April through June, 2000

Quarterly Technical Progress Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641--02

From:

Gary Nowakowski

GRI
8600 W. Bryn Mawr Ave
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May 5th, 2000

April Monthly Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641

To:

Cliff Carpenter
National Energy Technology Center
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Gary Nowakowski
GRI

Technical Progress:

A meeting was held at Alturdyne's facility in San Diego to discuss project progress. Cliff Carpenter, the NETL Program Manager, attended the meeting. As a result of the meeting, several decisions were made.

1. A General Motors engine would be specified as the prime mover
2. A Carrier reciprocating compressor would be specified, however a Hitachi screw compressor with an integral oil sump was an interesting candidate if it was available in the right size and for the right price.
3. The motor/generator would provide two functions: as an induction motor and as a synchronous generator. The variable speed, constant frequency feature will not be included in the first generation product.
4. The refrigerant will be R134-A

Steve Palm presented the status of the motor/generator product development. Steve presented two options (Concept I and II) to pursue as outlined in the attached meeting minutes. Steve and Dave LeCren had conducted a manufacturing cost analysis of both options. However, Dave was on his honeymoon and Steve did not have access to the estimates. While Steve indicated that Concept II was the most straightforward and lowest cost, it was not clear which concept had the lowest technical risk. It was agreed that Steve and Dave would discuss technical risk and recommend one of the concepts as well as provide the team with the information on costs. Steve would also outline the time, cost and process required to prove the concept in the laboratory. ***This component development and testing will now represent the critical path for this project. Bench top testing of this testing of this component is estimated to take three to four weeks.***

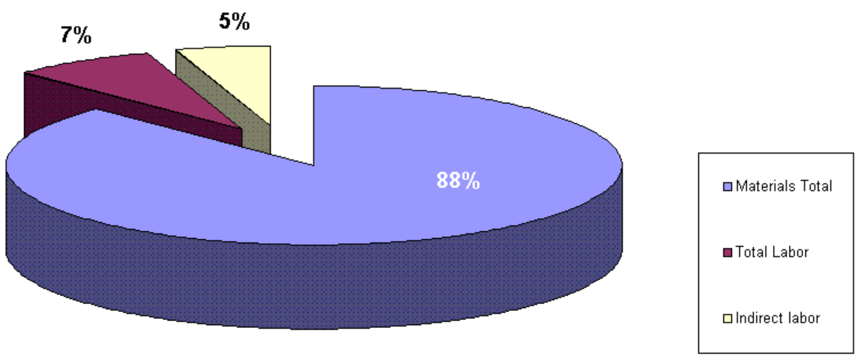
Meeting minutes are included as an attachment.

The format for a detailed product specification was completed and is included as an attachment. The specification sheet will be finalized in May.

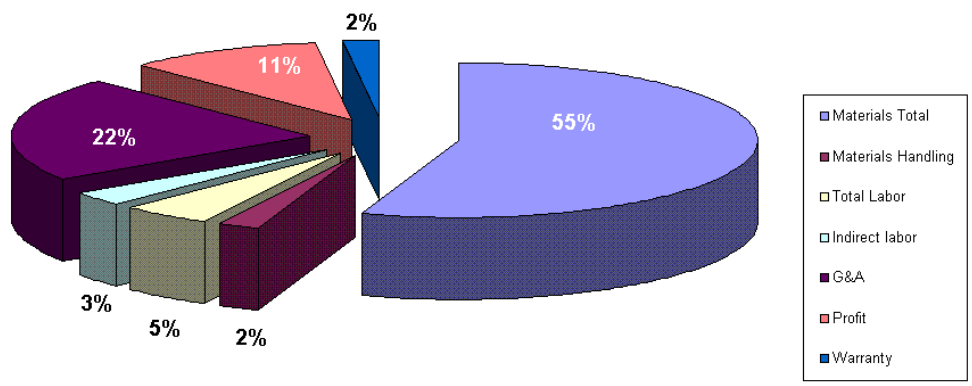
A first cut manufacturing cost estimate was completed. Results are shown below.

Materials	***Quantity***	***Cost, Each***	***Cost, total***
GM Engine	1	$4,779.00	$4,779.00
Clutch	2	$2,045.00	$4,090.00
Bearing	2	$82.00	$164.00
Motor/Generator	1	$2,369.00	$2,369.00
Carrier 5H86 Compressor	1	$8,652.00	$8,652.00
Flex Coupling	1	$456.00	$456.00
Oil Cooler Package	1	$245.00	$245.00
Motor Fastening	1	$147.00	$147.00
Crankcase Heater	1	$55.00	$55.00
Ketema Evaporator	1	$5,265.00	$5,265.00
Ketma Condenser	1	$2,869.00	$2,869.00
Engine Heat Exchanger	1	$686.00	$686.00
Frame and Brackets	1	$750.00	$750.00
Other Materials	1	$11,759.00	$11,759.00
Materials Total			$42,286.00
Materials Handling			$1,691.44
Materials Total			$43,977.44
Labor	***Hours***	***Rate, $/hr***	***Cost***
Project Engineer	35	27	$945.00
Electrical Engineer	15	27	$405.00
Draftsman	6	11	$66.00
ILS Data	8	17	$136.00
Foreman	4	19	$76.00
Quality Control	2	12.8	$25.60
Machinist	12	19	$228.00
Sheet Metal	8	9.36	$74.88
Welder	24	12.25	$294.00
Assembler	60	9.36	$561.60
Electrician	60	10.25	$615.00
Painter	24	9.17	$220.08
Test Technician	8	12.8	$102.40
Total Labor			$3,749.56
Indirect labor			$2,512.21
Manufacturing Cost			$50,239.21
G&A			$16,729.66
Manufacturing Cost & G&A			$66,968.86
Profit			$8,036.26
Manufacturing Cost, G&A, Profit			$75,005.12
Warranty			$1,500.10
Estimated Price			$76,505.23

Manufacturing Cost Breakdown
Alturdyne Advanced Hybrid Chiller/Generator



Product Price Breakdown
Alturdyne Advanced Hybrid Chiller/Generator



The following brief economic analysis was completed given the current manufacturing and pricing information.

Hybrid Product (100-tons of cooling and 75 kW) Price Estimate: **$76,000**
Electric 100-ton Chiller Price: **$35,000**
Emergency Generator Set (75 kW): **$15,000**
<u>Est. of installation cost savings (due to placing one vs. two pieces of equip): **$5,000**</u>
Price premium of Hybrid Product: **$21,000 or $210/ton**

In order to achieve a 3 year payback period, annual savings would have to be greater than $70/ton of cooling ($210/3 = 70). Based on past analyses, there are many cities across the U.S. in which $70 savings per ton of cooling is possible. Based on this early hybrid product price estimate, the product should be an attractive HVAC product in many areas of the country where the customer is interested in both cooling and emergency power generation.

Plans for April:

- Complete energy and economic analysis
- Continue to improve manufacturing cost estimate
- Continue motor/generator design
- Finalize a product specification sheet

Administrative:

Cummulative Net oulays for this project are $34,945.02. The Federal share is $27,956.02 and GRI's cost share is $6,989.00.

April 17, 2000

Trip Report -- April 12th 2000 Project Team Meeting

DOE/NETL Project

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641

A second meeting was held at Alturdyne's facility in San Diego, California on April 12th, 2000. The following people attended the meeting.

Clifford Carpenter, NETL
Gary Nowakowski, GRI
John Brogan, Onsite/Sycom
Mark Gramlich, Alturdyne
Steven Palm, Alturdyne
Dave Harwood, Alturdyne
Joe Browning, Alturdyne

The agenda for the day is shown below.

1. Introductions

2. Alturdyne background (VU graphs)

3. Program status (Dec., Jan., Feb., Mar.)

4. Current Status
   a. Motor generator development
   b. System/component design
   c. First article assembly
   d. Schedule

5. Pricing

6. Status of hybrid unit for Omni Metals

7. Plant tour

Mark Gramlich provided Cliff with an overview of Alturdyne and provided a perspective on the type of products that Alturdyne designs and sells. The meeting started off with a discussion of the proposed product design concept and several key components. Gary and Mark then updated Cliff on key progress from December through March including a major decision to not develop a motor/generator with variable speed, constant frequency capability. The reason is that the added cost would reduce the product's economic attractiveness and the interconnection requirements would significantly restrict sales volume.

Steve Palm then presented the status of the motor/generator product development. Steve presented two options (Concept I and II) to pursue as outlined on the following page. Steve and Dave LeCren had conducted a manufacturing cost analysis of both options. However, Dave was on his honeymoon and Steve did not have access to the estimates. While Steve indicated that Concept II was the most straightforward and lowest cost, it was not clear which concept had the lowest technical risk. It was agreed that Steve and Dave would discuss technical risk and recommend one of the concepts as well as provide the team with the information on costs. Steve would also outline the time, cost and process required to prove the concept in the laboratory. This component development and testing will now represent the critical path for this project.

Concept I: Induction Motor / Induction Generator / Synchronous Generator

Figure 1 shows a symbolic drawing for the motor/generator scheme. The device is constructed by modifying a conventional wound rotor motor. By rewinding the armature and adding a minimal amount of rotating electronics, it is possible to make a device that will act as an induction motor/generator as well as a synchronous generator. During induction operation, the rotating SCR's are allowed to trigger (close) using some of the induced current in the armature. Along with the reverse diodes in parallel, these thyristors form a short across windings allowing the necessary circulating currents to flow for induction operation both as a motor or generator.

During synchronous operation, current from the voltage regulator is applied to the exciter field. The resulting current in the exciter armature is detected by the rotating electronics and inhibits the operation of the SCR's. This allows the rectified exciter current to flow freely through the main field windings and synchronous operation is achieved.

One of the main advantages of this scheme is its passive nature. Very little extra control hardware is required. During induction operation, the voltage regulator is simply disabled. During synchronous operation, it is allowed to operate.

Concept II: Synchronous Motor/Generator

If induction generation for peak shaving is not required, a simpler scheme might be to use an off-the-shelf synchronous generator as a motor/generator.

Synchronous generation is trivial in this case. If the rotor is spinning; synchronous motor operation is achieved by applying fixed field current to the exciter. This is similar to the synchronous generation case with just the torque angle reversed.

The only difficulty is in starting the motor since the exciter will not commute any energy when it is not rotating. This is overcome by applying AC current to the exciter field during start-up. Once the armature is spinning, the field current is transitioned to DC.

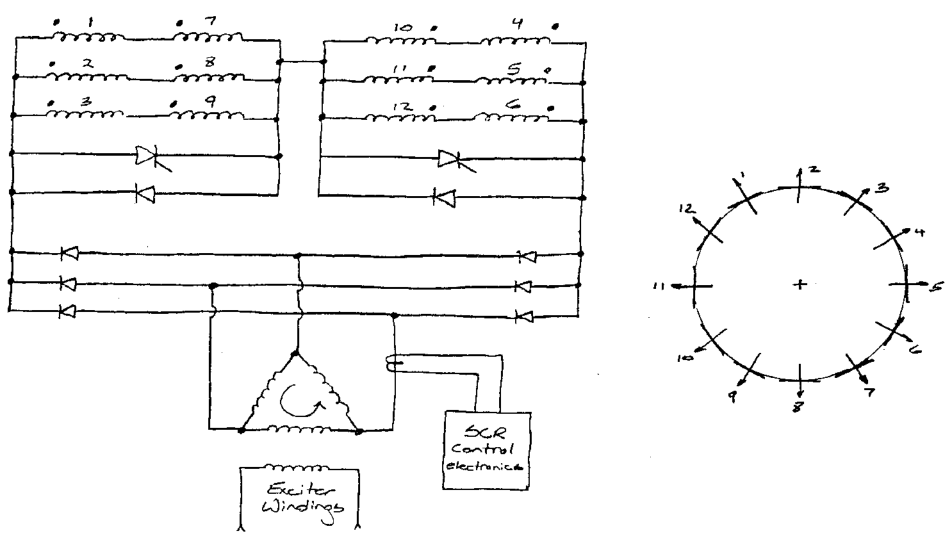


Figure 1

The engine/compressor pair was also discussed. Possible engines included the diesel-derivative Caterpillar, Cummins, and Waukesha and the gasoline-derivative Ford and General Motors. John Brogan mentioned a new screw compressor that is available through Hitachi with a "built-in" compact oil sump. John will provide Gary with the sales literature that he picked up at the annual ASHRAE show. Dave Harwood will then call on the pricing. If the pricing is reasonable ($8,000 to $10,000 range), this compressor would be an excellent selection since the engine could be operated at higher speeds thus offering a higher capacity machine (for the same GM engine) then a reciprocating compressor which would essentially limit the engine speed to 1800 rpm. ***If the compressor is too costly, a decision was made to utilize a General Motors engine in combination with the currently specified Carrier reciprocating compressor.*** The General Motors engine will need to be modified by the GM engine distributor to accommodate natural gas and include stellite valves, roller cam followers, roller rocker arms and a high flow lifter.

Additional discussion revolved around the high cost of the Carrier compressor, approximately $9,000. Alturdyne indicated that while other compressors were available, when fully specified, their cost was comparable to the Carrier product. Also, the Carrier compressor is highly reliable. Bitzer offers reciprocating compressors up to 45 HP and screw compressors at larger sizes. ***A decision was also made to specify R134-A as the refrigerant.***

Alturdyne is searching for computer programmers capable of modifying the control software to include the emergency generator logic. Computer software programmers are in such high demand that it is difficult to secure the services of a skilled individual.

Dave Harwood is comfortable with the electric clutch which he has specified. He will mount one clutch directly to the engine and the other clutch directly to the motor/generator. He just needs to design different adapter plates. The clutch is intended for static engagement.

The current product product design is 38 inches wide. Dave indicated that he would design the product so that it is less than 36 inches to accommodate most doorways.

Mark Gramlich introduced a first draft of a manufacturing cost and pricing estimate. An estimate of the price for a 100 ton/75 kW machine is $76,000 or

$760/ton. This compares to a price of $350/ton for an electric chiller and $400/kW for a 75 kW machine. The product could be sold at a slight first cost premium over a comparable electric chiller and emergency generator set. Cliff would like us to eventually conduct our economic analysis using a life cycle cost analysis.

All in all, it was a very productive meeting with key decisions resulting or planned in the near future.

PRODUCT SPECIFICATION SHEET

--Alturdyne Advanced Hybrid Chiller/Cogenerator—

April 19, 2000

Specification	
Water Chiller	
Full Load Cooling Capacity (tons)	100 refrigeration tons
Coefficient of Performance at Full Load - ARI-550-98 (HHV)	1.1
With No Heat Recovery	
With Engine Heat Recovery	
With Full (Engine & Exhaust) Heat Recovery	
IPLV - ARI-550-98 (HHV)	1.4
With No Heat Recovery	
With Engine Heat Recovery	
With Full (Engine & Exhaust) Heat Recovery	
Compressor Performance	
Manufacturer	
Type	
Model	
Pressure Rating	
Suction (PSI)	
Discharge (PSI)	
Full Load RPM	
Theoretical Displacement at Full Load RPM	
Operating Speed Range	
Refrigerant	
Unloading Scheme	
Evaporator Performance	
Manufacturer	
Model	
Chilled Water Temperatures – In / Out (°F)	
Flow Rate (GPM)	
Pressure Drop Across Evaporator at Full Load Rating (PSI)	
Maximum Allowable Flow (GPM)	
Condenser Performance	
Manufacturer	
Model	
Condenser Waterr Temperatures – In / Out (°F)	
Flow Rate (GPM)	
Pressure Drop Across Evaporator at Full Load Rating (PSI)	
Maximum Allowable Flow (GPM)	
Engine Dump Heat Eschanger	
Manufacturer	
Model	
Coolant Temperatures – In / Out (°F)	
Flow Rate (GPM)	
Pressure Drop Across Evaporator at Full Load Rating (PSI)	
Maximum Allowable Flow (GPM)	

Water Chiller Specification Continued			
	Cooling Tower Requirement		
		Total Heat Rejected (MBtu/hr)	
		Entering Tower Water Temperature (°F)	
		Leaving Tower Water Temperature (°F)	
		Total Tower Flow (gpm)	
	Electrical Requirements		
		Voltage	
		Frequency	
		Power Requirement (kW)	
		Service (phase / wires)	
	Acoustic Levels (dBa) @ 3 ft		

Engine Performance			
	Engine		
		Manufacturer	
		Model	General Motors 7.4 Liter
		Rated Horsepower	150 HP at 3600 rpm
		Rated RPM	
		Aspiration	
		Configuration	
		Displacement	
		Bore and Stroke (inches)	
		Compression Ratio	
		BMEP (PSI)	
		Ignition System	
	Heat Recovery Output @ Full Load (Mbtu/hr)		
		With Engine Heat Recovery	
		With Full (Engine & Exhaust) Heat Recovery	
	Fuel Consumption Data		
		Mbtu/hr (HHV)	
		SCFH Natural Gas	
		Fuel Pressure Requirements (inches of Water Column)	
	Exhaust System		
		Maximum allowable Backpressure (inches of water column)	
		Exhaust Manifolds (Dry / Water-cooled)	
		Flow Rate (ACFM)	
		Muffler Type (Standard / Industrial / Hospital Grade)	
	Lubrication		
		Type	
		Oil Type	
		Oil Filter	
		Oil Capacity	
	Cooling System		
		Type	
		Expansion Tank	

		Cooling Fluid	
	Starting System		
		Type	
		Battery	
		Starter	
		Battery Charge	

Emergency Generator			
	Full Load Rating		75 kW
	Rated Speed (RPM)		
	Motor / Generator		
		Model	Reuland Model No.
		Type	
		Voltage	
		Amps @ 120 / 240 V, Single Phase 60 Hz	
		Amps @ 208 / 230 V, Three Phase 60 Hz	
		Amps @ 240 V, Three Phase 60 Hz	
		Amps @ 480 V, Three Phase 60 Hz	
	Clutch and Couplings		
		Clutch Model	
		Clutch Rating	
		Flexible Coupling	
		Vibration Isolators	
	Controls		
		Start / Stop	
		Automatic Low Oil shutdown	
		Overspeed shutdown	
		Overcrank Protection	
		Automatic Voltage Regulator with Over-Voltage Protection	
		Engine Warm-up	
		Engine Cool-down	
		Safety FusStarter Lockoute	
	Transfer Switch		
		No. of Poles	
		Current Rating (amps)	
		Voltage Rating (VAC)	
		UL Listed	
Package Specifications			
	Length by Width by Height		161.5 in by 37 in by 85.8 in
	Weight		
	Enclosure		
		Type	
		Airflow (CFM)	

June 2, 2000

May Monthly Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641

To:

Cliff Carpenter
National Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

Gary Nowakowski
GRI

Technical Progress:

A search was done to determine whether any motor/generator manufacturers had designed a motor/generator capable of acting as a synchronous generator and an induction motor. Six manufacturers were contacted including Stamford Newage, AVK (Germany), W.E.G. (Brazil), Baylor, and Lima. Several said it can be done and has been done. We received a quote to design and deliver a product from AVK and W.E.G. Electric Motors Corp. The price is about $9,000 from AVK and $14,500 from W.E.G. Delivery time is 4 months from AVK and 3 months from W.E.G. We will pursue dual paths with both companies due to the importance of this component to the success of the entire project.

A quote was received from KEM Equipment, Inc. to provide the GM 8.1 Liter engine with the necessary accessories. The price is $7,500 and the delivery time is 60 to 90 days. John Brogan will investigate other General Motors engine sources including the possible use of the GM7.4 Liter engine.

A detailed product specification sheet is under development and will be completed by the end of June.

Modeling and simulation of the performance and economics of the new product applied to a variety of buildings and locations is being performed. Results will be included in a feasibility report which will be completed in mid-July.

Alturdyne hired a software programmer to finish the control algorithms.

The project is on course for the assembly of the product in October and performance testing and ETL safety certification in November/December timeframe.

Plans will be made with ETL to performance test the prototype and certify it for safety in November.

Administrative:

Dave Harwood, Alturdyne's engine chiller engineer has joined another company, but has offered his services on a part time basis for this project. John Brogan will be utilized to assist and supplement Dave's efforts.

July 10, 2000

June Monthly Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641

To:

Cliff Carpenter
National Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
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Gary Nowakowski
GRI

Technical Progress:

Purchase orders were issued to AVK (Germany) and W.E.G. (Brazil) for the motor/generator. Due to the critical nature of this component to the success of the project, we are sourcing the component from two different vendors. Both AVK and W.E.G. are large manufacturers of motors. Delivery dates are October 15th and August 10th, respectively. The compressor has been ordered from Carrier (Carlyle). The condenser and evaporator heat exchanger vessels were ordered from Ketema and Carrier, respectively. A distributor (KEM Equipment) for the new GM 8.1 liter engine was identified. John Brogan will be utilized to review the engine specification and insure that it is correct before issuing a purchase order.

Modeling and simulation of the performance and economics of the new product applied to a variety of buildings and locations is being performed. Results will be included in a feasibility report which will be completed in July. Early results are very promising. The ability to have greater control of demand reduction through both cooling and electric generation greatly improves the net energy savings in the three cities analyzed.

Work continues on the modification of the original hybrid controller.

The product specification is 80% complete and will be completed in July.

The project is on course for the assembly of the product in October and performance testing and ETL safety certification in November/December timeframe.

Plans will be made with ETL to performance test the prototype and certify it for safety in November.

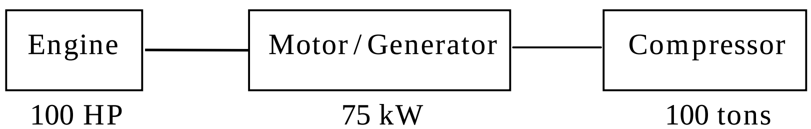
Administrative:

I spoke with Dave McCracken, President of Calmac, manufacturer of ice storage systems. Integrating the hybrid chiller with an ice storage system appears to be an attractive means for attacking the office building market segment. The electric motor could generate ice during evening hours. During peak daytime hours, the office building load could be satisfied by the combination of the ice storage capacity and the engine driving the compressor. In this way, the hybrid chiller could be downsized and the total "system cost" (hybrid chiller and ice storage) could be reduced. The installed ice storage system is estimated to cost about half that of the installed hybrid chiller.

Attachment

Preliminary Energy Cost Savings Analysis of Hybrid Gas/Electric Chiller/Cogenerator

Preliminary energy cost savings analyses were performed using the DOE-2 building energy analysis program to simulate the application of a hybrid chiller/cogenerator to a prototype retail store which could be cooled by a 100 ton cooling system. Analyses have been performed for Los Angeles, New York City and Detroit where a commercial building of this type would be on a time-of-day electric rate with an on-peak and off-peak electric cost schedule. The retail building was configured to have a peak cooling load of 100 tons in each city and was simulated as if it were equipped with an all electric cooling plant and with a hybrid cooling plant like that shown below.



The following cases were analyzed to develop a set of energy cost alternatives which allowed the incremental energy costs versus the baseline all electric cooling case to be determined for a range of operating scenarios:

<u>Case 1 - Baseline Electric Cooling Plant</u>

Cooling plant consists of conventional electric screw chiller rated at 0.79 kW/ton (4.45 COP) which is the minimum efficiency required by ASHRAE Standard 90.1-1999 for screw chillers less than 150 tons. Heating provided by gas-fired hot water boiler. All building utilities including electricity purchased at standard rates from local electric and gas utility services. Hourly simulation was performed for all building energy systems (lighting, cooling, heating, domestic hot water, etc.) along with part load operation of cooling equipment to determine total building monthly and annual energy consumption and energy costs.

<u>Case 2 – All Gas Cooling Plant</u>

Cooling plant consists of engine-driven screw chiller with a natural gas powered reciprocating engine driving a screw compressor to provide all cooling required by the building. Gas engine chiller was rated at 1.46 COP with 0.2 kW/ton electric parasitics. The hourly part load operating characteristics of the gas cooling equipment were simulated to determine total building monthly and annual energy consumption and energy costs. For this case, special gas cooling rates were used if available from local gas utility.

<u>Case 3 – Hybrid Cooling Plant With Gas and Electric Cooling and Cogenerator Available</u>

A hybrid cooling plant as configured in the above diagram was applied to the prototype retail building. Depending upon the local electric utility rate schedule, the hybrid plant was operated in the gas cooling mode during the on-peak period of the day to avoid high electric demand and energy charges. During off-peak evening and weekend hours, the hybrid plant was operated in the electric cooling mode when electric energy and demand charges are low. The following assumptions were used for the hybrid chiller/cogenerator:

1) Electric cooling mode efficiency was 0.79 kW/ton chiller

2) Gas cooling mode efficiency was 1.46 COP with 0.2 kW/ton electric parasitics

3) Gas engine runs at constant speed and fuel consumption anytime cooling is needed during the on-peak period

4) Generator runs at constant speed with variable output

5) After satisfying cooling load, unused engine HP is used to operate generator; generator output varies with available engine capacity

6) Generator allowed to operate only when cooling load is above 20% capacity since below 20% capacity the gas cooling system will cycle

Various scenarios with resized engine and motor/generator and simultaneous operation of engine, generator and compressor to provide cooling and electric power to the building were analyzed. These scenarios are further described in the diagram below. Cooling plant capacity remained fixed at 100 tons for all cases.

	Engine	Motor/Generator	Compressor
Case 3A	100 HP	75 kW	100 tons
Case 3B	150 HP	75 kW	100 tons
Case 3C	200 HP	75 kW	100 tons
Case 3D	150 HP	93 kW	100 tons
Case 3E	200 HP	112 kW	100 tons

For cases 3A through 3E, the generator was allowed to operate any hour during the on-peak period when cooling was required and cooling load was above 20% capacity. Priority was given to satisfying the cooling load any hour and the any unused engine HP was used to operate generator. Generator output therefore varied each hour inversely with cooling load.

Case 3A was also simulated as Case 3F with a different operating scenario for the generator. The chiller/cogenerator was allowed to operate every hour during the on-peak period whether cooling was required or not. This allowed maximum demand peak shaving and increased generation of electric energy.

<u>Preliminary Results</u>

The energy cost savings expressed in $/year/ton of gas cooling capacity installed for each of the cases analyzed is presented in the chart below. Further details for each case are included in an excel spreadsheet which accompanies this report. Results are very dependent on electric and gas costs in each city which are presented below for comparison purposes:

Los Angeles

Electric on-peak demand charge	$16.40/kW
Electric on-peak energy charge	$0.14896/kWh
Natural gas charge	$0.49858/therm

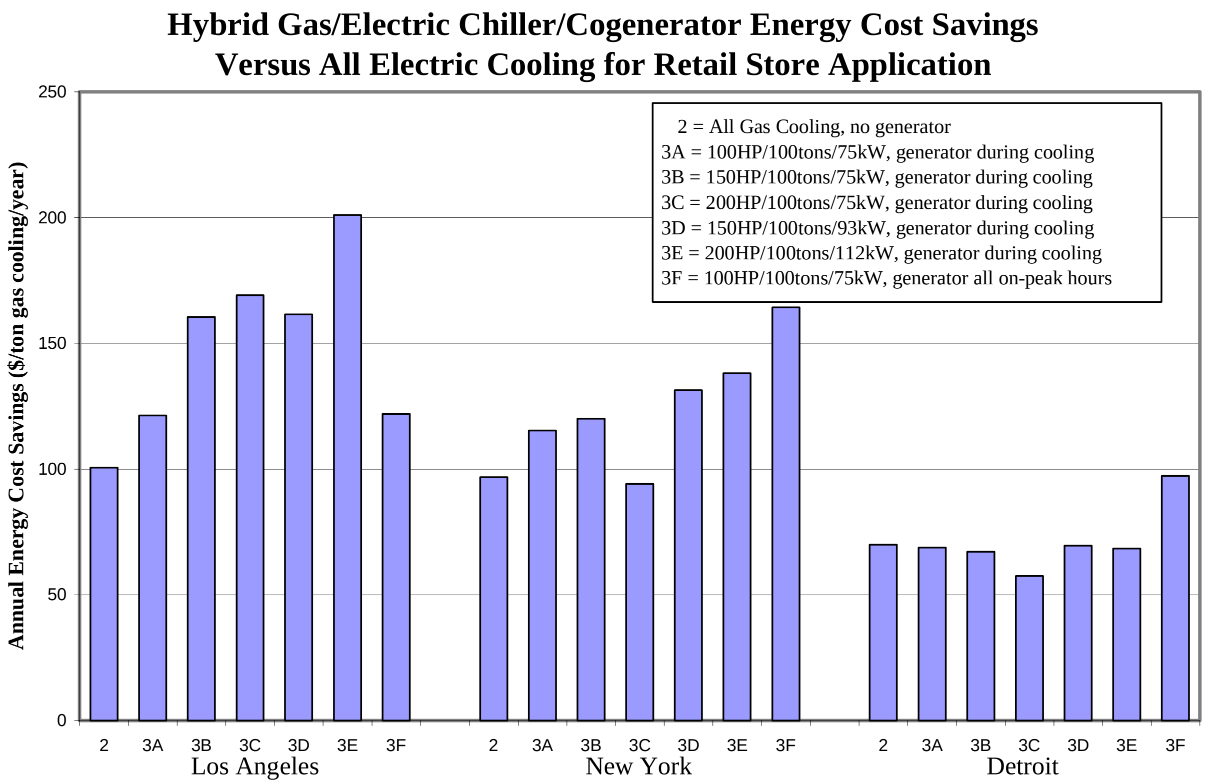
New York

Electric on-peak demand charge	$12.17/kW
Electric on-peak energy charge	$0.1041/kWh
Natural gas charge	$0.67264/therm

Detroit

Electric on-peak demand charge	$14.25/kW
Electric on-peak energy charge	$0.0296/kWh
Natural gas charge	$0.47679/therm

Savings of at least $100/yr/ton are possible in all three cities with savings as high as $200/yr/ton possible in Los Angeles. In New York and Detroit, Case 3F generated the most savings. In Los Angeles however, Case 3F generated little additional savings compared to 3A due to the fact that the cooling system in Case 3A was already operating almost every hour during the on-peak period, 496 hours out of 504 hours. Further analysis is planned for other cities such where typically gas cooling is harder to justify due to very competitive electric rates and/or shorter cooling seasons.


Hybrid Gas/Electric Chiller/Cogenerator Energy Cost Savings
Versus All Electric Cooling for Retail Store Application
Annual Energy Cost Savings ($/ton gas cooling/year)
250
200
150
100
50
0
2 = All Gas Cooling, no generator
3A = 100HP/100tons/75kW, generator during cooling
3B = 150HP/100tons/75kW, generator during cooling
3C = 200HP/100tons/75kW, generator during cooling
3D = 150HP/100tons/93kW, generator during cooling
3E = 200HP/100tons/112kW, generator during cooling
3F = 100HP/100tons/75kW, generator all on-peak hours
2 3A 3B 3C 3D 3E 3F
Los Angeles
2 3A 3B 3C 3D 3E 3F
New York
2 3A 3B 3C 3D 3E 3F
Detroit

Energy Cost Analysis
Hybrid Gas/Electric Chiller/Cogenerator

Los Angeles, California

Case	Equipment	Gas Engine Capacity (HP)	Cooling Capacity (tons)	Generator Capacity (kW)	Generator Operation During On-peak Period	Electric Cooling Provided (No. Hours)	Gas Cooling Provided (No. Hours)	Generator Operation (No. Hours)	Electricity Generated (kWh)	Annual Electric Costs ($)	Annual Gas Costs ($)	Annual Total Energy Costs ($)	Annual Savings Versus All Electric ($)	Annual Savings Per Ton Gas Cooling Installed ($/ton)
1	All Electric Cooling	-	100	-		4,590	-	-	-	103,625	4,802	108,427		
2	All Gas Cooling	-	100	-		-	4,590	-	-	92,523	5,855	98,378	10,049	100
3A	Hybrid Chiller/Cogenerator	100	100	75	When cooling needed	4,094	496	496	16,077	89,175	7,126	96,301	12,126	121
3B	Hybrid Chiller/Cogenerator	150	100	75	When cooling needed	4,094	496	496	33,666	84,095	8,288	92,383	16,044	160
3C	Hybrid Chiller/Cogenerator	200	100	75	When cooling needed	4,094	496	496	37,200	82,062	9,450	91,512	16,915	169
3D	Hybrid Chiller/Cogenerator	150	100	93	When cooling needed	4,094	496	496	34,462	83,988	8,288	92,276	16,151	162
3E	Hybrid Chiller/Cogenerator	200	100	112	When cooling needed	4,094	496	496	52,266	78,864	9,450	88,314	20,113	201
3F	Hybrid Chiller/Cogenerator	100	100	75	All on-peak hours	4,094	496	504	16,525	89,108	7,126	96,234	12,193	122

New York, New York

Case	Equipment	Gas Engine Capacity (HP)	Cooling Capacity (tons)	Generator Capacity (kW)	Generator Operation During On-peak Period	Electric Cooling Provided (No. Hours)	Gas Cooling Provided (No. Hours)	Generator Operation (No. Hours)	Electricity Generated (kWh)	Annual Electric Costs ($)	Annual Gas Costs ($)	Annual Total Energy Costs ($)	Annual Savings Versus All Electric ($)	Annual Savings Per Ton Gas Cooling Installed ($/ton)
1	All Electric Cooling	-	100	-		2,921	-	-	-	76,005	17,076	93,081		
2	All Gas Cooling	-	100	-		-	2,921	-	-	60,987	22,425	83,412	9,669	97
3A	Hybrid Chiller/Cogenerator	100	100	75	When cooling needed	1,797	1,124	1,124	52,167	54,299	27,255	81,554	11,527	115
3B	Hybrid Chiller/Cogenerator	150	100	75	When cooling needed	1,797	1,124	1,124	81,591	50,323	30,752	81,075	12,006	120
3C	Hybrid Chiller/Cogenerator	200	100	75	When cooling needed	1,797	1,124	1,124	84,300	49,427	34,248	83,675	9,406	94
3D	Hybrid Chiller/Cogenerator	150	100	93	When cooling needed	1,797	1,124	1,124	92,437	49,198	30,752	79,950	13,131	131
3E	Hybrid Chiller/Cogenerator	200	100	112	When cooling needed	1,797	1,124	1,124	123,741	45,024	34,248	79,272	13,809	138
3F	Hybrid Chiller/Cogenerator	100	100	75	All on-peak hours	1,797	1,124	2,520	135,927	40,713	35,941	76,654	16,427	164

Detroit, Michigan

Case	Equipment	Gas Engine Capacity (HP)	Cooling Capacity (tons)	Generator Capacity (kW)	Generator Operation During On-peak Period	Electric Cooling Provided (No. Hours)	Gas Cooling Provided (No. Hours)	Generator Operation (No. Hours)	Electricity Generated (kWh)	Annual Electric Costs ($)	Annual Gas Costs ($)	Annual Total Energy Costs ($)	Annual Savings Versus All Electric ($)	Annual Savings Per Ton Gas Cooling Installed ($/ton)
1	All Electric Cooling	-	100	-		2,322	-	-	-	56,848	14,202	71,050		
2	All Gas Cooling	-	100	-		-	2,322	-	-	48,634	15,429	64,063	6,987	70
3A	Hybrid Chiller/Cogenerator	100	100	75	When cooling needed	1,464	858	858	40,191	46,186	17,986	64,172	6,878	69
3B	Hybrid Chiller/Cogenerator	150	100	75	When cooling needed	1,464	858	858	62,396	44,461	19,878	64,339	6,711	67
3C	Hybrid Chiller/Cogenerator	200	100	75	When cooling needed	1,464	858	858	64,350	43,537	21,770	65,307	5,743	57
3D	Hybrid Chiller/Cogenerator	150	100	93	When cooling needed	1,464	858	858	70,836	44,213	19,878	64,091	6,959	70
3E	Hybrid Chiller/Cogenerator	200	100	112	When cooling needed	1,464	858	858	94,571	42,440	21,770	64,210	6,840	68
3F	Hybrid Chiller/Cogenerator	100	100	75	All on-peak hours	1,464	858	2,016	109,671	38,231	23,093	61,324	9,726	97