gri

January Monthly Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641--01

To

DOE/FETC

Gary Nowakowski
GRI

A kick-off meeting was held in San Diego with Alturdyne on January 21st. The proposed hybrid gas/electric chiller/cogenerator design concept was discussed in detail. The requirements and functionality of the key component, a variable speed, constant frequency motor/generator was presented. Variations of the proposed design were also discussed based on their technical feasibility, cost and market potential. The discussion is documented in a Trip Report. An engine generator set consisting of an engine, induction generator and synchronous generator all on one shaft appears to be the most practical product with the greatest market impact while still providing peakshaving and standby power generation functionality. The need to purchase a chiller is not a prerequisite for this product. Consequently, the market potential is enormous as all buildings are potential candidates. ***This alternative product design needs to be discussed with the DOE/FETC Program and Project Managers before we proceed with the project .*** Other topics discussed at the kick-off meeting included engine selection (Caterpillar vs. Cummins vs. General Motors), control development, clutch selection, total skid length and product cost.

Due to the delays in getting the budget resolved, a no-cost time extension will be required extending the project end date to 12/31/2000. The project milestones would include:

6/15/2000	**Feasibility Analysis**	**Report**
7/31/2000	**Product Design**	**Design Package**
9/30/2000	**Prototype Construction**	**Prototype**
11/15/2000	**Lab Testing/Safety Certification**	**Report**
11/30/2000	**Period 1 Final Report**	**Report**

March 7, 2000

February Monthly Report

Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Instrument Number DE-FC26-99FT40641

To:

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Gary Nowakowski
GRI

Technical Progress:
After significant GRI/Alturdyne discussion regarding alternative product design concepts, the team made a decision to continue with the proposed product design, a hybrid chiller capable of also providing emergency power. The primary benefits are: (a) the flexibility and operating cost savings associated with the product's dual fuel capability and (b) the emergency power feature. A variable speed, constant frequency motor/generator would significantly increase the cost of the product while providing marginal benefit. (The variable speed, constant frequency motor generator is estimated to cost $25,000 versus $4,000 for a constant speed version). In addition, the interconnection requirements to the electric grid would significantly limit market penetration of the product. We will proceed with a motor/generator design capable of serving as the electric prime mover for the compressor as well as the generator for emergency power needs. This component design is being discussed with two motor manufacturers. The first generation motor/generator will not be a variable speed, constant frequency design. The variable speed, constant frequency capability can be an advancement that is included at a later time. The induction motor/synchronous generator starts as a wound rotor motor with a brushless exciter and control electronics to switch between induction mode and synchronous mode. The exciter is a three-phase exciter with three phase rotating diode assembly. In the induction motor mode, the field windings are shorted out by SCRs located across the field. In the synchronous mode, a small ct on one of the exciter leads would power the rotating exciter electronics. Upon sensing exciter current, the electronics would automatically open the SCRs allowing synchronous operation. Quotes will be obtained from American Motor and Reuland, two motor/generator vendors.

Work is underway to determine the product specifications including engine, estimate manufacturing cost and price, develop a layout for the product and design the motor/generator. The current thinking on the engine selection is to proceed with a Cummins diesel derivative engine for the following reasons:

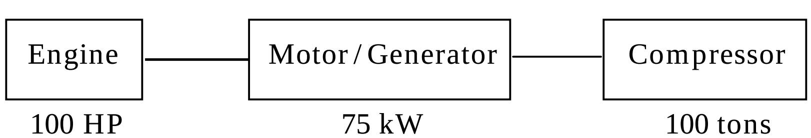
(1) The preferred engine would be a low cost General Motors 7.4 Liter engine currently used by Tecogen. However, GM is in the process of discontinuing the 7.4 L engine and the new 8.1 L design is still not readily available. Tecogen was able to achieve long life on their 7.4L engine by replacing "top end" factory parts with specialty parts such as ceramic valve seats, roller cam followers, etc. Alturdyne would have to spend considerable effort on determining the proper changes and identifying and qualifying vendors for the specialty parts. Due to this engine's low cost ($5,000 to $6,000 fully dressed), the 8.1 L would be a good engine to incorporate into this hybrid product at a later date.

(2) The Caterpillar engine that Alturdyne has used in the past is a very expensive engine ($15,000). Prior engine chiller experience with Tecogen and York has demonstrated that cost is an extremely important factor with regards to market potential and profitability. The Cummins engine is estimated to be 20 to 30% lower than the Caterpillar engine. The Cummins engine is also more compact and lower weight than the Caterpillar engine. Cummins engines have been successfully utilized for irrigation pumping applications in Southern California Gas territory.

The chiller controls for the hybrid chiller prototype would use the same A-World controller. The generator control would require an analog metering module to be added. The control code would have to be modified to accommodate the generator. Code from the existing chiller will be used.

Part of the feasibility analysis is to conduct an energy and economic analyses of the the hybrid gas/electric chiller cogenerator as outlined below.

The energy and economic analysis will use the DOE-2 building energy analysis program to simulate the application of a hybrid chiller / cogenerator to a prototype commercial building. An analysis will be performed for a commercial building located in a climate where there is a demand for cooling throughout the entire day for most of the year like in a hospital or hotel. Initially, an analysis will be done for the Los Angeles or San Diego area where there is a long cooling season and electric demand and energy rates are high. A small prototype building will be configured which has a peak cooling load of 100 tons and is equipped with a hybrid cooling plant like that shown below.



The following cases will be analyzed to develop a set of operating cost alternatives which will allow the incremental operating costs to be determined for a range of operating scenarios:

Case 1 - Baseline Conventional Cooling Plant

Cooling plant consisting of conventional electric screw chiller rated at 0.84 kW/ton (4.2 COP). The minimum efficiency by ASHRAE Standard 90.1 for screw chillers less than 150 tons is 3.8 COP. Heating provided by hot water boiler. All building utilities including electricity purchased at standard rates from local electric and gas utility services. Hourly simulation will be performed of 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 2A – Hybrid Cooling Plant, Gas Cooling Only</u>

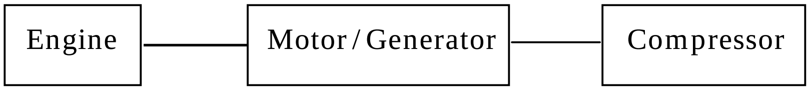
Hybrid cooling plant as shown above with the natural gas powered engine driving compressor to provide all cooling required by the building. Part load operating characteristics of hybrid plant operating in gas cooling mode based on latest design specifications will be used to simulate operation of cooling plant. Redo simulation for this case and take advantage of any special gas cooling rates if available from local gas utility.

<u>Case 2B – Hybrid Cooling Plant, Gas and Electric Cooling Available</u>

Hybrid cooling plant as shown above but with either gas cooling or electric cooling available as desirable. Depending upon local electric utility rate schedule, operate hybrid plant as many hours as possible in gas cooling mode during the peak time of the day to avoid high electric demand charges. During off-peak hours during the evening and on weekends, operate hybrid plant in the electric cooling mode when electric energy and demand charges are low. Part load operating characteristics of hybrid plant operating in both the gas cooling mode and electric cooling mode based on latest design specifications will be used to simulate operation of cooling plant. Redo simulation for this case and take advantage of any special gas cooling rates if available from local gas utility.

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

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 will be analyzed. These scenarios are further described in the diagram below. Cooling plant capacity remains unchanged.



100 HP	75 kW	100 tons
150 HP	75 kW	100 tons
200 HP	75 kW	100 tons
150 HP	112.5 kW	100 tons
200 HP	112.5 kW	100 tons

Operate plant under the same scenario as described in Case 2B except that when operating during the day in the gas cooling mode, also simultaneously operate variable speed constant frequency generator to provide as much electric power as engine will allow. During hours of high demand for cooling, generator output will be reduced, and vice versa. Part load operating characteristics of hybrid plant operating in both the gas cooling / power generation mode and electric cooling mode based on latest design specifications will be used to simulate operation of hybrid plant. Redo simulation for this case and take advantage of any special gas cooling rates if available from local gas utility.

<u>Case 4 – Hybrid Cooling Plant with Ice Storage</u>

Case 2B will be rerun with an ice storage system available. During the off-peak night-time hours when electricity is cheap and demand for cooling is reduced, the hybrid cooling plant would be operated in the electric cooling mode at full cooling capacity with any excess cooling used to charge the ice storage plant. Then, during the daytime on-peak hours the building would be cooled by the ice storage plant and supplemented with cooling from operation of the hybrid cooling plant in the gas cooling mode as needed. This would allow the capacity of the hybrid plant to be reduced and the first cost savings used to offset the cost of the ice storage plant. The result should be an overall first cost reduction from the Case 2B scenario. Part load operating characteristics of hybrid plant operating in both the gas cooling mode and electric cooling mode based on latest design specifications will be used to simulate operation of hybrid plant. Hourly operation of the ice storage plant will also be simulated. Redo simulation for this case and take advantage of any special gas cooling rates if available from local gas utility. Other applications such as an office building will be investigated to determine where the best economics occur.

<u>Comparison of Economics</u>

An economic analysis will be completed for all cases analyzed accounting for annual energy costs, equipment maintenance costs, and first cost of equipment. Incremental costs and savings between alternatives will be examined to determine payback period.

Priority of Analysis

Cases 1, 2A, 2B and 3 will be given first priority. Case 4 will be undertaken once the results from other cases are available and if there are still time and funds remaining

Plans for March:

- Begin energy and economic analysis
- Continue manufacturing cost estimating process
- Continue motor/generator design
- Develop a product specification sheet
- Select an engine, compressor and clutches

Administrative:

The budget for period one was reworked according to FETC Project Manager “crosswalk” of SOW and funding from Technical Evaluation. The budget by summary and task is included below. The total revised budget is $438,279.

DE-PS26-99FT40528 (GRI Internal ATC)

Summary of Cost and Price Estimate

3/8/00 9:11 AM

File: DOE Template

Description	Rates (1)	Total Project Hours	$'s	
~~**GRI Direct Labor**~~				
Project Mgr D	$ 52	626.1	$	33,119
Contract Administrator	#DIV/0!	73.1		4,217
Administrative Staff	#DIV/0!	140.6		3,453
Total GRI Direct Labor		**839.8**	**$**	**40,790**
Add: Overhead	52.15%		$	21,272
Add: Travel Costs			$	7,503
~~**Add: Subcontractor Costs:**~~				
Altrudyne			$	290,615
GARD Analytics				30,000
Onsite Energy				-
Subtotal- Subcontract Costs			**$**	**320,615**
Add: Other Direct Costs (e.g., supplies, report printing, etc.)			$	10,552
Subtotal- Total Direct Costs			**$**	**400,731**
Add: G&A on Labor & Overhead Costs	9.37%		$	5,815
Add: G&A on Travel, Subs & ODC's	9.37%			31,733
Subtotal- G&A Costs			**$**	**37,548**
Subtotal- Total Costs			**$**	**438,279**
Total Price			**$**	**438,279**
				-
~~**Cofunding:**~~				
GRI	20.0%		**$**	**87,656**
DOE- FETC	80.0%			350,623
Total Price			**$**	**438,279**

Summary of Cost Estimate by Task

	Task # 1 Feasibility Analysis			Task # 2 Product Design			Task # 3 Prototype Construction		
	…s	Hours	$'s	Rates (1)	Hours	$'s	Rates (1)	Hours	$'s
	2	120.0	$ 6,240	#DIV/0!	-	$ -	#DIV/0!	-	$ -
	1	-	-	#DIV/0!	-	-	#DIV/0!	-	-
	1	-	-	#DIV/0!	-	-	#DIV/0!	-	-
		120.0	$ 6,240		-	$ -		-	$ -
			$ 3,264	#DIV/0!		$ -	#DIV/0!		$ -
			$ -			$ -			$ -
			$ 17,059			$ 67,828			$ 122,742
			30,000			-			-
			-			-			-
			$ 47,059			$ 67,828			$ 122,742
…ts.)			$ -			$ -			$ -
			$ 56,563			$ 67,828			$ 122,742
			$ 880	#DIV/0!		$ -	#DIV/0!		$ -
			4,409	9.37%		6,337	9.37%		11,501
			$ 5,289			$ 6,337			$ 11,501
			$ 61,852			$ 73,965			$ 134,243
			$ 61,852			$ 73,965			$ 134,243
						-			-
	%		$ 12,370	20.0%		$ 14,793	20.0%		$ 26,849
	%		49,482	80.0%		59,172	80.0%		107,394
			$ 61,852			$ 73,965			$ 134,243

Task # 4 Lab Testing/Safety Certification			Task # 5			Task # 6			Grand Total		
Ave Rates	Hours	$'s	Ave Rates	Hours	$'s	Ave Rates	Hours	$'s	Ave Rates	Hours	$'s
#DIV/0!	-	$ -	#DIV/0!	-	$ -	$ 53	506.1	$ 26,879	$ 53	626.1	$ 33,119
#DIV/0!	-	-	#DIV/0!	-	-	$ 58	73.1	4,217	$ 58	73.1	4,217
#DIV/0!	-	-	#DIV/0!	-	-	$ 25	140.6	3,463	$ 25	140.6	3,463
	-	$ -		-	$ -		719.8	$ 34,559		839.8	$ 40,798
#DIV/0!		$ -	#DIV/0!		$ -	52.15%		$ 18,018	52.15%		$ 21,272
		$ -			$ -			$ 7,503			$ 7,503
		$ 83,186			$ -			$ -			$ 290,815
		-			-			-			30,000
		-			-			-			-
		$ 83,186			$ -			$ -			$ 320,815
		$ -			$ -			$ 10,552			$ 10,552
		$ 83,186			$ -			$ 70,622			$ 400,731
#DIV/0!		$ -	#DIV/0!		$ -	9.37%		$ 4,936	9.37%		$ 6,816
9.37%		7,795	#DIV/0!		-	9.37%		1,682	9.37%		31,733
		$ 7,795			$ -			$ 6,617			$ 37,548
		$ 90,981			$ -			$ 77,239			$ 438,279
		$ 90,981			$ -			$ 77,239			$ 438,279
		-			-			-	-	-	-
20.0%		$ 18,196	#DIV/0!		#DIV/0!	20.0%		$ 15,448	20.0%		$ 87,656
80.0%		72,784	#DIV/0!		#DIV/0!	80.0%		61,791	80.0%		$ 350,623
		$ 90,981			#DIV/0!			$ 77,239			$ 438,279

…s that only include salaries and fringe benefits

April 6, 2000

March Monthly Report

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To:

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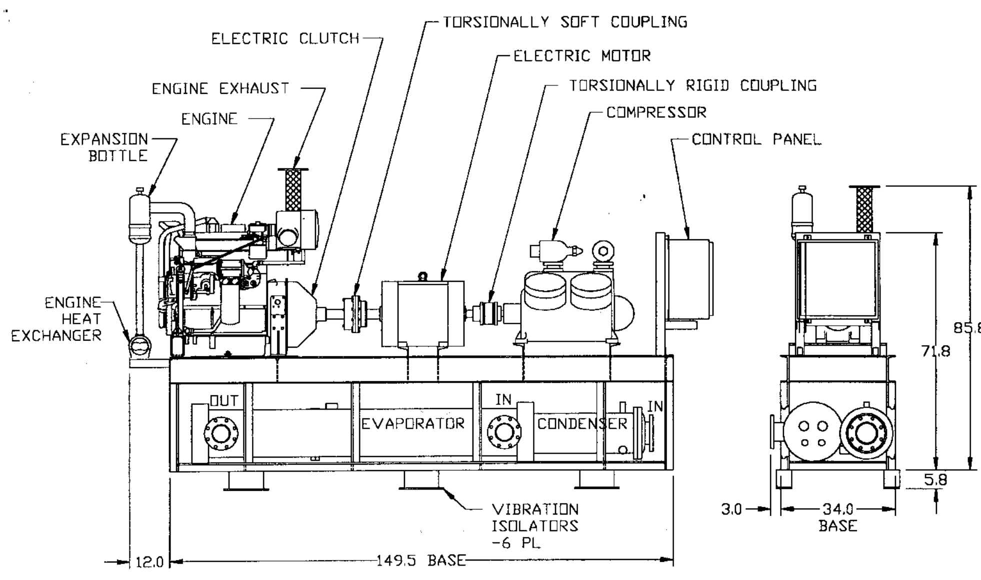
Technical Progress:

A product layout was completed. See Figure below. The width is reduced significantly from the original hybrid design because the evaporator and condenser tube in shell heat exchangers are located below the engine/motor/compressor drive-line.



Alturdyne is searching for a consultant to perform a drive-line torsional analysis. This analysis is necessary to ensure that the drive-line is not subject to undue vibrations operating through its entire speed range.

Much effort was directed toward motor/generator selection. A decision was made to use Reuland Electric. A motor with double-end shafts will be purchased. The design effort which will be completed at Alturdyne will involve the modification of the wound rotor motor to also provide synchronous power. Work has been completed on developing the new controller which will be utilized for the original hybrid product as well as this advanced product.

Work continues toward developing a manufacturing cost estimate. A detailed bill of material will be developed for the product.   Key components include the engine, compressor and motor/generator.   The current thinking is to utilize a Cummins engine, although the GM and Ford engine haven't been totally ruled out. The GM and Ford engines are gasoline-derivative engines with a cost of about $6,000. Estimated cost for the Cummins diesel-derivative engine is between $8,000 and $12,000. Tecogen has demonstrated that the GM engine can achieve more than 20,000 hours of longevity with modification to the top end (i.e. hydraulic valve lifters, ceramic valve seats, etc.). Southern California Gas Company has had success utilizing the Cummins engine for irrigation pumping applications. The Caterpillar engine is also a diesel-derivative engine, but is priced at about $15,000. Alturdyne has specified a Carrier reciprocating compressor for engine chillers in this size range, however, it is a costly component. We are in the process of determining whether there is a lower cost alternative, possibly a Bitzer compressor. Purchased parts and materials will represent between 70 and 80% of the total product manufacturing cost so it is important that we focus on evaluating all of the alternatives possible with respect to the key components.

A product specification is under development. The specification will delineate performance parameters such as weight, length, width, engine, compressor and motor/generator ratings, target efficiency levels, cooling output, electric output, etc. This specification will be utilized to ensure that we are all on the same page with regards to the product that is ultimately designed and built. Performance and economic analyses (per February's monthly report) will be completed by mid-May and will provide us with guidance on the optimum sizing combination for the engine, compressor and motor/generator.

Plans for April:

- Continue energy and economic analysis
- Continue manufacturing cost estimating process
- Continue motor/generator design
- Develop a product specification sheet
- Select an engine, compressor and clutches
- A review meeting is planned for April 12th

Administrative:

The total revised budget is $438,279. A contract modification is requested to add the needed funds and extend the contract through December 31st. A review meeting is planned for April 12th in San Diego. Selection of the engine, compressor and motor/generator will be discussed at this meeting. In addition, the meeting will focus on the motor/generator design and future plans.