facility became operational on December 24, 2004. For the billing period beginning on January 10 and ending on February 10 of 2005, the electric demand was reduced by approximately 120 kW. Following the repair of the hydronic hot water circuit, the heat recovery system became operational during late February 2005. Hence, additional savings is anticipated from the reduced consumption of Natural Gas normally used for building heat. See the Appendix for a table of the electric utility bills for the past two years.

Energy Benefits. The data acquired for the heat recovery system:
Hot Water Inlet = 188 degrees F
Hot Water Outlet = 210 degree F
Heat Recovered = 1.27 million BTU

Economic Benefits. As a result of electric demand load shaving provided by the microturbines, the savings for the aforementioned billing period was approximately $2,200 (this value includes an increase of approximately 20 kW of electric power relative to last year).

Environmental Benefits. Environmental benefits are projected to accrue and be attributable to the displacement of emissions that would otherwise be produced onsite by the existing Boilers and Domestic Hot Water Heater which operate on natural gas, and the displacement of regional emissions from central power stations due to the decreased consumption of grid-supplied electricity (decreased consumption of grid-supplied electricity occurs due to self-generation of electricity, and due to displacement of electric-driven cooling by waste-heat-driven absorption cooling). Westchester County is one of several ozone (O_3) non-attainment areas in New York State. Oxides of nitrogen (NO_X) emissions, produced by coal, diesel, and natural gas power plants, contribute to the formation of ground level ozone (O_3). O_3 is formed photochemically from a mixture of hydrocarbons (HC), NO_X, and ultraviolet solar radiation. The significant human health issues associated with exposure to O_3 include eye and throat irritation, lung tissue damage, and increased susceptibility to respiratory illness.

Reduced emissions of SO_2 and NO_X are the major environmental benefits resulting from the installation of the CHP system. Together, SO_2 and NO_X are the major precursors to acidic deposition (acid rain), which is associated with the acidification of lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. The table below presents mass emission data based on power production, and annual emissions based on facility energy consumption. The Capstone Microturbine Model C60 emits less of these gaseous pollutants per kilowatt hour than the average utility operated fossil fuel (i.e., coal, diesel, or natural gas) electric power plant in New York State. Further improvements in air quality can also be achieved with the CHP system because the thermal energy recovered shall: 1) eliminate pollutants normally emitted by burning fossil fuel for the facility's heating system and provide domestic hot water, and 2) drive the absorption chillers, thus eliminating the pollutants associated with generating the electric energy required to operate the vapor compression air conditioning system.

Power Plant Emissions Comparison

Pollutant	**Averaged Emissions for Fossil Fueled Electric Power Plants in New York State** [a]		***Emissions for Capstone Microturbine operating on Natural Gas at Full Power***	
	lb/MWh	***lb/year (based on annual consumption for the facility)***	***lb/MWh***	***lb/year (based on annual consumption for the facility)***
NO_X	*1.13*	*814*	*0.507*	*365*
SO_2	*3.32*	*2390*	*negligible b*	negligible

[a] *Source:* U.S. Department of Energy (DOE). Emission data for New York State in 1999. Emission data for New York State in 2000 not available at time of initial writing.
[b] Hydrogen Sulfide (H_2S) is removed from natural gas prior to its use as a fuel; therefore a negligible quantity of SO_2 is measured in the combustion products.

Timeline of Progress for Conducting the V.I.P. Country Club Cogeneration Project		
Date	**Description of Milestone**	**Comments**
January 2002	Advanced Power Systems Engineering meets with the owners of the V.I.P. Country Club to present the economic benefits of installing a microturbine cogeneration system at the site. The upcoming funding opportunity PON-669 and the Loan Fund Program offered by NYSERDA are also discussed.	
February 2002	The owners of the V.I.P. Country Club authorize Advanced Power Systems Engineering to prepare the proposal for funding opportunity PON-669.	
March 2002	Advanced Power Systems Engineering submits the completed proposal for funding opportunity PON-669 to NYSERDA.	
June 2002	The V.I.P. Country Club is awarded 50% of the cost of the proposed microturbine cogeneration project by NYSERDA under funding opportunity PON-669.	
March 2003	Advanced Power Systems Engineering and the V.I.P. Country Club enter into a contractual agreement to conduct the project.	
March 2003	Three Capstone 60 kW MicroTurbines and three Copeland Gas Compressors are ordered.	This equipment was delivered to the site 7 weeks behind schedule.
March 2003	Three Yazaki 20 Ton Absorption Chillers are ordered.	This equipment was delivered to the site 6 weeks behind schedule.
March 2003	File the construction plans for building the generator and equipment rooms with the City of New Rochelle Bureau of Buildings.	
April 2003	Three Custom Designed Heat Recovery units are ordered.	This equipment was delivered to the site on schedule.

June 2003	One 160 Ton Baltimore Air Coil Cooling Tower, pumps for various water circuits, and one 250 KVA transformer are ordered.	This equipment was delivered to the site 2 weeks behind schedule.
July 2003	One Capstone Dual Mode Controller rated for 600 Amps and 208 VAC is ordered.	This equipment was delivered to the site 7 weeks behind schedule.
July 2003	Switchgear, circuit breakers, circuit breaker panels, fused disconnect switches, motor starters, electric enclosures, control system components are procured.	
August 2003	Build concrete block building for housing the heat recovery units and chillers, and set all major components of the cogeneration system in place.	
September through December of 2003	Procure Stainless Steel double wall insulated engine exhaust ducts (three individual orders were required).	
December 2003	Install Capstone Dual Mode Controller and complete all electrical and mechanical connections.	
January through February of 2004	Install Stainless Steel double wall insulated engine exhaust ducts between microturbines, heat recovery units and outlet to atmosphere.	
March 2004	Procure external protective relay devices and load following power meter.	
April through May of 2004	Complete electric control connections for Capstone Dual Mode Controller, external protective relay devices, and load following power meter. Commission Capstone MicroTurbines.	
June 2004	Conduct Pre-Operational Relay Test as required by Consolidated Edison of New York (first attempt).	The protective relay control system failed the electrical interconnection test because of problems discovered with the control wiring.

July 2004	Conduct Pre-Operational Relay Test as required by Consolidated Edison of New York (second attempt).	The protective relay control system failed the electrical interconnection test because of problems discovered with the design of the electric circuitry.
August 2004	Commission Yazaki Absorption Chillers.	
September through October of 2004	Leaks were discovered in both the low and high pressure natural gas piping. Replace pipe fittings as required to correct the pipeline.	
November 2004	Conduct Pre-Operational Relay Test as required by Consolidated Edison of New York (third attempt).	The protective relay control system passed the electrical interconnection test.
December 2004	The Capstone MicroTurbines, Dual Mode Controller, and external protective relay system becomes fully operational.	
January 2005	Procure and install fiberglass pipe insulation and PVC protective covers on all exterior hydronic piping. Fill the exterior hydronic piping with Ethylene Glycol.	
February 2005	The comfort heating system becomes fully operational.	

APPENDIX

Photographs, Schematics, Charts, and Tables

Capstone Microturbines and Copeland Natural Gas Compressors

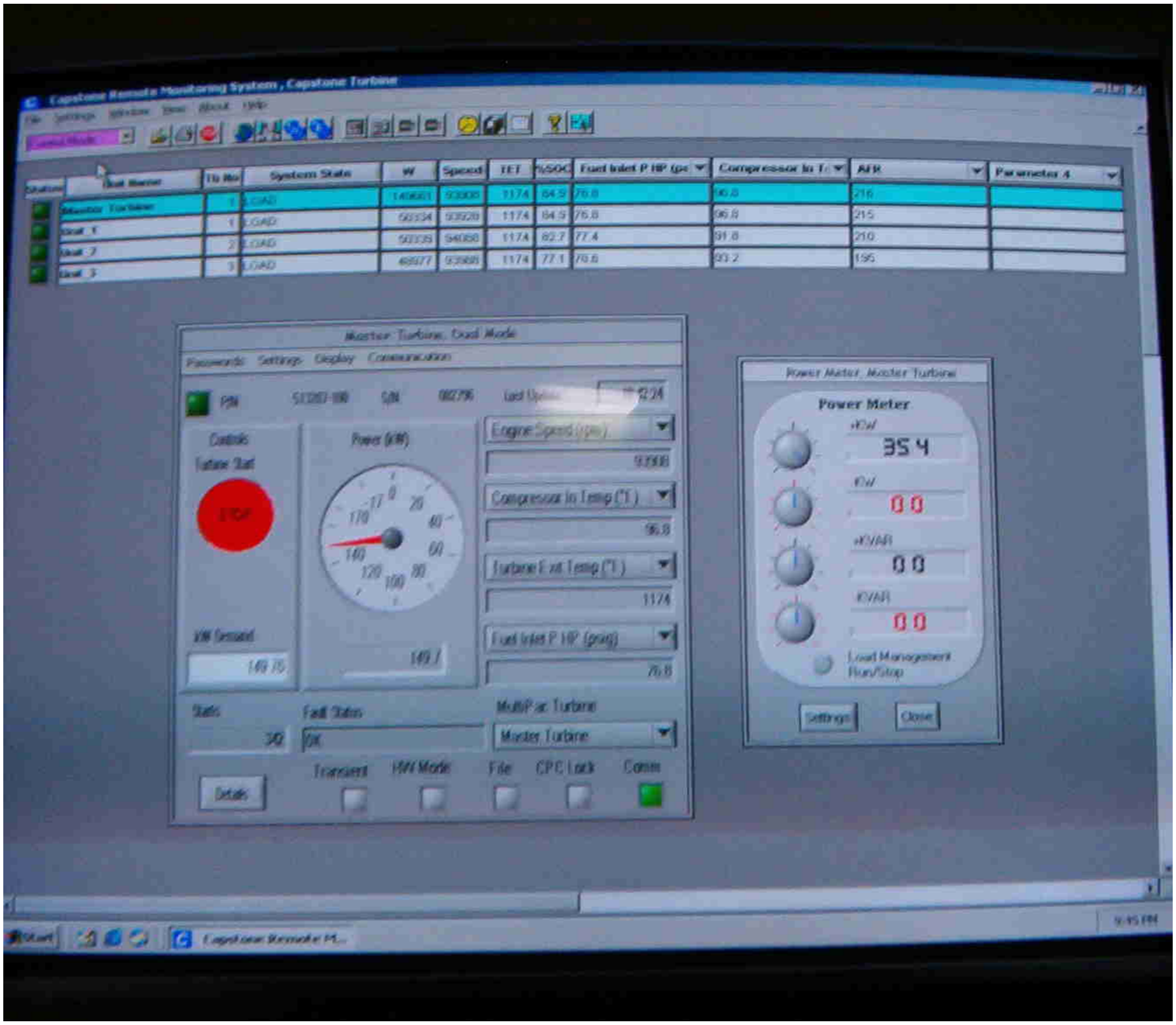
Three Heat Recovery Units

Three 20 Ton Yazaki Absorption Chillers

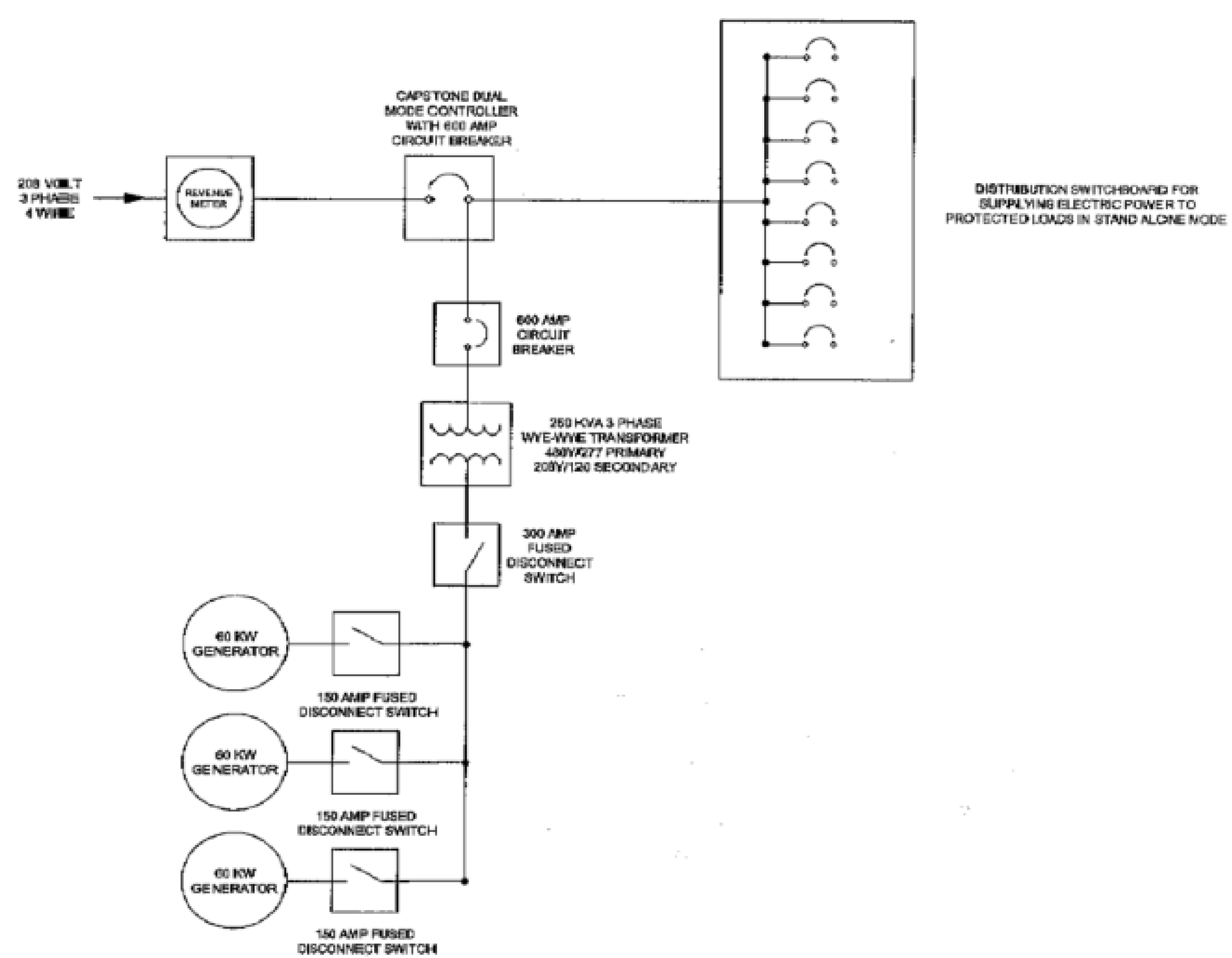
600 Amp Capstone DMC Equipped Shunt Trip Intertie Breaker

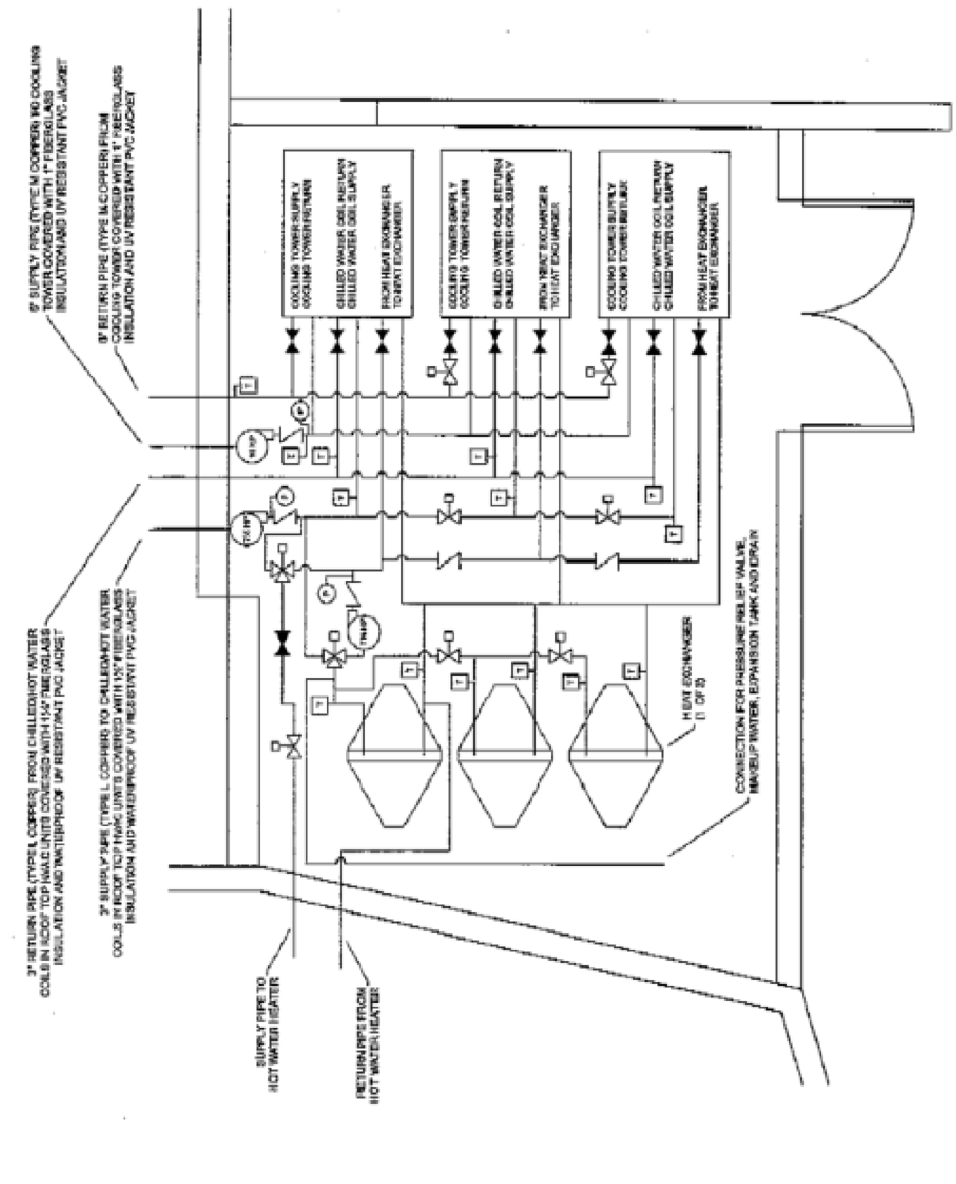
ABB Alpha Plus Power Meter and Protective Relay Control Panel

Capstone Remote Monitoring Software (Display Shows 143 kW)



FACILITY ONE-LINE CIRCUIT DIAGRAM

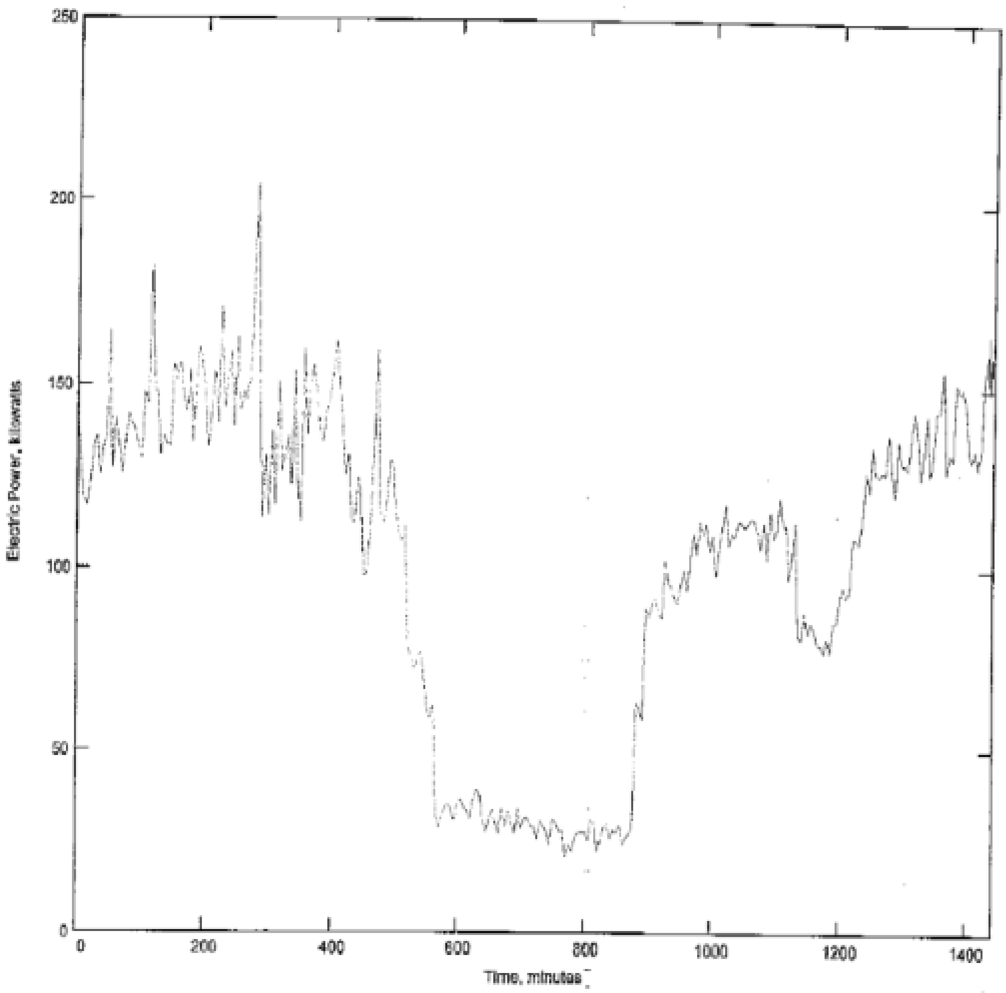



SUPPLY PIPE TO HOT WATER HEATER
RETURN PIPE FROM HOT WATER HEATER
HEAT EXCHANGER (1 OF 3)

ELECTRIC POWER PROFILE FOR A TYPICAL BUSY WINTER DAY

Measured values for electric power were obtained for a period of 24 hours at 5 minute intervals.

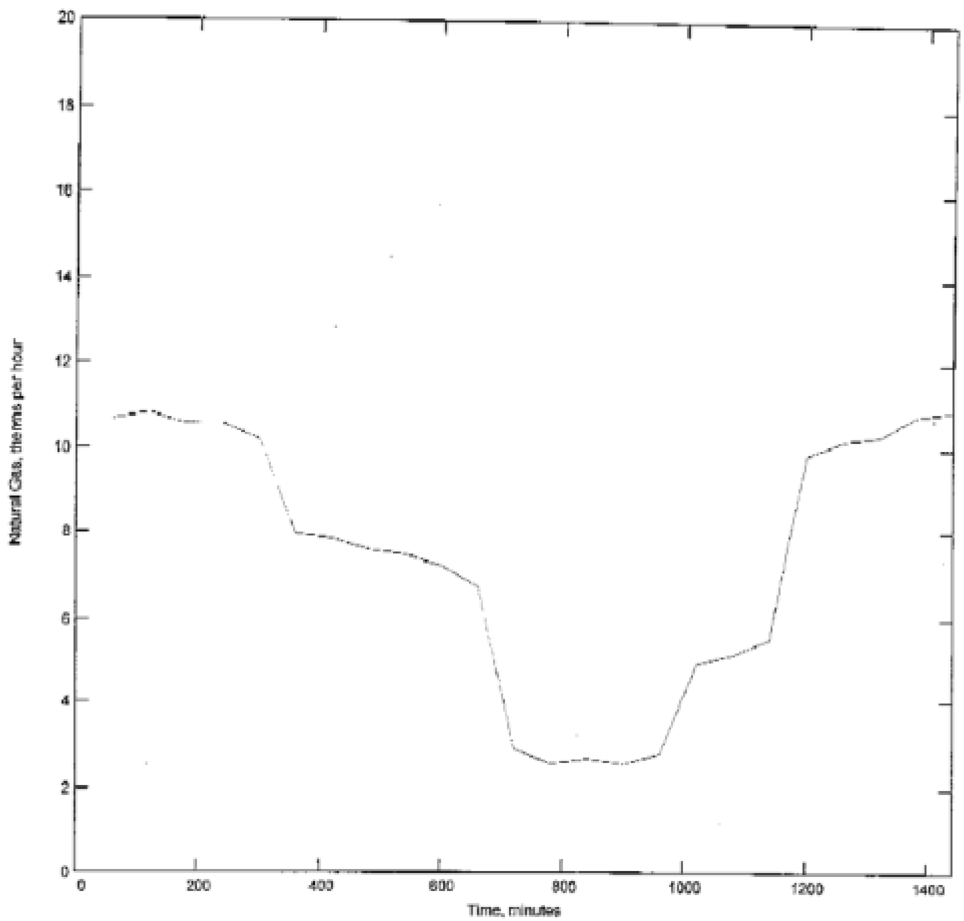
Average Voltage for Each of 3 Phases = 209.3
Average Power Factor = 0.93
Maximum Power = 204.9 kilowatts
Minimum Power = 21.39 kilowatts

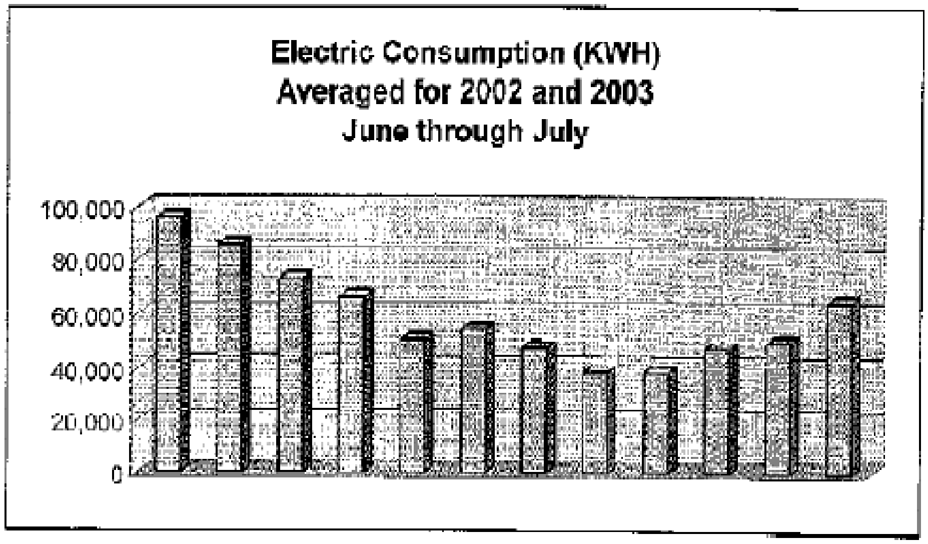


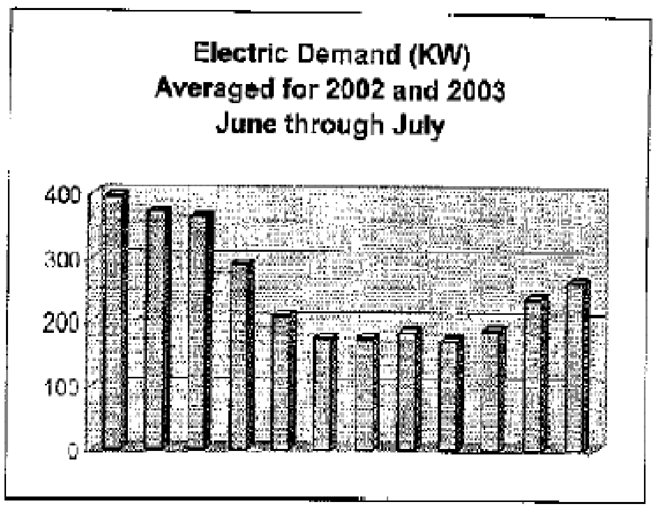
THERMAL PROFILE FOR A TYPICAL BUSY WINTER DAY

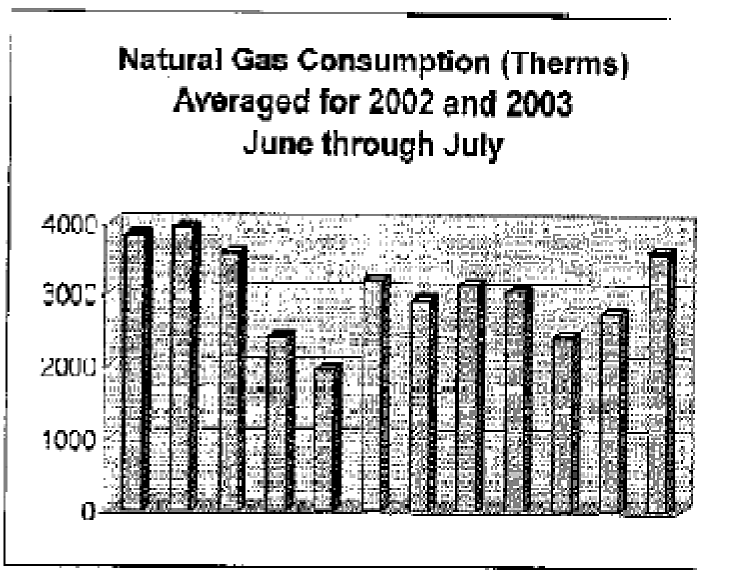
Measured values represent natural gas consumed for comfort heating and domestic hot water during a period of 24 hours at 1 hour intervals.

Total Natural Gas Consumed during the Period of Data Aquisition = 176.2 Therms
Higher Heating Value of Natural Gas = 1044 Therms per Cubic Feet




Electric Consumption (KWH)
Averaged for 2002 and 2003
June through July
100,000
80,000
60,000
40,000
20,000
0


Electric Demand (KW)
Averaged for 2002 and 2003
June through July
400
300
200
100
0


Natural Gas Consumption (Therms)
Averaged for 2002 and 2003
June through July
4000
3000
2000
1000
0

From Date	To Date	Elec Use	Elec Demand	Electric Bill Amt
01/11/2005	02/10/2005	--	--	--
01/26/2005	02/10/2005	12,800	80.00	$898.73
01/11/2005	01/26/2005	2,000	188.00	$734.93
12/10/2004	01/11/2005	47,200	176.00	$4,124.30
11/08/2004	12/10/2004	45,600	192.00	$4,429.86
10/08/2004	11/08/2004	53,200	232.00	$5,659.23
09/09/2004	10/08/2004	57,200	260.00	$6,970.00
08/10/2004	09/09/2004	--	--	--
08/13/2004	09/09/2004	76,800	360.00	$9,322.74
07/12/2004	08/13/2004	85,600	304.00	$9,628.91
07/12/2004	08/10/2004	--	--	--
06/10/2004	07/12/2004	--	--	--
06/10/2004	07/12/2004	84,400	304.00	$9,165.42
05/11/2004	06/10/2004	64,400	264.00	$6,750.48
04/12/2004	05/11/2004	49,200	236.00	$5,112.29
03/12/2004	04/12/2004	47,200	188.00	$4,239.76
02/11/2004	03/12/2004	38,800	172.00	$3,583.56
11/07/2003	02/11/2004	--	--	--
01/12/2004	02/11/2004	38,800	184.00	$3,942.47
12/11/2003	01/12/2004	47,200	176.00	$4,712.51
11/07/2003	12/11/2003	54,000	176.00	$5,093.57
09/10/2003	11/07/2003	101,600	260.00	$12,526.71
10/09/2003	11/07/2003	--	--	--
09/10/2003	10/09/2003	--	--	--
06/11/2003	09/10/2003	254,400	364.00	$32,708.89
08/11/2003	09/10/2003	--	--	--
07/11/2003	08/11/2003	--	--	--
06/11/2003	07/11/2003	--	--	--
05/12/2003	06/11/2003	68,000	252.00	$6,759.88
04/11/2003	05/12/2003	53,200	240.00	$5,442.36
03/13/2003	04/11/2003	43,600	192.00	$4,395.69
02/11/2003	03/13/2003	42,000	144.00	$3,553.98
02/28/2003	03/13/2003	--	--	--
02/11/2003	02/28/2003	--	--	--