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Project Title: Innovative Hybrid Gas/Electric Chiller Cogeneration

Department of Energy
Instrument Number: DE-FC26-99FT40641

Phase 1 Final Technical Report

GTI Project No. 65113

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Executive Summary

The purpose of this project is to develop a new hybrid chiller that can 1) reduce end-user energy costs, 2) lower building peak electrical load, 3) increase energy efficiency, and 4) provide standby power. This new hybrid product is designed to allow the engine to generate electricity or drive the chiller's compressor, based on the market prices and conditions of the available energy sources. Building owners can minimize cooling costs by operating with natural gas or electricity, depending on time of day energy rates. In the event of a blackout, the building owner could either operate the product as a synchronous generator set, thus providing standby power, or continue to operate a chiller to provide air conditioning with support of a small generator set to cover the chiller's electric auxiliary requirements. The ability to utilize the same piece of equipment as a hybrid gas/electric chiller or a standby generator greatly enhances its economic attractiveness and would substantially expand the opportunities for high efficiency cooling products.

This product design leverages off a gas/electric hybrid chiller recently commercialized by Alturdyne. This previously designed unit is a single shaft unit able to operate as either a gas or electric driven chiller, through the operation of a clutch installed between the engine and motor. For electrical operation, the clutch is disengaged and the motor turns the compressor. When gas is the desired choice of energy, the clutch was engaged and the engine is used to drive the compressor, with the motor continuing to spin, but not importing or exporting any current. The new unit designed through this project operates in three different modes:

1. Engine operating and driving the compressor with the motor/generator de-energized (Gas Chiller Mode)
2. Engine declutched with motor/generator driving the compressor (Electric Chiller Mode)
3. Engine operating with compressor declutched and synchronous generator/motor delivering standby power to local bus (Generator Mode)

Though all of the components used to construct the unit are considered 'off the shelf' items, the synchronous generator/motor, clutches, and the associated power controls distinguish this product from other existing chillers.

This new Alturdyne hybrid chiller developed through this project is ready to be deployed in the field. The unit and its individual components have been factory tested with satisfactory results. The field testing (to be witnessed by ETL laboratory personnel) will be performed in accordance with (Air-Conditioning and Refrigeration Institute (ARI) 550 Certification Program. After the field testing is complete, the unit will be monitored for a minimum period of one year to document the performance of the unit. At the conclusion of this period of time, barring any unforeseen difficulties, the unit can be ready for further commercial development.

After reviewing the cost of this project and the expected maintenance expenditures, it is estimated that this unit (75 kw – 100 ton cooling capacity) will be available for a cost between $100,000 to $120,000, depending on some of the options specified. When compared to the cost of an electric cooling plant (comparable units range from $85,000 to $100,000), the payback for this unit is between 3 and 4.5 years.

In all modes of operation, additional cost savings are available by utilizing heat recovery equipment installed with the engine. The recovered energy can be used to preheat a boiler or domestic water, where available. The unit can also be operated in parallel with an ice storage system that would allow the chiller to make ice at night and only operate in the day when the ice storage is depleted.

It is expected that these hybrid chillers will be marketed to commercial buildings, including schools, business parks, hotels, and office buildings, as well as specific industrial applications.

Though not defined at this point, recent electric power trends in New York and California indicate that statewide incentives may be developed for building loading profiles that reduce peak load. No allowance for this is provided in the financial statements prepared for this report, however, future development of these incentives would increase cost savings and further reduce the payback for this unit.

If the unit can performs in the field demonstration as well as initial testing indicates, this unit will provide a significant saving to its owners as well improve power versatility and overall reliability.

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1.0 Introduction and Background

Engine-driven chillers are quickly gaining popularity in the market place (increased from 7,000 tons in 1994 to greater than 50,000 tons in 1998) due to their high efficiency, electric peak shaving capability, and overall low operating cost. The product offers attractive economics (5 year pay back or less) in many applications, based on areas cooling requirements and electric pricing structure. When heat is recovered and utilized from the engine, the energy resource efficiency of a natural gas engine-driven chiller is higher than all competing products.

As deregulation proceeds, real time pricing rate structures promise high peak demand electric rates, but low off-peak electric rates. An emerging trend with commercial building owners and managers who require air conditioning today is to reduce their operating costs by installing hybrid chiller systems that combine gas and electric units. Hybrid systems not only reduce peak electric demand charges, but also allow customers to level their energy load profiles and select the most economical energy source, gas or electricity, from hour to hour. Until recently, however, all hybrid systems incorporated one or more gas-powered chillers (engine driven and/or absorption) and one or more conventional electric units. Typically, the cooling capacity of hybrid chiller plants ranges from the hundreds to thousands of refrigeration tons, with multiple chillers affording the user a choice of cooling systems. But this flexibility is less of an option for building operators who have limited room for equipment.

To address this technology gap, a hybrid chiller was developed by Alturdyne that combines a gas engine, an electric motor and a refrigeration compressor within a single package. However, this product had not been designed to realize the full features and benefits possible by combining an engine, motor/generator and compressor.

The purpose of this project is to develop a new hybrid chiller that can 1) reduce end-user energy costs, 2) lower building peak electrical load, 3) increase energy efficiency, and 4) provide standby power. This new hybrid product is designed to allow the engine to generate electricity or drive the chiller's compressor, based on the market prices and conditions of the available energy sources. Building owners can minimize cooling costs by operating with natural gas or electricity, depending on time of day energy rates. In the event of a blackout, the building owner could either operate the product as a synchronous generator set, thus providing standby power, or continue to operate a chiller to provide air conditioning with support of a small generator set to cover the chiller's electric auxiliary requirements. The ability to utilize the same piece of equipment as a hybrid gas/electric chiller or a standby generator greatly enhances its economic attractiveness and would substantially expand the opportunities for high efficiency cooling products.

This project was performed as a government/industry partnership involving personnel from Department of Energy's National Energy Technical Laboratory, Alturdyne Manufacturing, Gard Analytics, Inc., and the Gas Technology Institute.

2.0 Design and Construction of the Hybrid Unit

Key Challenges

A key challenge during the development of the hybrid gas/electric chiller/generator was to integrate the three major components of the system (spark ignited gas engine, electric motor generator, and compressor) with clutches and microprocessor controls to form a cost effective and reliable single product capable of providing cooling with either gas or electricity, additional electric power at peak times, and standby electric power.

Another challenge for this project was the development of a controls system that would allow for automatic mode changes for the hybrid unit as conditions demand. A patented Alturdyne controls design, which allows the motor/generator to operate as an electric motor or synchronous generator, has been tested satisfactorily in the laboratory through another project and is presently ready for field testing. The ability to operate the generator as an electric motor or a synchronous standby generator is a key technical advancement crucial to the success of this product development.

Approach to Developing the Hybrid Gas/Electric Chiller/Generator

The product design leverages off of a gas/electric hybrid chiller recently commercialized by Alturdyne. This previously designed unit is a single shaft unit that is able to operate as either a gas or electric driven chiller, with only one clutch operating between the engine and motor. For electric operation, the clutch is disengaged and the motor turns the compressor. When gas was the desired choice of energy, the clutch was engaged and the engine drives the compressor with the motor spinning, but not importing or exporting any current. The new unit is designed to operate in three different modes:

1. Engine operating and driving the compressor with the motor/generator de-energized (Gas Chiller Mode)
2. Engine declutched with motor/generator driving the compressor (Electric Chiller Mode)
3. Engine operating with compressor declutched and synchronous generator/motor delivering emergency power to local bus (Generator Mode)

Mode changes require the unit to be shutdown and restarted. This action is designed to take place automatically with no manual intervention required.

To operate in these modes, the new product utilizes the following main components (See Appendix A for component cut sheets):

1. Wound-Rotor (Slip Ring) Synchronous Generator/Motor (100 kVA, 208/120 V, 60 Hz/ 75 kW, 208 V, 60 Hz)
2. Natural Gas Engine operating at 1800 rpm (75 kilowatts (kW) or 100 horsepower (hp)
3. Chiller compressor (100 ton)
4. Evaporator and Condenser
5. Associated Control Panels

6. Clutches

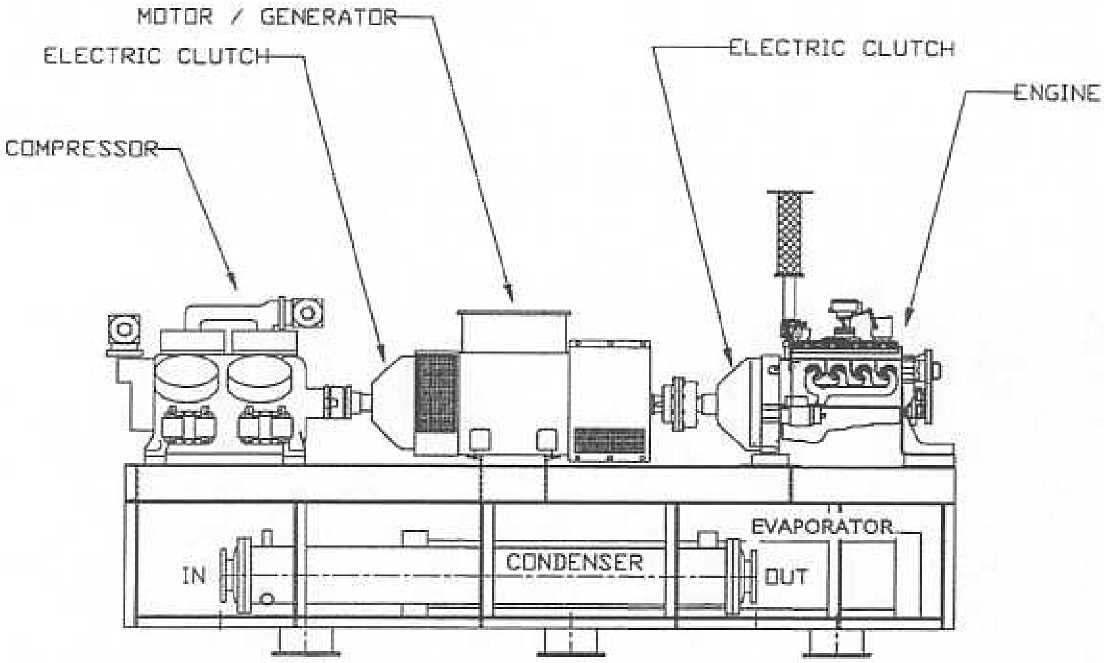


Figure 1

Though all of these components are considered 'off the shelf' components, the synchronous generator/motor, clutches, and the advanced power controls are the items that distinguish this product from other existing chillers.

Wound-Rotor (Slip Ring) Synchronous Generator/Motor

The stator of a wound rotor synchronous generator/motor is identical to that of a normal induction motor. The rotor consists of coils of many turns instead of the heavy bars of the squirrel cage rotor. The ends of the wound-rotor winding are connected to slip rings mounted on the rotor shaft. An external resistance may be connected to the slip rings in order to control the rotor current. Increased resistance in the rotor circuit during starting reduces the starting current the motor draws, and allows control of starting torque. As the motor comes up to operating speed, the resistance is gradually shorted out.

In any induction motor, in order to develop high starting torque with low starting current, the rotor resistance needs to be high. As the machine speeds up, the resistance of the rotor needs to be reduced in order to maintain a high level of torque. The resistance of a squirrel cage rotor is fixed, and a high resistance rotor giving high starting torque unfortunately also gives high slip when fully accelerated.

Any synchronous machine can be run as an alternator or a motor. Both require a DC supply to the rotor. The difference is that the alternator is driven by a prime mover and generates

AC electromotive force in the stator windings. The synchronous generator/motor on the other hand has an AC supply connected to the stator windings. Unlike an induction motor rotor which depends on slip for its torque, the DC rotor field "locks in" to the rotating field of the stator causing the rotor to rotate at synchronous speed from no-load to full load. A synchronous generator/motor has an exciter that enables the generator to produce its own reactive power and regulate its voltage, even when it is not connected to another power source. This means that it can operate either in parallel with the utility or it can operate in "stand-alone" mode (independent of any other power source).

Because of these qualities, the synchronous generator/motor is used in this design to fully optimize the energy sources available to a building owner in providing power to the chiller or other building loads.

Clutches

Another component of this system that is considered a key design difference from previous designs are the two clutches installed between the engine, the synchronous generator/motor, and the chiller compressor. The clutch design for this unit has been a concern since the project was started. The concern stems from clutch failures associated with the first Alturdyne hybrid chiller that was installed in a plastics manufacturing facility in California. It appears the last set of clutches failed due to rapid loading and unloading of the compressor, which caused the clutches to overheat and fail.

To ensure a similar problem does not occur, the estimated torque curves between the three components were developed (Appendix B) and reviewed amongst the project design group. Because the unit is shutdown between mode changes, the maximum amount of torque is approximately 408 ft-lbs. The new clutch manufactured by Warner Electric is designed to handle 1350 ft-lbs. of force at no speed difference between the power source and the load. The new high torque clutches are robust in design and are expected to handle any loading and unloading cycles of the equipment.

Control System

The first version of Alturdyne's hybrid chiller utilized an OPTO22 microprocessor based controller. This controller was used due to its ability to be programmed in an open protocol environment. The logic used in this controller was used as a basis for the control scheme utilized on this project.

The latest hybrid chiller is controlled by a Z-World PK-2600 microprocessor. This unit is a NEMA 4 rated, C-programmable controller with a built-in 320 x 240 touch-screen display. The display is also C-programmable and has a storage area for bitmaps, display lists and screens. This controller comes standard with 16 protected digital inputs and 16 high-current sinking outputs. It also has eight 12-bit analog channels as a standard feature. The unit is powered by a 24 VDC supply and has an operating temperature range of 0 to 50 ° C, with a storage temperature range of –20 ° C to + 70 °C. These features give the unit the control and monitoring diversity needed to implement the functional control requirements of this unit.

As part of this project, Alturdyne customized its latest microprocessor to develop a control scheme that would ensure the unit operated in only one mode at a time and that all safety trips and interlocks needed for protection of personnel as well as equipment were functioning when needed.

When the unit is operated in its automatic mode, the chiller is controlled on a daily schedule with up to six mode changes per day. Each day of the week can be programmed differently, depending on the customer's needs. In the event standby power is called for, the chiller is automatically shutdown and the unit switches to Generator Mode.

A monitoring package was also designed to operate through the touch screen controller. This package monitors several digital inputs including the following points:

- Chilled Water Freeze
- Chilled Water Flow
- Low Generator Voltage
- High Generator Voltage
- High Generator Current
- Low Engine Oil Pressure
- Low Coolant Level
- High Engine Coolant Temperature
- Low Engine Oil Level
- Magnetic Pickup Open Signal
- Emergency Stop
- Critical Overspeed
- Generator Start

The control system configuration also monitors twenty analog inputs. These inputs include the following points:

Chiller Compressor Values
- Suction Pressure
- Discharge Pressure
- Compressor Oil Sump Temperature
- Compressor Oil Pressure
- Suction Temperature
- Discharge Temperature

Water Values
- Chilled Water Inlet Temperature
- Chilled Water Outlet Temperature
- Chilled Water Flow
- Condenser Water Inlet Temperature
- Condenser Water Outlet Temperature
- Condenser Water Flowrate (Optional)

Engine Values
- Engine Oil Pressure
- Engine Speed
- Engine Coolant Temperature

Generator Values
- Active Power (kW)
- Apparent Power (KVA)
- Power Factor
- Active Energy (kW/hr)
- Current
- Voltage
- Generator Speed

These inputs are scaled in the controller and used for both system monitoring and control.

The alarm and trip setpoints were determined by the design team to ensure abnormal operation of the unit would prevent personnel from being harmed while also minimizing equipment damage. These following settings were programmed into the controller and verified during factory testing:

- Engine Overspeed – alarm @ 1900 RPM, shutdown @ 1950 RPM
- Engine Low Oil Pressure – alarm @ 20 PSI, shutdown @ 12 PSI
- Engine High Water Temperature – alarm @ 205 °F, shutdown @ 215 °F
- Generator Underspeed – alarm @ 1750 RPM, shutdown @ 1700 RPM
- Motor Overcurrent – alarm @ 300 amps, shutdown @ 325 amps
- Compressor Low Suction Pressure – alarm @ 28 psi, shutdown @ 23 psi
- Compressor High Discharge Pressure – alarm @ 225 psi, shutdown @ 250 psi
- Compressor Low Comp Oil Pressure – alarm @ 18 psi, shutdown @ 12 psi
- Chilled Water Freeze – alarm @ 37 °F, shutdown @ 35 °F
- Compressor Low Comp Low Temp – alarm @ 90 °F, shutdown @ 80 °F
- Engine Stall – alarm @ 1000 RPM, shutdown @ 900 RPM

When any of the alarms are received, the source of the alarm, time and date, and the alarm type are stored in the event log to allow for further review and analysis of the event.

In the event the engine does not start on its first attempt, the controller is programmed to allow five start attempts to occur with a waiting period between each attempt.

The hybrid chiller that has been developed through this project, has been designed and constructed to operate in the previously specified modes. These modes allow for the unit to operate the chiller's compressor from the offsite or engine power sources and allow for emergency power to be generated when the need arises.

3.0 Factory Test Results and Analysis

A comprehensive test plan was prepared to verify proper operation of the new hybrid unit. Due to the complexity of the new hybrid unit's control system, a test procedure was developed by the Design Team that would run the unit in a variety of different scenarios to verify the unit would operate and/or trip as designed.

The testing was broken into four sections, each section testing a different portion of the control circuitry. These sections are as follows:

1. Generator Static Testing
2. Gas Chiller Static Testing
3. Dynamic Testing
4. Transient Response Testing

These tests do not verify proper operation of the closed chiller loop. Operation of the compressor could not be completed at Alturdyne's test facility due to the lack of equipment to needed to test this loop. The testing of the closed chiller loop side was scheduled to be completed at ETL testing laboratories in Courtland, New York, but due to their backlog, the unit can not be tested per ARI 550 until August 2001 or until the unit is installed in the field. This testing will take place with an ETL representative present when the unit is installed in the field.

Generator Static Testing

The first portion of the testing performed (See Appendix F for Actual Test Data), the Generator Static Test, was performed to verify proper setpoints for the protective trip setpoints (listed in the previous section under the Control Systems description) as well as verifying proper operation of the magnetic pickup. The individual inputs were simulated and the controller was checked to confirm that it was reading the proper input. The magnetic pickup frequency input was tested using a frequency generator to verify that the controller was reading the proper values. Proper operation of the clutch failure circuits was also verified through the following sub-tests that were performed within this section:

1. Engine to Motor Clutch Engagement Failure Test –

Simulate the failure of the clutch to engage by removing clutch coil power. Observe and record system response to fault.

2. Engine to Motor Clutch Dis-engagement Failure Test –

Simulate the failure of the clutch to dis-engage by applying a suitably rated power source to the clutch coil to keep clutch engaged when it should release.

3. Motor to Chiller Clutch Engagement Failure Test –

Simulate the failure of the clutch to engage by removing clutch coil power. Observe and record system response to fault.

4. Motor to Chiller Clutch Dis-engagement Failure Test –

Simulate the failure of the clutch to dis-engage by applying a suitably rated power source to the clutch coil to keep clutch engaged when it should release.

Gas Chiller Static Testing

The second part of the test was the Gas Chiller Static Test. The first part of the test involved the verification of proper temperature readings of the chilled water, condenser water and compressor temperatures. Suction pressure, discharge pressure and compressor oil pressure were all set and the various high and low pressure shutdown alarm conditions were tested and verified.

Dynamic Testing

After the completion of the static testing, the dynamic testing was initiated, which consisted of actual operation of the unit. The main objective of this portion of the testing was to ensure the data being collected from the individual components was indicative of proper operating components. No abnormal settings or operation were noted. During this time, acoustical data around the unit was recorded. With background noise levels measured at 70 DBA at ten feet from the unit, the non-attenuated unit emitted sound levels between 89 and 92 DBA. Without any sound attenuation, this amount of noise is considered normal.

After the no load readings were verified, the unit was run fully loaded for a period of one hour, with parameter readings taken every 15 minutes. The readings indicated the unit was operating relatively stabile. Engine oil temperature varied from 219 to 221 deg F. Engine oil pressure remained constant at 44 psi. Measured voltage was also shown to be stable as well with L1-L2 at 204.6 VAC, L2-L3 at 206.2 VAC and L1-L3 at 205.5 VAC. Frequency held steady at 59.8 Hz. This section of the testing was also used to verify the unit's expected responses to loss of its power source and response to Emergency power needs through the following sub-tests as part of the main test:

1. System Response to Loss of Motor

   While operating system at full load, initiate a signal to trip motor and record system response.

2. System Response to Loss of Engine

   While operating system at full load, initiate a signal to trip engine and record system response.

3. System Response to Loss of Motor

   While operating system at no load, initiate a signal to trip motor and record system response.

4. System Response to Loss of Engine

   While operating system at no load, initiate a signal to trip engine and record system response.

5. Emergency Power Loading Test

   Initiate emergency power start signal and record the amount of time the unit requires to reach rated speed, voltage, and the amount of load placed on the unit.

Transient Response Testing

To verify the unit's ability to respond to transient load changes, a series of transient response tests were performed. The maximum frequency departure was 5 Hz with a response time of five seconds and the maximum voltage departure was 10 VAC with a response time of 0.5 seconds. Both values were within the acceptance criteria. The sub-tests utilized to perform this testing are listed below:

1. Generator Loading Test

   Load generator electrically at 25, 50, 75, 90, and 100% and record the following parameters at each load step:

   - Voltage
   - Current
   - Engine RPM
   - Frequency
   - Watts

2. Generator Full Load Reject Test

   Load generator electrically at 100% and record the listed parameters. After recording the parameters, open the main load breaker to simulate a loss of full load and record the system response.

   - Voltage
   - Current
   - Engine RPM
   - Frequency

- Watts

3. Overspeed Trip Test

   While engine is operating at rated speed, simulate loss of MPU signal and record engine reaction, and overspeed trip point if applicable.

4.0 Economic Analysis Review

To evaluate economic feasibility of the development and commercialization of this type of hybrid chiller product, an economic analysis report (Appendix G) was prepared. This report, developed by GARD Analytics, Inc., looked at several different chiller product designs and their associated development, production, and operational costs and estimated their economic impact in different areas of the country.

To allow for performance and economic comparisons between different hybrid design possibilities and a basic electric chiller, a retail store was selected as the application model due to their long operating hours and sustained demand for cooling during a significant portion of the year. The baseline conventional cooling plant was assumed to be a single 100 ton water cooled electric chiller, which would be available all year to meet the store's cooling demands. The different hybrid designs that were reviewed included the following:

1. Engine – Clutch – Motor – Compressor: Chiller is powered by engine or offsite power source, no electricity is generated

2. Engine – Clutch – Synchronous Motor/Generator – Clutch – Compressor: Chiller is powered by engine or offsite power source, electricity can be generated as either standby backup or while chiller is operating, depending on customer needs.

3. Engine – Clutch – Induction Motor/Generator – Clutch – Compressor: Chiller is powered by engine or offsite power source, though engine operation would require grid interconnection. Standby power generation is not an option with this unit.

4. Engine – Synchronous Generator – Clutch – Induction Motor/ Generator – Clutch - Compressor: Chiller is powered by engine or offsite power source, though engine operation would require grid interconnection. Due to the added components, the physical size of the unit would be very large.

5. Engine – Synchronous Generator – Induction Generator: Unit functions only as a generator, not as a chiller. Unit requires grid interconnect.

6. Engine – Synchronous Generator – wired to --Semi–Hermetic Compressor: Chiller is powered engine or offsite power source. This design allows for engine skid to be installed in a separate location from chiller. Design allows for emergency power generation, but will require larger generator.

7. Engine – Synchronous Generator – Clutch – Compressor: Chiller is powered by engine only. Choice of offsite power is not available.

Since operating costs and savings will vary depending on the installation location (variations in the climate and cost of electricity and natural gas), three cities were chosen for investigation: New York, Detroit, and a Los Angeles suburb. The electricity and natural gas rate structures assumed for these cities are as follows:

	Summer Rates	Winter Rates
➢ **New York City**		
Natural Gas rates (Rate 2)		
Energy, $/therm		
1st 6 therms	22.50	22.50
Next 94 therms	0.94864	1.01114
All other usage	0.66664	0.72914
Electric Rates (Rate 9-III- Low Tension)		
Demand, $/kW		
All Hours, All Days	9.79	3.17
On-peak	12.17	0
Mid-peak	11.05	17.69
Energy, $/kWh		
On-peak	0.1041	0.0685
Mid-peak	0.0523	0.0478

(See Report in Appendix C for peak period time definitions)

	Summer Rates	Winter Rates
➢ **Detroit**		
Natural Gas rates (Rate 1)		
Energy, $/therm		
All therms	0.47679	0.47679
Electric Rates (Rate D6 – TOU Primary Service)		
Demand, $/kW		
For primary service	3.75	3.75
On-peak	14.25	14.25
Off-peak	0	0
Energy, $/kWh		
On-peak	0.0296	0.0296
Off-peak	0.0296	0.0296

(See Report in Appendix C for peak period time definitions)

	Summer Rates	Winter Rates
➢ **Los Angeles Suburb**		
Natural Gas rates (Rate GN-10)		
Energy, $/therm		
1st 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other usage	0.51314	0.51314

Natural Gas rates (Rate G-AC Gas Cooling)

Energy, $/therm		
All cooling gas	0.49858	N/A
Electric Rates (Rate TOU-GS-2B)		
Demand, $/kW		
Facility charge	5.40	5.40
On-peak	16.40	0
Mid-peak	2.45	0
Off-peak	0	0
Energy, $/kWh		
On-peak	0.14896	0
Mid-peak	0.06613	0.07811
Off-peak	0.04271	0.04271

(See Report in Appendix C for peak period time definitions)

These cities were chosen due to their variation in utility rates and charges as well as climate.

It should be noted that maintenance costs associated with this report were assumed to be $0.015/ton-hr (for gas engine cooling) and $0.015/hp-hr (for generator output).

Based on the above listed input, the hybrid chiller (Hybrid Design #2) designed and constructed for this project was determined to be the most economical and productive unit that was reviewed. The report also concluded the following points:

1. **The project designed unit (100 hp, 100 ton compressor, and a 75 kW generator) that would operate during all on-peak hours even when no cooling is required gives annual savings (including maintenance) of $7,000 - $12,000 per year versus the all electric cooling plant.**

2. The optimum configuration appears to be a system that utilizes a 150 hp gas engine, a100 ton compressor, and a 93 kW generator operating all on-peak hours. This scenario can provide an annual savings of $9,000 - $15,000 per year.

3. Where interconnection with the grid is a problem, a 150 hp engine powering a 100 ton gas chiller and a 35 kW synchronous generator, which serves a fixed load, can provide an annual savings of $8,000 to $13,000 per year.

With the possibility of annual savings between $7,000 and $12,000 per year for the unit that was constructed, the new hybrid chiller developed through this project, can provide a better alternative to an all electric cooling plant. In addition to the cost savings, the hybrid unit provides the end user with the flexibility to achieve cooling by using the most economical energy source and provides the end user backup electrical power.

5.0 Conclusions

The Alturdyne hybrid chiller that has been developed through this project is ready to be deployed in the field. The unit and its individual components have been factory tested with satisfactory results. The field testing (to be witnessed by ETL personnel) will be in accordance with ARI 550. After the field testing is complete, the unit will be monitored for a minimum period of one year to document the performance of the unit. At the conclusion of this period of time, barring any unforeseen difficulties, the unit should be ready for commercial production.

After reviewing the cost of this project and the expected maintenance expenditures, it is estimated that this unit will be available for value between $100,000 to $120,000, depending on some of the options specified. When compared to the cost of an electric cooling plant (comparable units range from $85,000 to $100,000), the payback for this unit is between 3 and 4.5 years.

In all modes of operation, additional cost savings are available by utilizing heat recovery equipment installed with the engine. The recovered energy can be used to preheat a boiler or domestic water, where available. The unit can also be operated in parallel with an ice storage system that would allow the chiller to make ice at night and only operate in the day when the ice storage is depleted.

It is expected that these hybrid chillers will be marketed to commercial buildings, including schools, business parks, hotels, and office buildings, as well as specific industrial applications.

Though not defined at this point, recent electric power trends in New York and California indicate that statewide incentives may be developed for building loading profiles that reduce peak load. No allowance for this is provided in the financial statements prepared for this report, however, future development of these incentives would increase cost savings and further reduce the payback for this unit.

If the unit can performs in the field demonstration as well as initial testing indicates, this unit will provide a significant saving to its owners as well improve power versatility and overall reliability.

Appendix A

Component Cut Sheets

ALTURDYNE ENERGY SYSTEMS
HYBRID CHILLER NATURAL GAS PERFORMANCE

ALTURDYNE Model: EGMG881-15HWW100

Nominal Cooling Load Level (%)	25	50	75	100

COMPRESSOR: Carlyle 5H126

Capacity (USRT)	27.6	52.3	75.0	95.4
Speed (RPM)	900	900	1,350	1,800
Working Cylinders/Total Cylinders	6/12	12/12	12/12	12/12
Refrigerant	R-134a	R-134a	R-134a	R-134a
Condenser Heat Rejection (BTU/HR)	395,100	735,400	1,074,800	1,388,000

ENGINE: General Motors GMG-881

Power (BHP)	25.3	43.2	69.6	98.2
Fuel Consumption (BTU/HR) HHV	222,600	380,200	592,200	834,700
Engine Jacket Heat Rejection (BTU/HR)	66,800	114,000	177,700	250,400
Recoverable Exhaust Jacket Heat (BTU/HR)	33,400	57,000	88,800	125,200

EVAPORATOR: API / KETEMA DXT-1610-S2

Chilled Liquid	Water	Water	Water	Water
EFT (F)	46.9	49.5	51.9	54.0
LFT (F)	44.0	44.0	44.0	44.0
SST (F)	37.0	37.0	37.0	37.0
Flow (GPM)	229.0	229.0	229.0	229.0
Pressure Drop (PSI)	2.3	2.3	2.3	2.3

CONDENSER: API / KETEMA AHX-1406B-2

EWT (F)	66.3	72.5	78.8	85.0
LWT (F)	69.2	77.9	86.7	95.1
SCT (F)	81.3	87.5	93.8	100.0
Flow (GPM)	273.8	273.8	273.8	273.8
Pressure Drop (PSI)	3.1	3.1	3.1	3.1

PERFORMANCE:

BHP/TON	0.92	0.83	0.93	1.03
KW/TON	0.68	0.62	0.69	0.77
C.O.P. (w/o Heat recovery)	1.49	1.65	1.52	1.37
C.O.P. (w/ Jacket heat recovery)	1.79	1.95	1.82	1.67
C.O.P. (w/ Jacket & exhaust heat recovery)	1.94	2.10	1.97	1.82

ALTURDYNE ENERGY SYSTEMS
HYBRID CHILLER ELECTRICAL PERFORMANCE

ALTURDYNE Model: EGMG881-15HWW100

Nominal Cooling Load Level (%)	33	50	67	100

COMPRESSOR Model: Carlyle 5H126

Capacity (USRT)	35.8	50.7	64.6	92.2
Speed (RPM)	1,750	1,750	1,750	1,750
Working Cylinders/Total Cylinders	4/12	6/12	8/12	12/12
Refrigerant	R-22	R-22	R-22	R-22
Condenser Heat Rejection (BTU/HR)	503,100	736,300	945,700	1,349,451

MOTOR: AVK Type DSU 43M1-4

Power (BHP)	29.2	50.4	66.7	95.5
Current @ 460VAC/3 Phase	32	55	73	105

EVAPORATOR: API \ KETEMA DXT-1610-S2

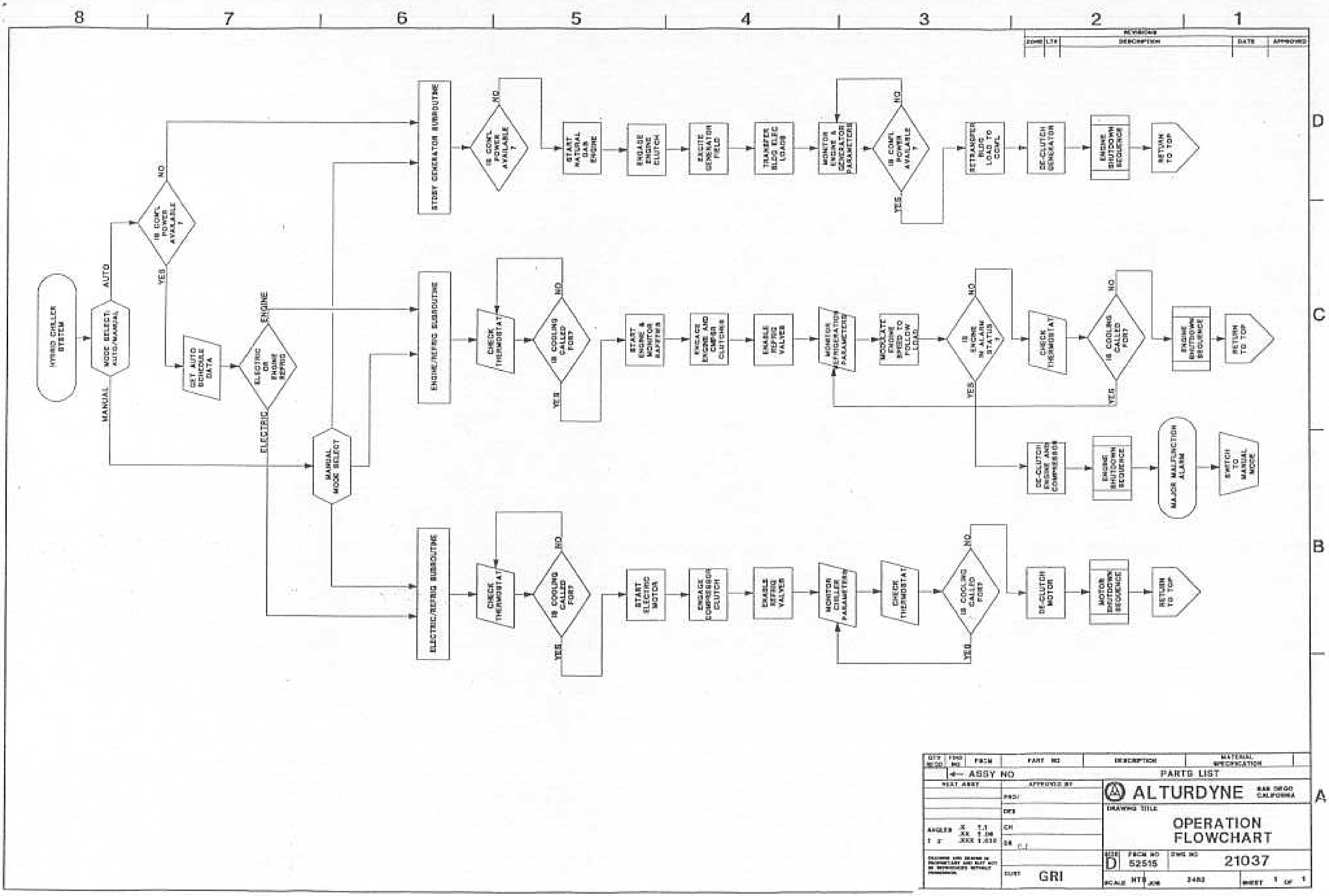
Chilled Liquid	Water	Water	Water	Water
EFT (F)	47.7	49.3	50.9	53.7
LFT (F)	44.0	44.0	44.0	44.0
SST (F)	37.0	37.0	37.0	37.0
Flow (GPM)	229.0	229.0	229.0	229.0
Pressure Drop (PSI)	2.3	2.3	2.3	2.3

CONDENSER: API / KETEMA AHX-1406B-2

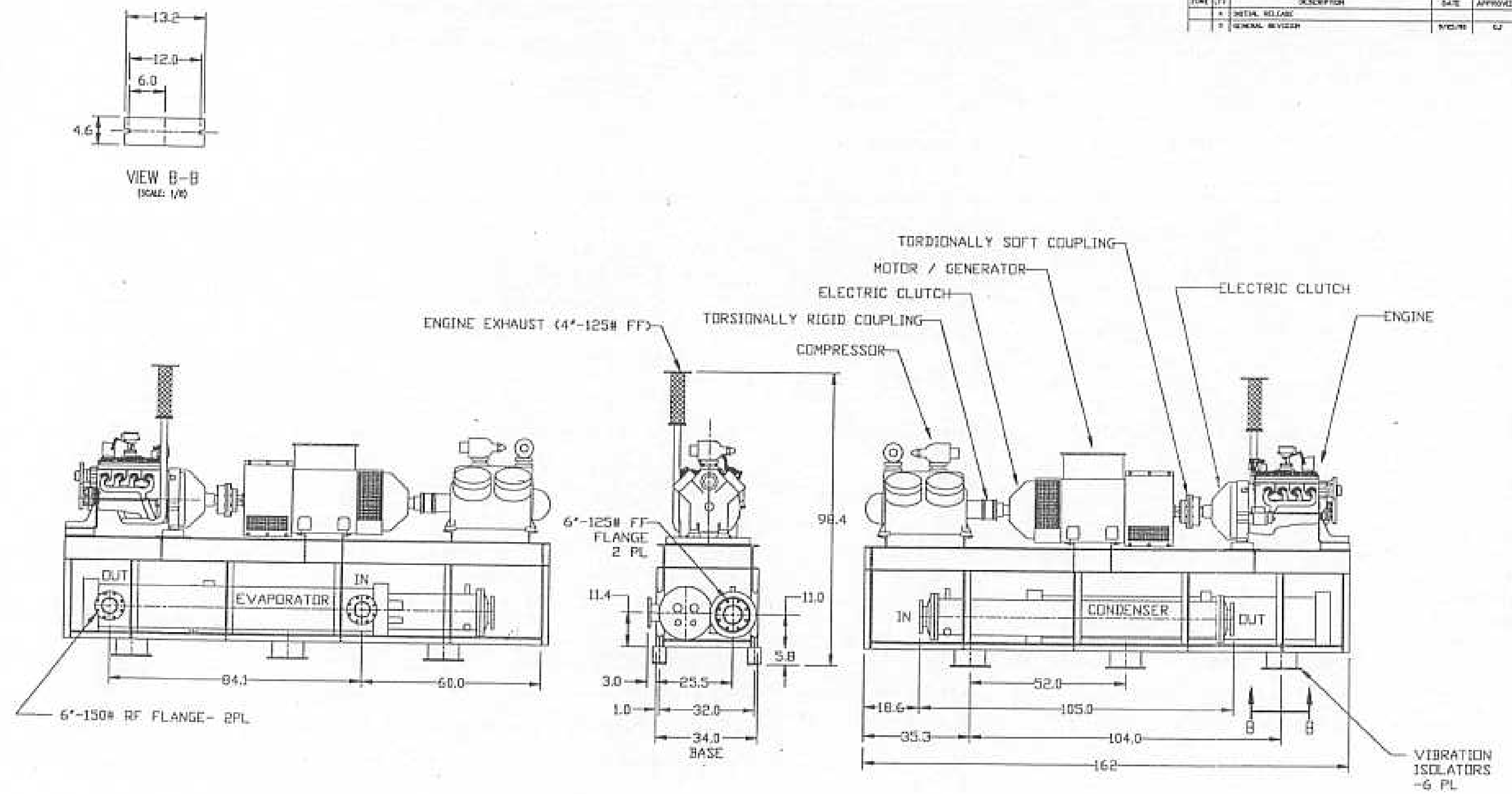
EWT (F)	66.3	72.5	78.8	85.0
LWT (F)	71.7	77.4	83.0	94.0
SCT (F)	81.3	87.5	93.8	100.0
Flow (GPM)	273.8	273.8	273.8	273.8
Pressure Drop (PSI)	3.1	3.1	3.1	3.1

PERFORMANCE:

BHP/TON	0.81	0.99	1.03	1.04
KW/TON	0.61	0.74	0.77	0.77
C.O.P.	2.06	1.69	1.62	1.62


8
7
6
5
4
3
2
1
D
C
B
A
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
HYBRID CHILLER SYSTEM
MODE SELECT: AUTO/MANUAL
AUTO
MANUAL
IS COM'L POWER AVAILABLE ?
NO
YES
GET AUTO SCHEDULE DATA
ELECTRIC OR ENGINE REFRIG
ENGINE
ELECTRIC
MANUAL MODE SELECT
STDBY GENERATOR SUBROUTINE
IS COM'L POWER AVAILABLE ?
NO
START NATURAL GAS ENGINE
ENGAGE ENGINE CLUTCH
EXCITE GENERATOR FIELD
TRANSFER BLDG ELEC LOADS
MONITOR ENGINE & GENERATOR PARAMETERS
IS COM'L POWER AVAILABLE ?
NO
YES
RETRANSFER BLDG LOAD TO COM'L
DE-CLUTCH GENERATOR
ENGINE SHUTDOWN SEQUENCE
RETURN TO TOP
ENGINE/REFRIG SUBROUTINE
CHECK THERMOSTAT
IS COOLING CALLED FOR?
NO
YES
START ENGINE & MONITOR SAFETIES
ENGAGE ENGINE AND CMPSR CLUTCHES
ENABLE REFRIG VALVES
MONITOR REFRIGERATION PARAMETERS
MODULATE ENGINE SPEED TO FOLLOW LOAD
IS ENGINE IN ALARM STATUS ?
NO
YES
CHECK THERMOSTAT
IS COOLING CALLED FOR?
NO
YES
ENGINE SHUTDOWN SEQUENCE
RETURN TO TOP
DE-CLUTCH ENGINE AND COMPRESSOR
ENGINE SHUTDOWN SEQUENCE
MAJOR MALFUNCTION ALARM
SWITCH TO MANUAL MODE
ELECTRIC/REFRIG SUBROUTINE
CHECK THERMOSTAT
IS COOLING CALLED FOR?
NO
YES
START ELECTRIC MOTOR
ENGAGE COMPRESSOR CLUTCH
ENABLE REFRIG VALVES
MONITOR CHILLER PARAMETERS
CHECK THERMOSTAT
IS COOLING CALLED FOR?
NO
YES
DE-CLUTCH MOTOR
MOTOR SHUTDOWN SEQUENCE
RETURN TO TOP
FSCM
PART NO
DESCRIPTION
MATERIAL SPECIFICATION
ASSY NO
PARTS LIST
NEXT ASSY
APPROVED BY
ALTURDYNE
SAN DIEGO CALIFORNIA
DRAWING TITLE
OPERATION FLOWCHART
SIZE D
FSCM NO 52515
DWG NO 21037
CUST GRI
SCALE NTS
SHEET 1 OF 1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	INITIAL RELEASE		
	B	GENERAL REVISION	[illegible]	[illegible]



EQUIPMENT RATINGS:

ELECTRIC MOTOR W/ REFRIGERATION CMPSR: 92.2 RT
NATURAL GAS ENGINE W/ REFRIG. CMPSR: 95.4 RT
NATURAL GAS ENGINE W/ AC GENERATOR: 75kW @ 208V

NOTE: RATINGS ARE SPECIFIED AT ARI 550/590-98 CONDITIONS

ALTURDYNE SAN DIEGO CALIFORNIA

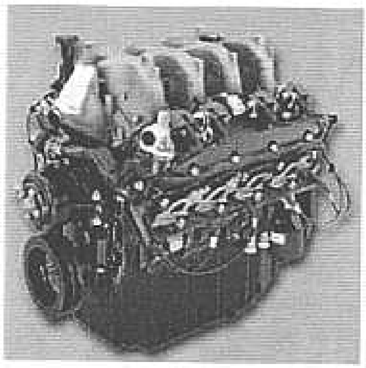
DRAWING TITLE: HYBRID CHILLER- GAS/ELECTRIC (MECHANICAL INTERFACE)

SIZE D | FSCM NO 52515 | DWG NO 21027

SHEET 1 OF 1

GM POWERTRAIN

Vortec 8100 (8.1L V8 Industrial Engine -- Model Year 2001)



Product Specifications

Type:
90° 8.1L V8
Displacement:
496 cid (8127 cc)
Compression Ratio:
9.1:1
Valve Configuration:
Pushrod Actuated Overhead Canted Valves
Manufactured:
Tonawanda, New York
Valve Lifters:
Hydraulic Roller
Bore x Stroke:
4.25 x 4.37 in (107.95mm x 111 mm)
Main Bearing Caps:
4-Bolt Cast Iron
Balance Method:
Internal
Intake Manifold:
Factory-Installed Alternate Fuel Manifold
Firing Order:
1-8-7-2-6-5-4-3
Oil Pan Capacity:
8 qt
Fuel Type:
CNG/LPG
Engine Rotation:
Clockwise (from the front)
Sparkplugs:
Platinum (1.5-mm gap)

Paint Protection:
Component Painted
Shipping Weight:
729 lb (307.49 kg)
Horsepower:
264 hp @ 3000 rpm (Propane)
240 hp @ 3000 rpm (Natural Gas)
Torque:
462 lb-ft @ 3000 rpm (Propane)
417 lb-ft @ 3000 rpm (Natural Gas)

Correction to SAE J1995. Actual power levels may vary depending on OEM calibration and application.

Materials:
Block: Cast Iron
Cylinder Head: Cast Iron (with sintered powder metal exhaust valve seat inserts)
Intake Manifold: One-Piece Cast Aluminum
Crankshaft: High-Density Nodular Iron (with undercut and rolled fillets)
Pistons: Hypereutectic Cast Aluminum
Connecting Rods: Forged 1141 SAE Steel (shot-peened and magnafluxed, with 9-mm diameter connecting rod bolts)

Information may vary with application. All specifications listed are based on the latest product information available at the time of publication. The right is reserved to make changes at any time without notice.

GM POWERTRAIN

Vortec 8100 (8.1L V8 Industrial Engine -- Model Year 2001)

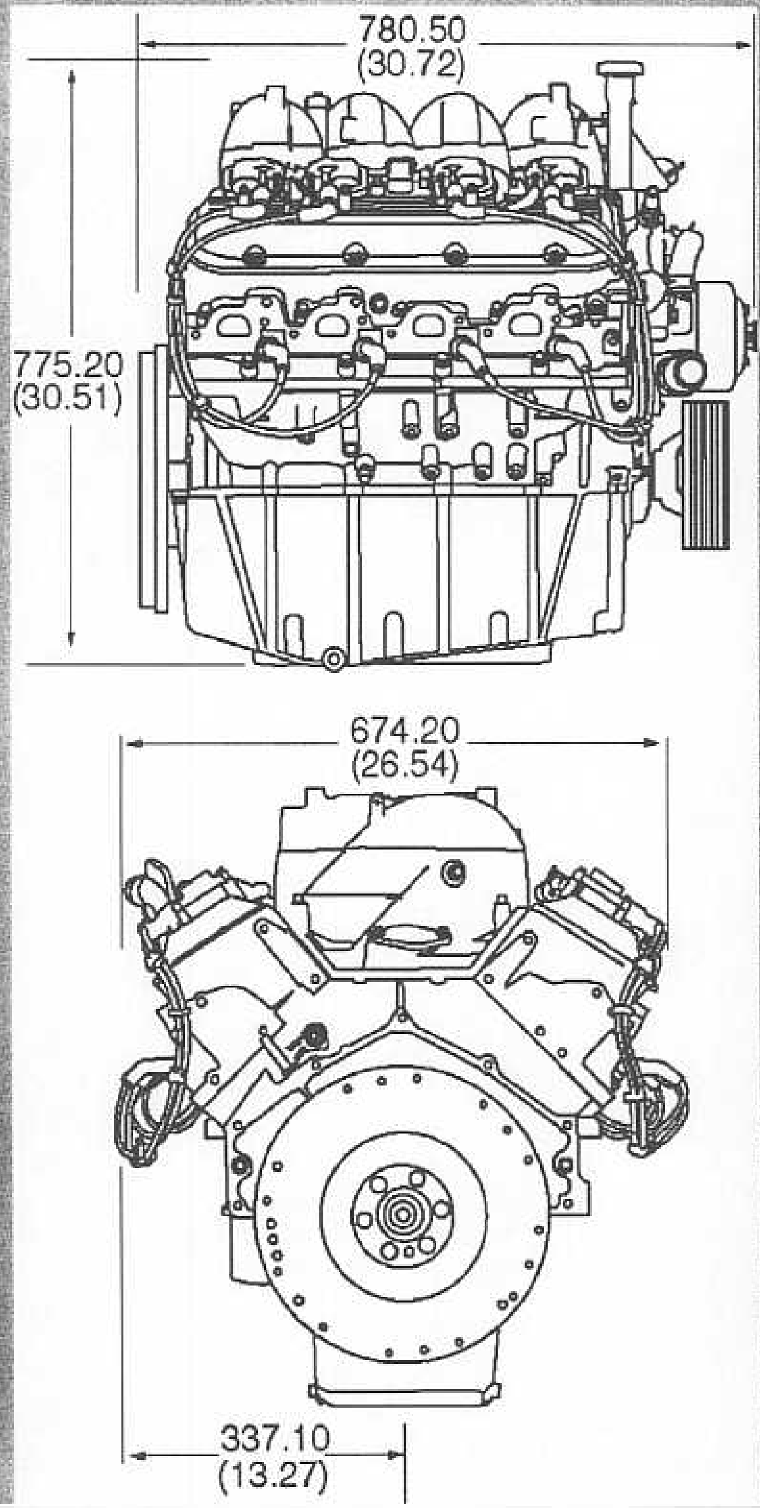
Features / Benefits

- Coil-near-plug ignition includes crankshaft sensor, camshaft sensor, ESC sensors, and eight ignition coils.
- Cylinder head features high-flow replicated ports and sintered powder metal exhaust valve seat inserts for durability.
- Industrial torsional damper with integral six-rib pulley to accommodate serpentine accessory drive hardware.
- Iron exhaust valve seat facing for better valve durability with alternative fuel applications.
- Platinum tip long-life spark plugs.
- High torque camshaft with hydraulic roller valve lifters provides maximum performance.
- Positive Crankcase Ventilation (PCV) system is integral to intake manifold (no valve required) .
- Coated cast aluminum 8-quart oil pan with full baffle and 12-mm drain plugs on port and starboard sides.
- Industrial external water crossover.
- Coated, flat top hypereutectic cast aluminum pistons.
- Engine block quick-connect oil fittings for easy assembly of oil coolers or remote oil systems.

Options

- "Vortec 8100" Sight Shield and related mounting hardware available in kit form.
- A fourth-generation Electronic Control Module (MEFI IV) utilizing state-of-the-art hybrid technology and related parts is available in kit form.
- GM-designed accessory drive components available in kit form.
- Engine block heater for cold climate operations available in kit form.

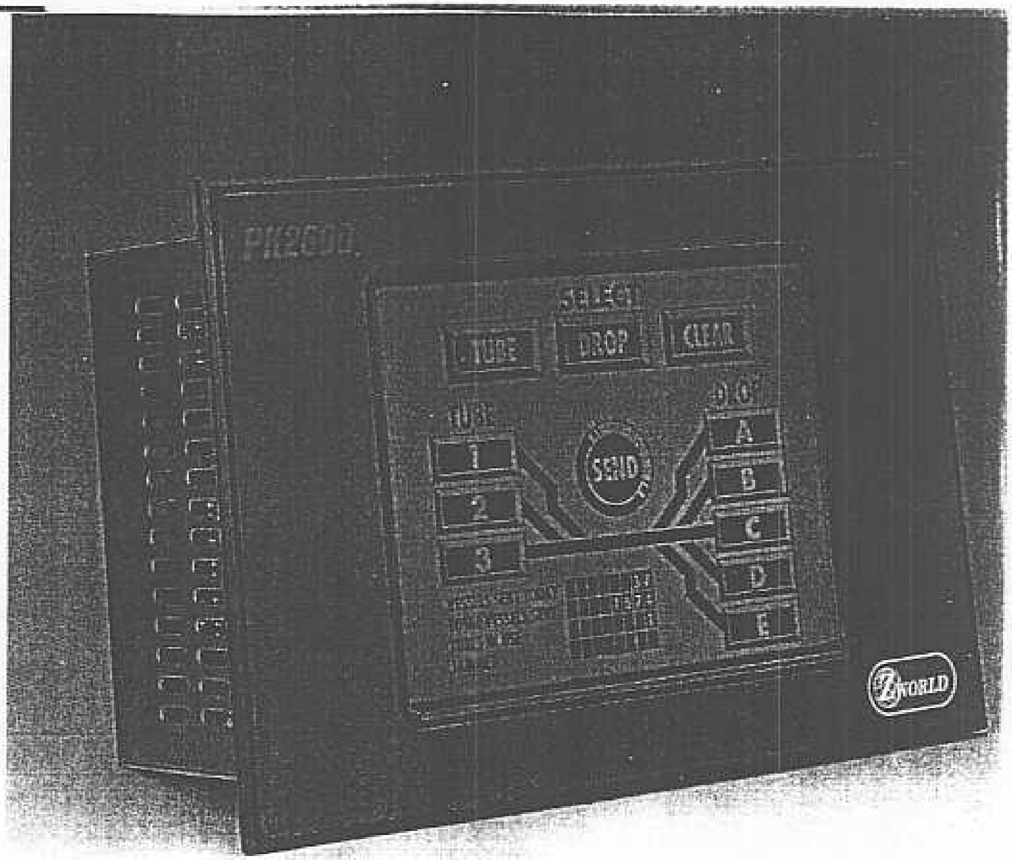
Dimensions



CE
pending

NEW! PK2600

- *NEMA-4 panel*
- *Dual processors (both are C-programmable)*
- *Large memory (up to 512K flash or 1M SRAM)*
- *32K VRAM*
- *320 x 240 (1/4 VGA) graphics LCD with adjustable contrast and CCFL backlighting*
- *8 x 8 (interpolated to 15 x 15) transparent touchscreen overlay*
- *Storage for up to 50 bitmap screens and hundreds of display lists.*
- *8 conditioned 12-bit analog inputs*
- *16 digital inputs, 16 high-current outputs (factory configurable other ways)*
- *PLCBus expansion port*
- *3 Serial ports (RS232, RS485)*



The PK2600 is a C-programmable controller with a built-in 320× 240 (1/4 VGA) touchscreen display. The display is also C-programmable and has a large storage area for bitmaps, display lists, and screens. The PK2600 is ideal for control systems that require an interactive graphic interface.

The PK2600 comes standard with 16 protected digital inputs and 16 high-current sinking outputs. The 32 I/O lines can be ordered as inputs or outputs in banks of eight. The sinking outputs can be converted to sourcing outputs using the optional sourcing driver kit.

The PK2600 has 8 12-bit analog input channels. Each input has socketed bias and gain resistors and an op-amp for signal conditioning. In production quantity, the gain and offset resistors can be surface-mounted.

The PK2600 has 3 serial ports. Port 1 can be RS-485 or 3-wire RS-232. Ports 2 and 3 can be RS-485 or 5-wire RS-232 and support DMA. The PK2600 also has a PLCBus expansion port, allowing you to add extra I/O such as relays or DAC channels.

The PK2600 is NEMA-4, having a gas-tight bezel. The digital, analog, and serial ports use DB25 and DE9 connectors on the rear of the protective enclosure.

Programming the PK2600

Both the controller and display are C-programmable using Dynamic C® described on page 60. A dip-switch on the enclosure allows you to select which component to program.

Developer's Kit

The PK2600 Developer's Kit contains all the hardware tools necessary for rapid development: manual, schematics, programming cables, AC adapter, sourcing high-current driver, and mounting hardware. International orders do not include an AC adapter unless specifically requested.

A SIB-2 is required for development.

Versions

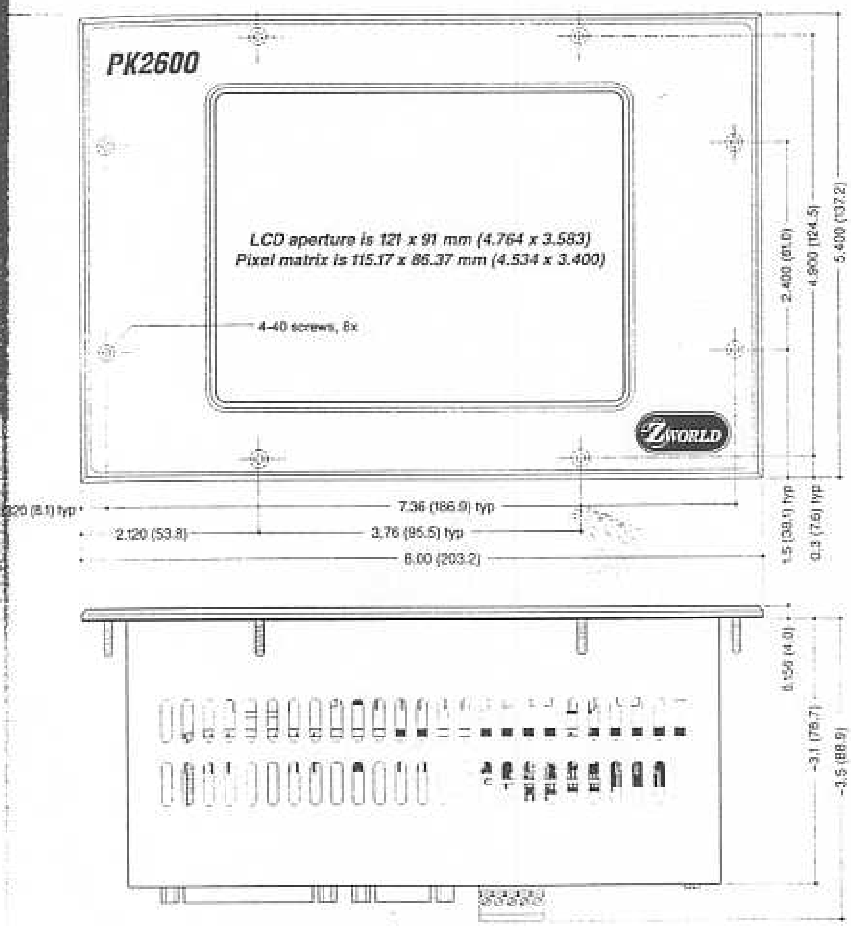
PK2600 Full-featured controller. Specifications given above.

Options and Upgrades

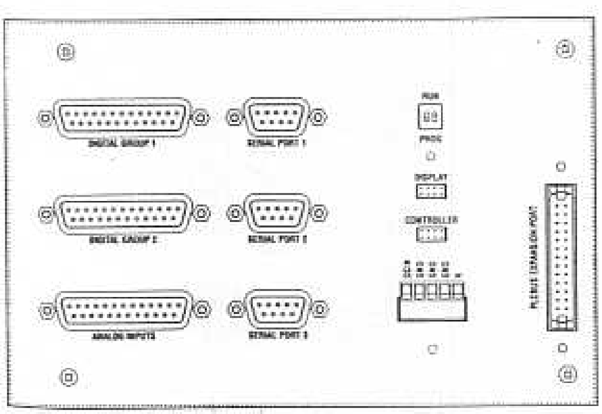
SIB. Serial interface board. Allows programming through the special programming port on the PK2600. Includes programming cable.

Sourcing driver kit. Provides two (2985) sourcing driver chips. At 25°C, a channel can source up to 250 mA continuously. Output subject to package power limits and duty cycle. Load limit 30V.

PK2600 Dimensions



PK2600 Connections



PK2600 Specifications

Bezel Size	5.4" × 8.0" × 0.156" with gasket
Enclosure size	4.511" × 6.026" × 1.244"
Clearance at rear	3.5" case, 5.5" for case and cables
Operating temp.	0°C to 50°C, r.h. 25–65% non-condensing. Storage temp. –20°C to +70°C
Power	24VDC. Requries 7.9 W or more
Configurable I/O *	By custom order
	Serial ports 1, 2, & 3 can be RS-232 or RS-485. Ports 2 & 3 support DMA
Digital inputs	16 standard. Continuous operation from –20V to +24V. Logic threshold at 2.5V. Protected against spikes in the range ±48V. 10K pull-up or pull-down
Digital outputs	16 standard, high-current. At 25°C, a channel can sink up to 500 mA continuously. Output is subject to package power limits and duty cycle. Load limit is 48V. Sourcing outputs optional
Analog inputs	Eight 12-bit channels. Up to 5,000 samples/sec. TLC2543. Factory configured for a 0–10V range
Analog outputs	PWM, using digital outputs, up to 7 channels
LCD	FSTN, 320×240 pixels, black on white background. Pixel matrix is 115.2 x 86.4 mm (0.36 mm pitch). Aperture in bezel is 121× 91 mm (4.76"× 3.58"). Software-adjustable contrast
Backlight	CCFL (cold-cathode fluorescent) with software control (on/off)
Processor	(Controller) Z180 at 18.432 MHz. (Display) Z180 at 9.216 MHz
SRAM	(Controller) 128K–512K (Display) 128K–512K
EEPROM	Simulated in flash
Flash	(Controller) 128K–256K (Display) 128K–256K
Image storage	Up to 256K flash or 512K SRAM. 32K VRAM
Serial Ports	Three, up to 57,600 bps. Port 1 can be RS-485 or 3-wire RS-232. Ports 2 and 3 can be RS-485 or 5-wire RS-232
Reliability	Watchdog, supervisor, battery-backed time/date clock, two 3V lithium coin-type batteries, 165 mA-h and 190 mA-h
Expansion Port	PLCBus™
Connectors	Screw terminals for power. DB25 for digital and analog I/O. DE9 for serial ports. 26-pin PLCBus port. Run/program DIP switch. Two SIB headers

* *Configurable I/O: The 32 digital lines can be specially ordered in any combination of inputs and outputs. The voltage range of analog inputs can be configured at the factory, by special order.*

Product Line

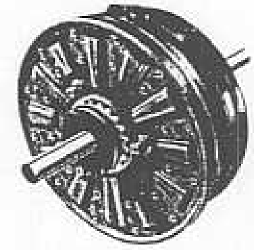
Model Size Selection Charts

Clutches

SF
SFC

Model Number	Max. Rated Torque	Outside Diameter in.	Overall Length in.	Page No.
SF-120	5 lb. in.	1 1/4	1 3/8	B-20, 24
SF-170	15 lb. in.	1 3/4	1 7/8	B-36, 40
SFC-120	5 lb. in.	1 1/4	1	B-28, 32
SFC-170	15 lb. in.	1 3/4	1 3/8	B-44, 48
SF-250	70 lb. in.	2 5/8	3 1/2	B-52, 56
SF-400	270 lb. in.	4 1/4	3 3/4	B-68, 72
SFC-250	70 lb. in.	2 5/8	2 1/4	B-60, 64
SFC-400	270 lb. in.	4 1/4	2 3/4	B-76, 80
SF-500	50 lb. ft.	5 1/4	4	B-84
SFC-500	50 lb. ft.	5 1/4	3 7/8	B-92, 96
SF-650	95 lb. ft.	6 3/4	3 3/8	B-108, 112
SFC-650	95 lb. ft.	6 3/4	3 5/8	B-116, 120
SF-825FM	125 lb. ft.	8 5/8	3	B-136, 140
SF-825BM	150 lb. ft.	8 5/8	2 3/4	B-148, 152
SFC-825FM	125 lb. ft.	8 5/8	4 3/8	B-144
SFC-825BM	150 lb. ft.	8 5/8	4 5/8	B-156
SF-1000FM	240 lb. ft.	10 3/8	3 1/8	B-136, 140
SF-1000BM	240 lb. ft.	10 3/8	3 1/8	B-148, 152
SFC-1000FM	240 lb. ft.	10 3/8	5 7/8	B-144
SFC-1000BM	240 lb. ft.	10 3/8	5 7/8	B-156
SF-1225FM	465 lb. ft.	12 3/4	3 3/4	B-172, 176
SF-1225BM	465 lb. ft.	12 3/4	3 3/4	B-184, 188
SFC-1225FM	465 lb. ft.	12 3/4	6 3/8	B-180
SFC-1225BM	465 lb. ft.	12 3/4	6 3/8	B-192
SF-1525FM	700 lb. ft.	15 3/4	4 1/4	B-172, 176
SF-1525BM	700 lb. ft.	15 3/4	4 1/4	B-184, 188
SF-1525H.T.FM	1,350 lb. ft.	15 3/4	5	B-196
SF-1525H.T.BM	1,350 lb. ft.	15 3/4	5	B-204
SFC-1525FM	700 lb. ft.	15 3/4	6 1/2	B-180
SFC-1525BM	700 lb. ft.	15 3/4	6 1/2	B-192
SFC-1525H.T.FM	1,350 lb. ft.	15 3/4	6 1/2	B-200
SFC-1525H.T.BM	1,350 lb. ft.	15 3/4	6 1/2	B-208

Clutches



PC
PCC

Model Number	Max. Rated Torque	Outside Diameter in.	Overall Length in.	Page No.
PC-500	40 lb. ft.	6	3 1/4	B-88
PCC-500	40 lb. ft.	6	4 1/4	B-100
PC-825	125 lb. ft.	9 1/4	3 1/2	B-124, 128
PCC-825	125 lb. ft.	9 1/4	4 3/8	B-132
PC-1000	240 lb. ft.	10 7/8	3 7/8	B-124, 128
PCC-1000	240 lb. ft.	10 7/8	5 7/8	B-132
PC-1225	465 lb. ft.	12 7/8	4 1/2	B-160, 164
PCC-1225	465 lb. ft.	12 7/8	6 1/2	B-168
PC-1525	700 lb. ft.	16 1/8	4 3/4	B-160, 164
PCC-1525	700 lb. ft.	16 1/8	6 3/4	B-168

Model Size Selection Charts

Nomenclature:

BM	Bearing Mount
FM	Flange Mount
HT	High Torque
MB	Motor Brake
PB	Brake – Primary Style
PC*	Clutch – Primary
PCC*	Clutch Coupling – Primary
PCB*	Clutch Brake – Primary
PCBC*	Clutch Brake Coupling – Primary
SF**	Clutch – Stationary Field Style
SFC**	Clutch Coupling – Stationary Field
SFPBC**	Clutch Brake Coupling – Stationary Field

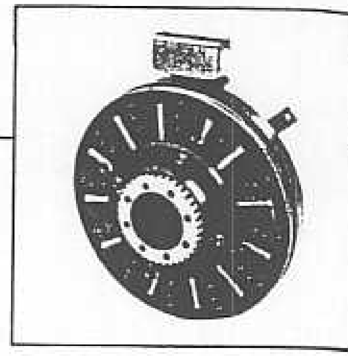
* Current is carried through brushes and collector ring.

** Do not have brushes or collector ring.

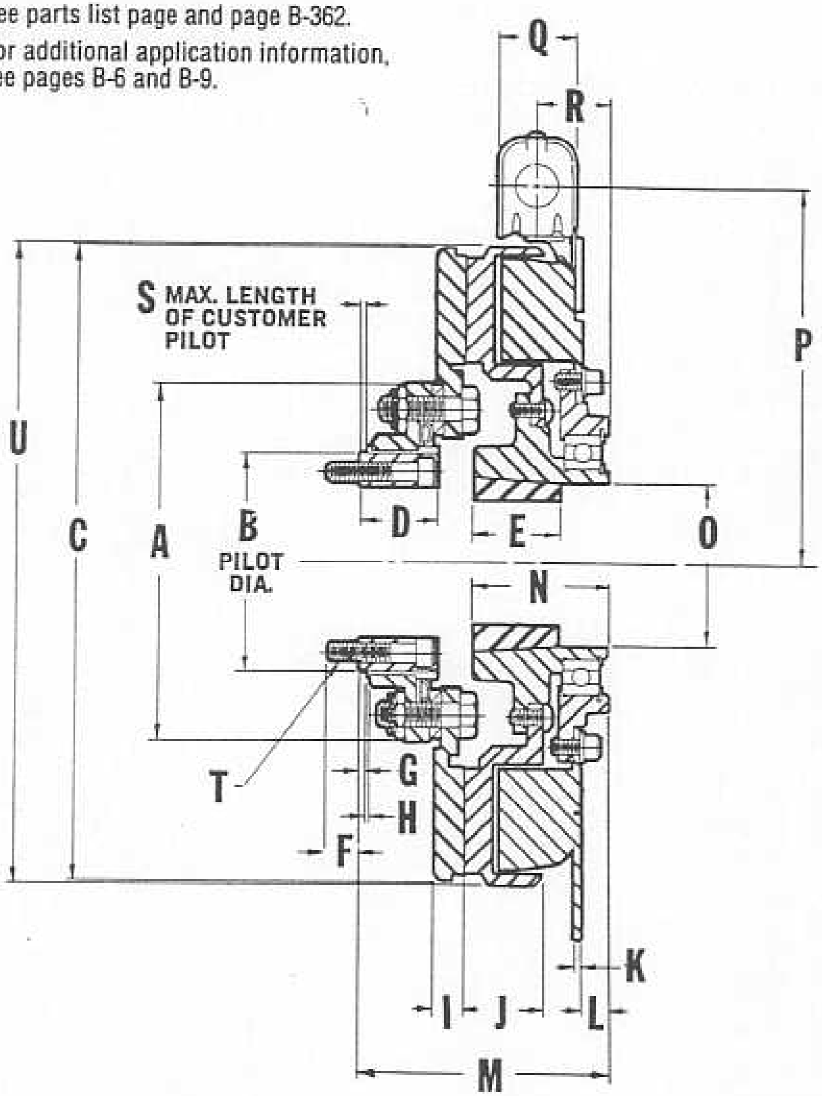
Clutch, Hi-Torque

SF-1525 H.T.

Bearing Mounted



See parts list page and page B-362.
For additional application information, see pages B-6 and B-9.



Drawing I-25643

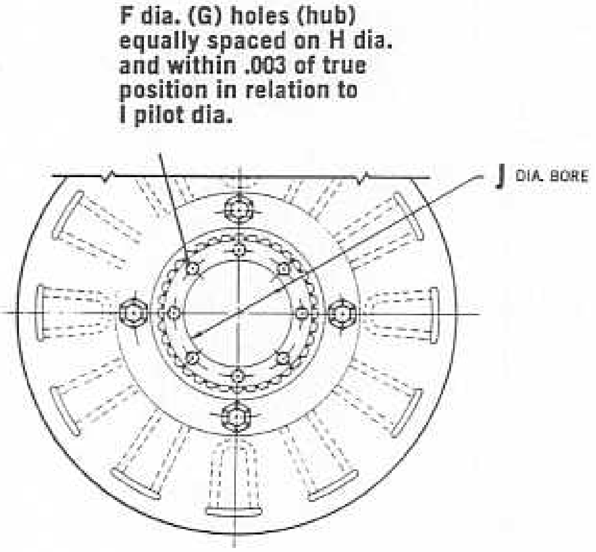
All dimensions are nominal, unless otherwise noted.

A Dia.	B	C Dia.	D	E	F Max.	G	H	I	J
8¾	4.313 / 4.311	15 37/64	1½	2	23/32	⅛	1/16	9/16	1 9/16

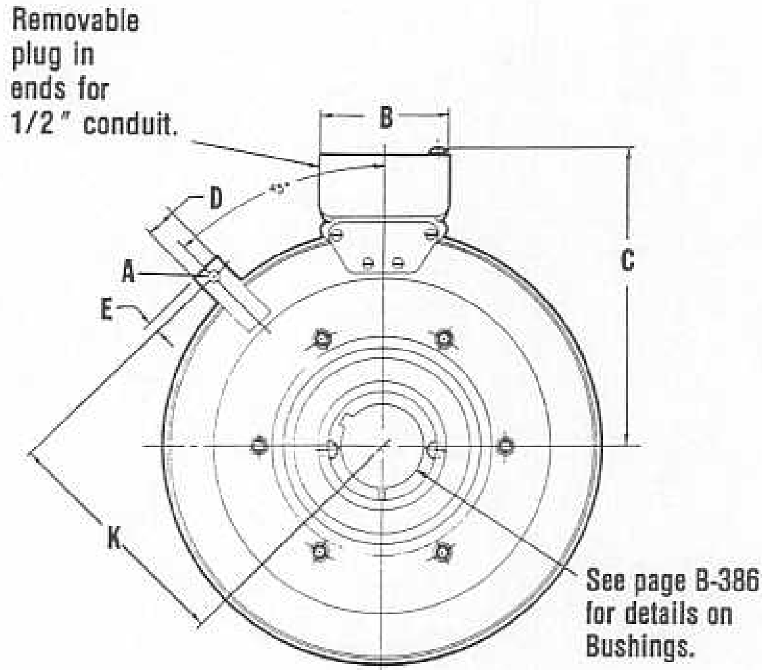
K	L	M Max.	N	O Dia.	P	Q	R	S	T	U Max. Dia.
3/16	1⅛	5 19/32	2 15/16	3 31/32	9 3/16	1 35/64	2 3/32	3/32	⅜-16 UNC-2A	15 43/64

Clutch, Hi-Torque

Bearing Mounted



ARMATURE VIEW



FIELD VIEW

CUSTOMER SHALL MAINTAIN:
Armature hub pilot dia. to be concentric with field and rotor mounting shaft within .010 T.I.R.

Information on Coil Data, Inertia and Weights begins on page B-378.

All dimensions are nominal, unless otherwise noted.

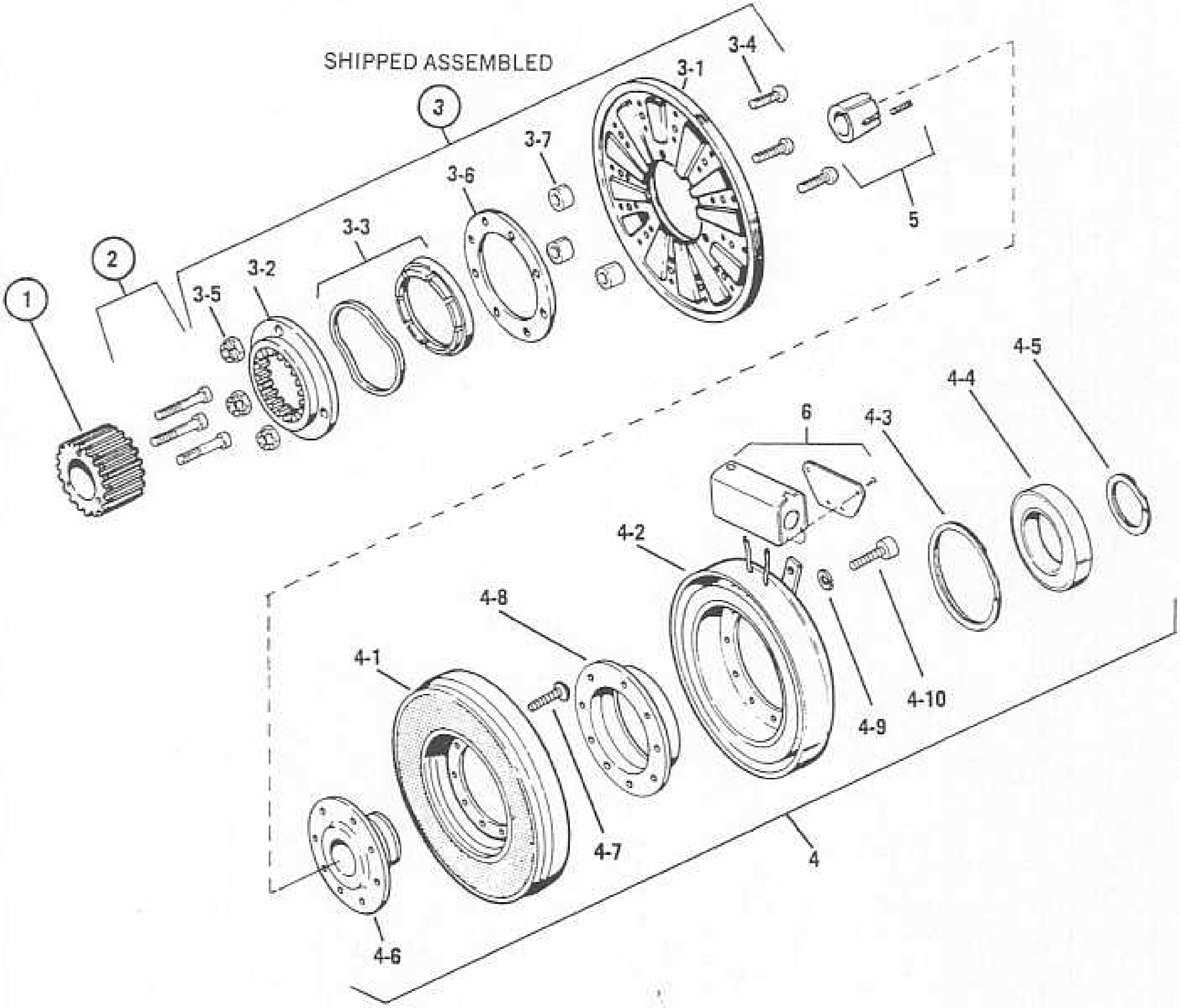
A Dia.	B	C Max.	D	E	F	G	H	I	J	K
.350 / .342	3¾	10 11/32	7/8	11/32	.397 / .388	8	3.625	4.313 / 4.311	3 1/16	8 17/32

Drawing No.	Shaft Size	Static Torque	Maximum Speed	Standard Voltages
I-25643	15/16" - 3"	1350 lb. ft.	1800 rpm	D.C. 90

Clutch, Hi-Torque

SF-1525 H.T.

Bearing Mounted

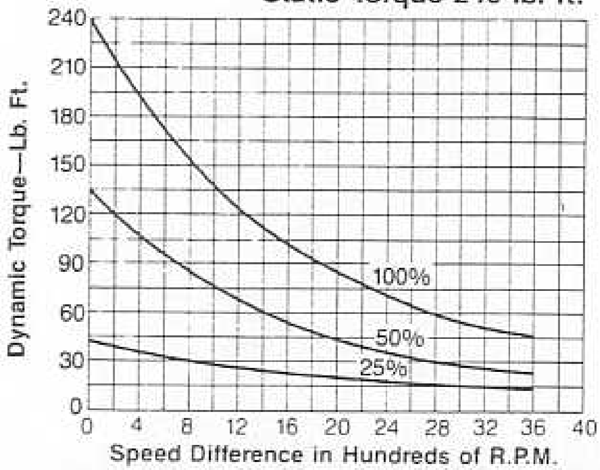


Drawing I-25643

Dynamic Torque Curves

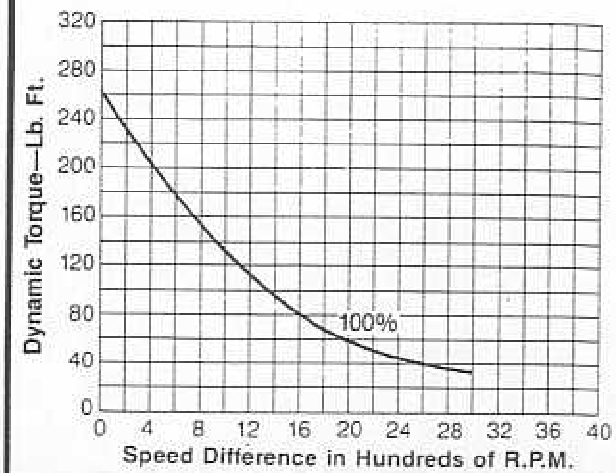
Size 1000

Maximum Speed 3,600 rpm
Electro-Pack 3,000 rpm
Static Torque 240 lb. ft.



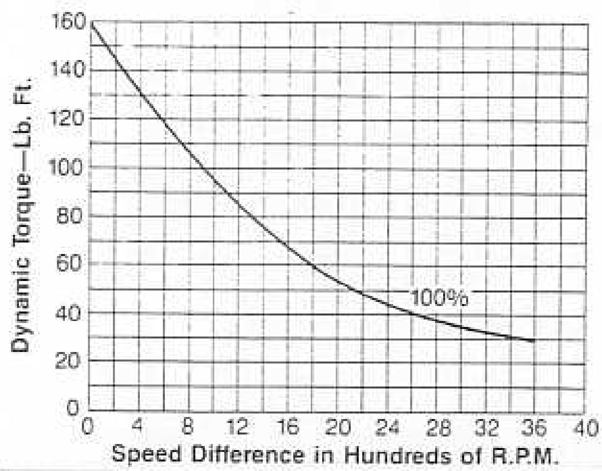
Size 1225-MB

Maximum Speed 3,000 rpm
Static Torque 260 lb. ft.



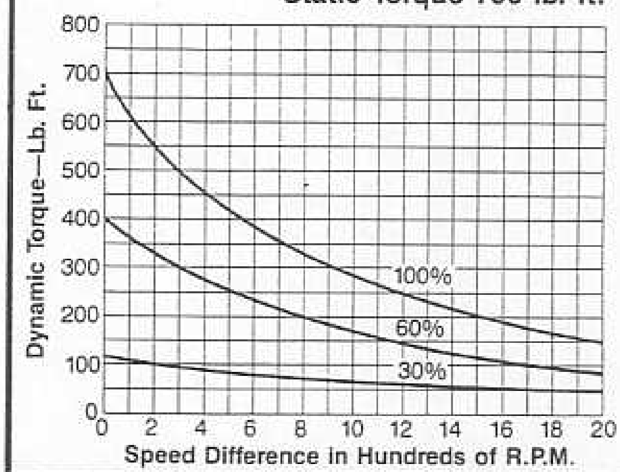
Size 1000-MB

Maximum Speed 3,600 rpm
Static Torque 160 lb. ft.



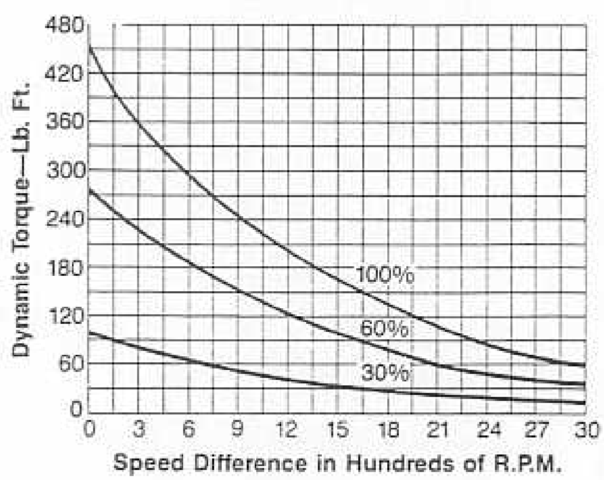
Size 1525

Maximum Speed 2,000 rpm
Electro-Pack 1,800 rpm
Static Torque 700 lb. ft.



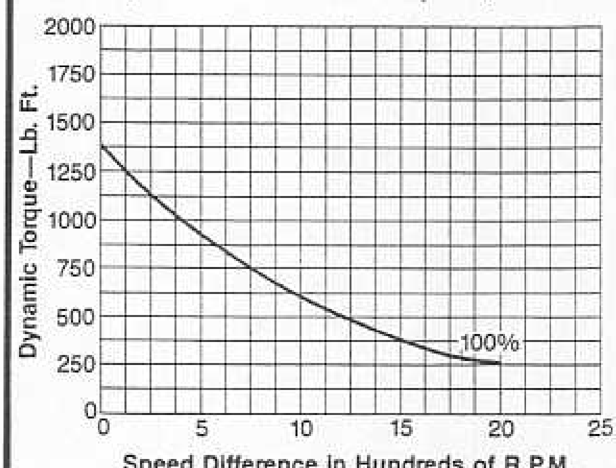
Size 1225

Maximum Speed 3,000 rpm
Static Torque 465 lb. ft.



Size 1525— Hi Torque

Maximum Speed 2,000 rpm
Static Torque 1,350 lb. ft.



Verteiler: VD VK WA Vertr.

AVK
Deutschland GmbH & Co KG Niederlassung Dreieich Tel. 06103-5039-, zuständig: Herr Ambrosch 54 / Herr Krämer 55

Technical data sheet SYNCHRONOUS-GENERATOR/MOTOR

Date: 05.06.2000

Alteration status: **1** 13.06.2000

Delivery: Week 38/2000

Machine number: **64 23 999 A0 01**

Customer	Alturdyne	Inspection	not required
Your order	19422	Certificate	not applicable
		Shipyard	not applicable
		Building no.	not applicable

Classification	:	not applicable	
Quantity	:	1	piece
Type	:	*D S U 43 M1-4*	
Rated data			
Generator operation:			
Rating	:	100	kVA
Power factor	:	0,8	cos phi
Rated voltage	:	208/120	V
Rated current	:	278	amps
Frequency	:	60	Hz
Rated speed	:	1800	1/min
Motor operation:			
Rating	:	75	kW (100 HP)
Power factor	:	0,95	cos phi
Rated voltage	:	208	V, 3-ph.
Rated current	:	237	amps
Frequency	:	60	Hz
Rated speed	:	1800	1/min
General details			
Standards	:	DINVDE 0530, IEC 34	
Specification	:	**PN 1630 (voltage changed to 208V)**	
Project no.	:	P00.10876/USA	
Ambient temperature	:	40	°C
Altitude at site a.s.l.	:	1000	m over sea level
Insulation class	:	*"H"*	temp. rise acc. to *"F"*
Radio interference supres.	:	*"N"*	DINVDE 0875

Order-number	:	64 23 999 A0 01			

Electrical details

Voltage adjustment range	:	± 5	%		
Voltage performance	:	± 1	%	steady state	
Distortion factor	:	< 5	%	ph-ph, no load, DINVDE 0530	
Winding	:				
Parallel operation	:	No			
Sustained short circuit current:		app.	3x	I_N 3-phase	
Overload	:	50	%	for 30 s	
Efficiency	:	91,5% at 0,8 p.f.,		93,5% at p.f. 1	

Design details

Prime mover	:	Gas engine			
Rotation	:	clockwise looking at the generator shaft (from engine drive end) (AS)			1
Permanent overspeed	:	2160	$^1/_{min}$ for 2 min.		
Enclosure	:	*IP 23*			
Cooling	:	IC 01			
Design	:	IMB3	height of feet:	280	mm
Flange	:	No	installation dept.:		mm
Terminal box location	:	on top			
Terminals/number	:	4	pieces		
Cable outlet	:	right	looking at (AS) generator drive end		
		Side to be advised by return			
Cable glands	:	No glands. Undrilled gland plate only			
Antifriction bearings	:	two, regreasable			
Droop transformer	:	-			
Temp. detect./ winding	:	6	pieces, PT100		
Temp. detect./ bearing	:	-	pieces,		
Tripping device	:	-	pieces, -	volts	
Anticondensation heater	:	200	watt, 230	volts	

Voltage regulation

Voltage regulator	:	Cosimat N+,	built-in
Setting rheostat	:	500 Ω	loose
Additional module	:	COS	
	:	ZSM1	

Additional details

Painting	:	AvK Standard, RAL 6011
Label	:	English, VDE

Attention ! Rotor balanced with half key !

Order-number : 64 23 999 A0 01

Functional details

Second shaft end for 75kW to drive a compressor.
Main drive end (AS) for gas engine drive (generator operation)
Second drive end (BS) for driving the compressor.

Star connection (four terminals) for generator and motor operation.

Transformer – starting with discoupled gas engine.

Starting current = 4 x I_N (rated current) results in a starting torque (moment) M_A = 445 Nm.
Starting current = 3 x I_N (rated current) results in a starting torque (moment) M_A = 339 Nm.
Starting current = 2 x I_N (rated current) results in a starting torque (moment) M_A = 222 Nm.

The necessary break-away torque has been calculated with 154 lb-ft = 209 Nm.

The moment of inertia of compressor has been calculated with 0,684 lb-in-sec² = 0,0773 kgm²

Winding data	WD 1807 / WRW 79	Dimension drawing
Circuit diagram	Z2807.051	Moment of inertia dwg.
		Part list
T6: prim. 1 Wdg!		Operation instruction
		Spare parts list
EB 09.06.2000/wz	EK	Test report

20/06 '00 DI 15:28 FAX +49 6103 503940 AVK DEUTSCHLAND-VERTRIEB 006

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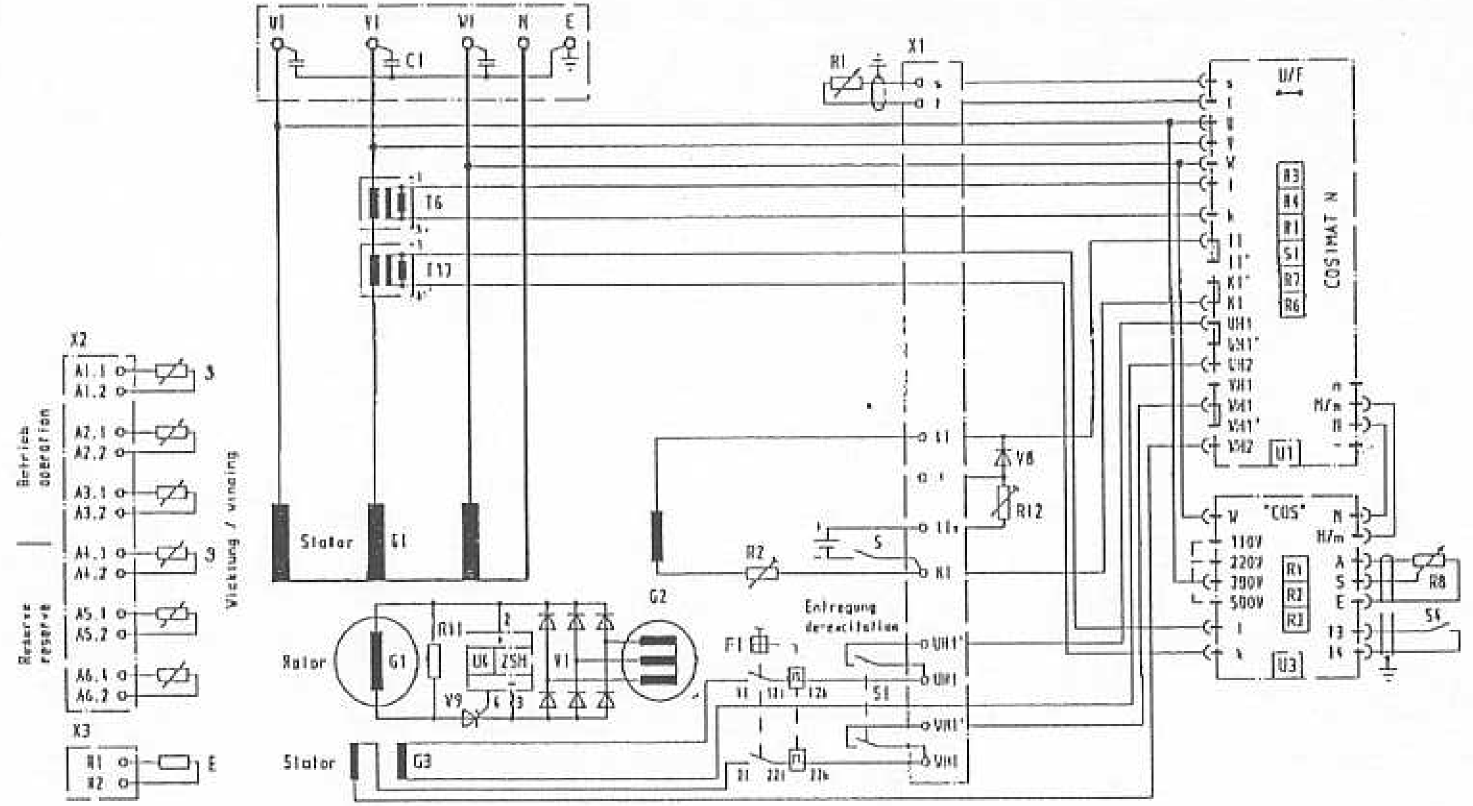


G1 Hauptmaschine
main machine
G2 Erregermaschine
exciter machine
G3 Hilfswicklung
auxiliary winding
V1 rot. Gleichrichter
rotating rectifiers
V9 Thyristor
T6 Statikwandler
droop transformer
R2 Vorwiderst. (nur b. Bedarf)
series resistor (if requd.)
R11 Schutzwiderstand
protective resistor
F1 Schutzschalter
protective switch
U4 Zündbaustein
ignition module
V8,R12 Anfangserregung
ignition excitation
C1 Entstörkondensatoren
interference capacitors
E Stillstandsheizung
anti condensation heater
3 Widerstandsthermometer
resistance thermometer

U1 Spannungsregler / A.V.R.
- R7 Unterdrehzahlschutz / underspeed protection
- R4 Spannungssollwert grob / voltage set-point coarse
- R1 P-Teil / P-part
- S1 I-Teil / I-part
- R7 Statik / droop
- R6 Ia-Abgleich / Ia-balancing

R1 Spannungs-Sollwertfeinsteller
voltage set-point adjuster

U3 cos φ-Regler COS
cos φ regulator COS
Abgleich: / balancing:
- R1 cos φ-Bereich / cos φ range
- R2 Min.-Erreg. / min. excitation
- R3 Strombegrenzg / current limit

T11 Stromwandler / C.T.
R8 cos φ- Einsteller
cos φ adjuster
S4 Schalter / switch
offen = Betrieb Spannungsregler
open = operation with AVR
geschl = Betrieb mit COS
closed = operation with COS

Kein AvK-Lieferumfang: / not AvK supply:
S; S1; S4 Schalter / switch

Linkslauf: Meßleitungen U-V tauschen
counter-clockwise rotation:
sensing lines exchange U-V

Nr	Änderung	Nr	Änderung	2000	Datum	Name
3		6		Bearb.	07.06.	ez
2		5		Gepr.		
1		4				

Umkehrmaschine Typ DSU
Reversing machine
mit Regelgerät COSIMAT N + COS
with A.V.R. COSIMAT N + COS

AVK Deutschland GmbH & Co KG
Niederlassung Dreieich

Schaltb.-Nr. / circ diagram no.
Z 2807.051

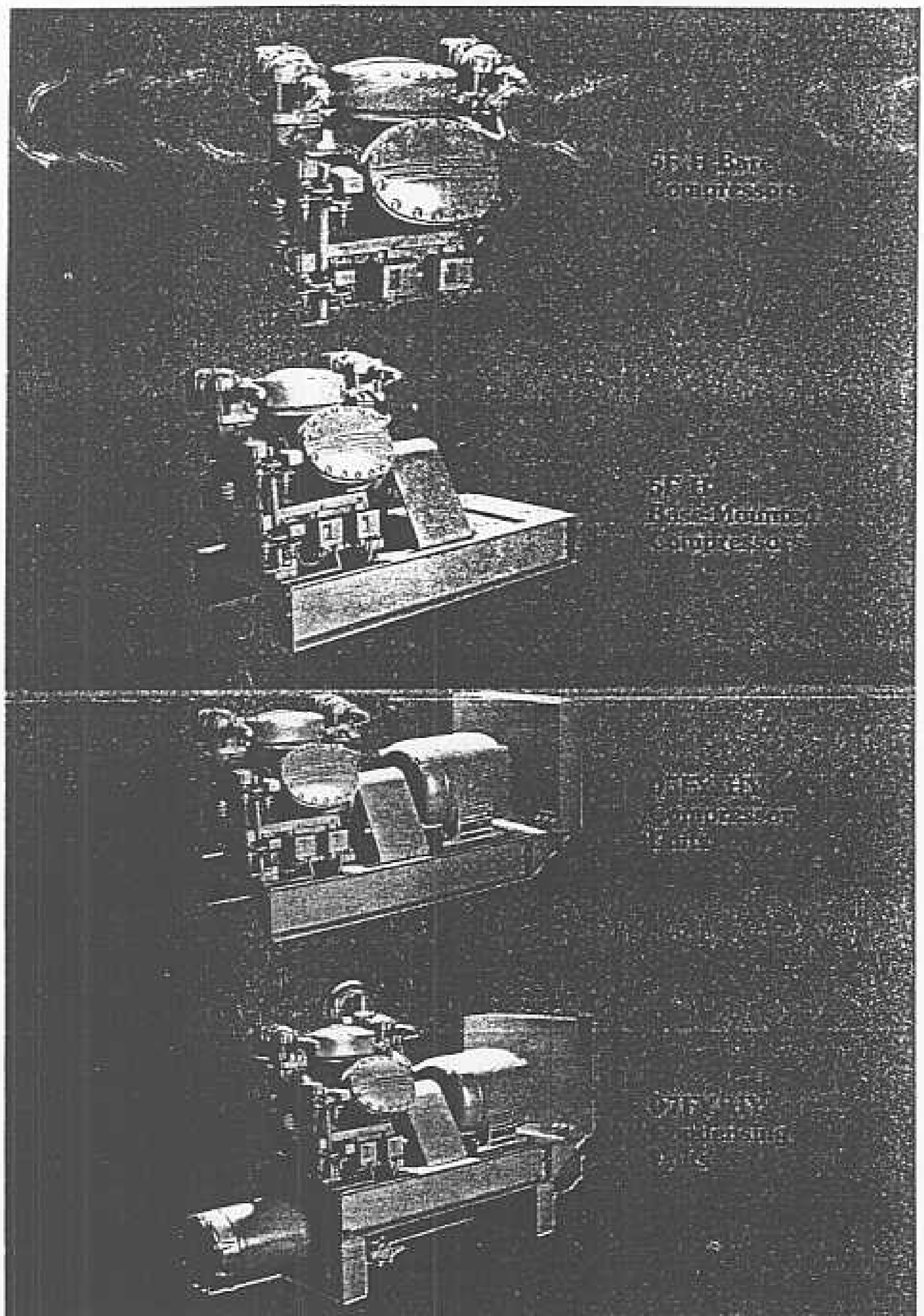
Carrier
HEATING & COOLING

Product Data

5F,H Compressors
05FY,HY Compressor Units
07FY,HY Condensing Units
5F,09RH Condensers

5 to 150 Nominal Tons

With CARLYLE COMPRESSORS 5F, 5H COMPRESSORS



Carlyle Series 5F and 5H open-drive compressors, used on Carrier compressor units and condensing units, have been the workhorses of the air conditioning and refrigeration industry for more than 45 years.

Series 5F and 5H are offered as bare compressors and also as factory-assembled compressors, factory-assembled 05FY and 05HY compressor units, and factory-assembled 07FY and 07HY condensing units. Complete systems include motor, drive arrangement, control panel, and condenser as required. Or, all components may be ordered as separate sale items for field assembly and installation.

Features/ Benefits

The traditionally high quality of Carlyle 5F and 5H compressors provide efficient, reliable operation with unsurpassed performance, whatever the application.

Series 5F, 5H Standard Features

- 3-year warranty
- used with most refrigerants
- 5 to 150-ton range
- high operating efficiency
- 45 years of proven reliability
- multi-drive application
- multi-speed range
- multi-motor/voltage combinations
- multi-condenser combinations
- multi-control-panel designs

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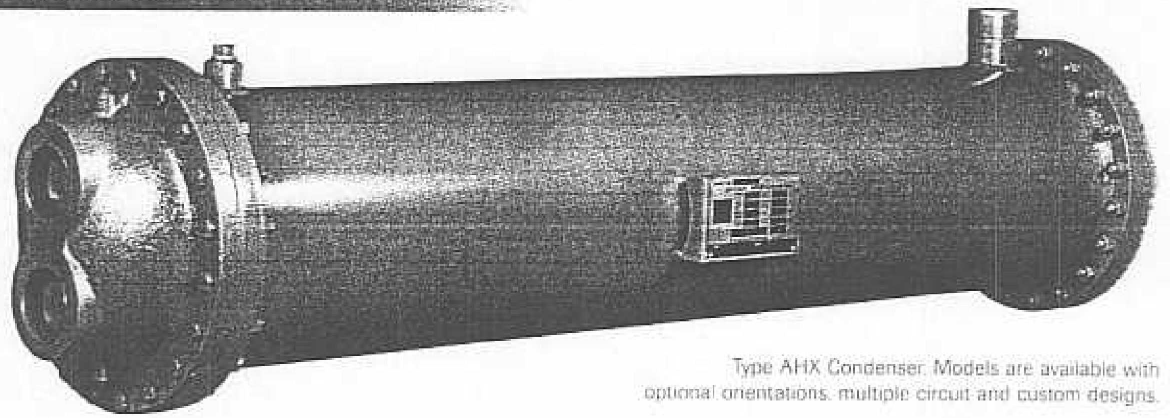
ACME® Condensers

3 to 2,500 tons



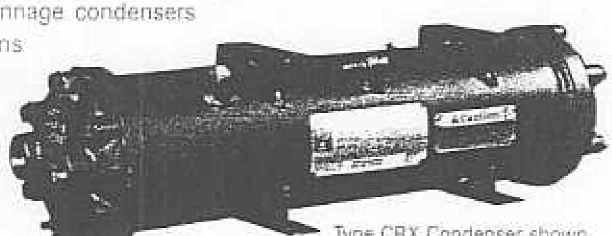
Type AHX Condenser. Models are available with optional orientations, multiple circuit and custom designs.

Select from standard models from our extensive stock or custom models with short lead times.

Superior by Design

Standard Designs

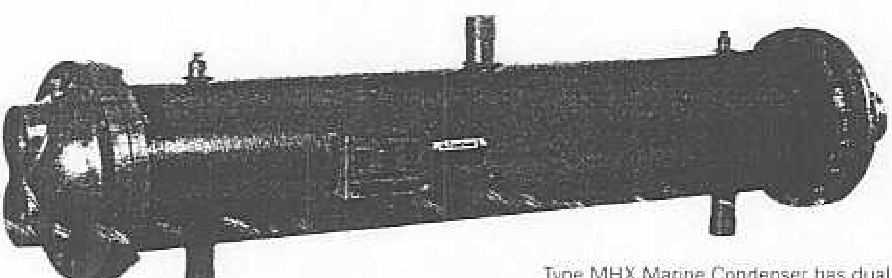
ACME condensers are available from standard designs for fresh or sea water duty. Small tonnage condensers from 7 to 19 nominal tons of duty include special multi-pass heads and are manufactured in very large quantities to provide the highest capacity per ton available.



Type CRX Condenser shown with special port configuration and special brackets.

Multi-Circuit Flexibility

Condensers are available with dual circuits by welding two shells together end-to-end. This allows the use of one water circuit to reduce piping costs. Each circuit has its own ASME code stamp.



Type MHX Marine Condenser has dual refrigerant discharge ports and Cupro-Nickel or Titanium tubes and tube sheets and cast bronze heads.

Modern Tube Materials

ACME AHX Condensers utilize the latest technology tubing available. Years of research and development, combined with thorough testing in our own labs has resulted in the highest efficiency condensers available. All condensers are manufactured with enhanced 3/4" diameter tubing to provide heavy wall construction and ease of service from commonly available tube cleaning devices.

Modifications

Vessels are available with special materials of construction as required. Condensers can be made from stainless steel for increased life with poor quality cooling water. Vessels can be equipped with Cupro-Nickel or Titanium tubes and tube sheets for sea water duty. If your application calls for something special, just ask.

Standard Construction

- ***Shells*** - Steel pipe to ASME specification. Shells are shot blasted and cleaned prior to assembly.
- ***Tubes*** - Copper high performance enhanced design roller expanded into multiple-grooved tube sheet. Other materials available for corrosive duty.
- ***Tube sheet*** - Flange quality steel to ASME specifications. Precision machined for excellent sealing.
- ***Tube Supports*** - Quality steel, tack welded to shell interior.
- ***Heads*** - Cast or fabricated to ASME specifications using steel ring and cover design with superior gas distribution.
- ***Connections*** - All water side connections are FPT except 12" 1-pass, 14" and 16" models which have flanges. Refrigerant connections are steel and bored to ODS of copper tubing. Relief, vent and drain connections are provided. Numerous nozzle orientations are available to facilite ease of packaging.
- ***Codes*** - The refrigerant side is constructed to the latest edition of the ASME Section VIII Div 1 code and stamped accordingly. Refrigerant side pressure is designed for 350 PSI minimum at 250°F. Water side design pressure is 150 PSI minimum at 150°F. Both circuits are tested at 1.25 times the design pressure.
- ***Finish*** - Exterior surfaces are cleaned and painted with a medium gray enamel paint.

• factory assembled system or separate components for field assembly
• 6-week maximum availability

Custom-tailored systems

To fit your job requirements, Carrier compressor and condensing units and Carlyle open-drive compressors are available in any combination. Customized selection enables you to order one factory-assembled system that fits your application, regardless of strict specifications and special power needs. For field installation, you can also select bare or base-mounted compressors and order the balance of the system components as separate items or supply your own.

Select quality by ordering:

• 5F and 5H Bare Compressors
• 5F and 5H Base-Mounted Compressors
• 05FY and 05HY Compressor Units
• 07FY and 07HY Condenser Units

The 5F, H compressors

Use the 5F, H line of open compressors to build a system tailored to your equipment needs. These compressors come in 12 sizes, ranging from 5 to 150 tons of cooling, so you can select just the configuration you need. The compressor's "building block" design lets you choose water-cooled, air-cooled, or evaporative condensers.

The 5F, H compressors can use Refrigerants 12, 22 or 502. The compressor base accommodates several motor sizes, with either belt or direct drive, to fill both refrigerant and job requirements.

Consider these additional advantages when choosing a 5F, H compressor:

Save on first costs:

• With automatic, unloaded starting, expensive high-torque motors are unnecessary, reducing your initial expense.

Save on operating costs:

• The design of the crankcase casting cylinder heads and valve plates allows a smooth, unrestricted refrigerant flow through the compressor, resulting in greater operating efficiency.

• As suction pressure changes, capacity control automatically reduces compressor capacity to as low as 25% of full design load, reducing horsepower requirements and demand charges. This part-load operation, in turn, increases energy efficiency and lowers utility bills.

Internal pressure capacity control is standard on 5F40-5H126 units. External unloading, either pneumatic or electric, can also be special ordered. The 5F20 and 5F30 units offer external pressure unloading as an accessory feature.

Save on maintenance costs:

• A large-capacity, manually reversible oil pump, an automatic pressure regulator, and an oil-filtering system provide positive pressure lubrication for extended compressor life.

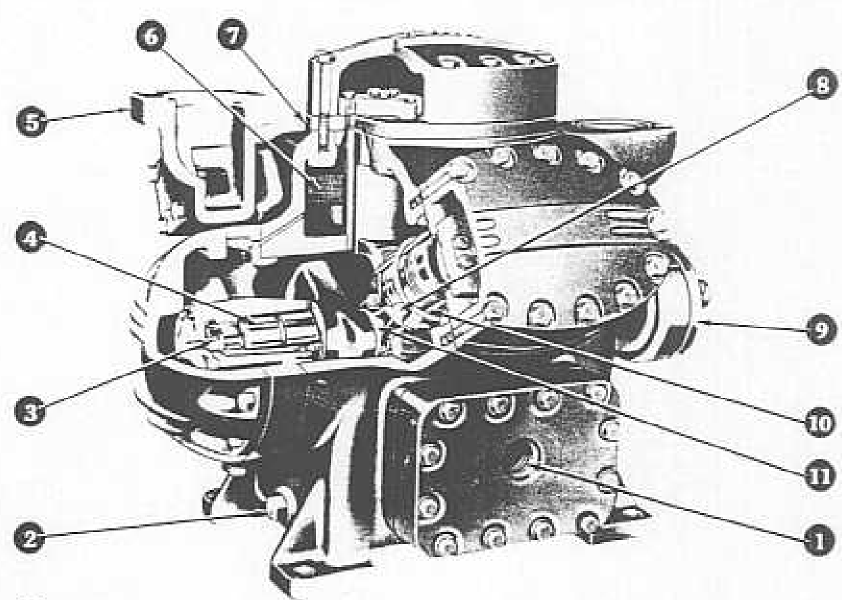
• On all units, the oil passes through a fine-mesh screen before reaching the oil pump. A full-flow filter, standard equipment on 5H120, 126 units, ensures clean flow of the large-volume oil charge in these compressors.

• Suction gases stay in contact with cylinder sleeve to keep oil cool and reduce cylinder wear.

• Simple field maintenance and replacement of components such as cylinder liners, pistons, and bearings minimize field service costs and equipment downtime.

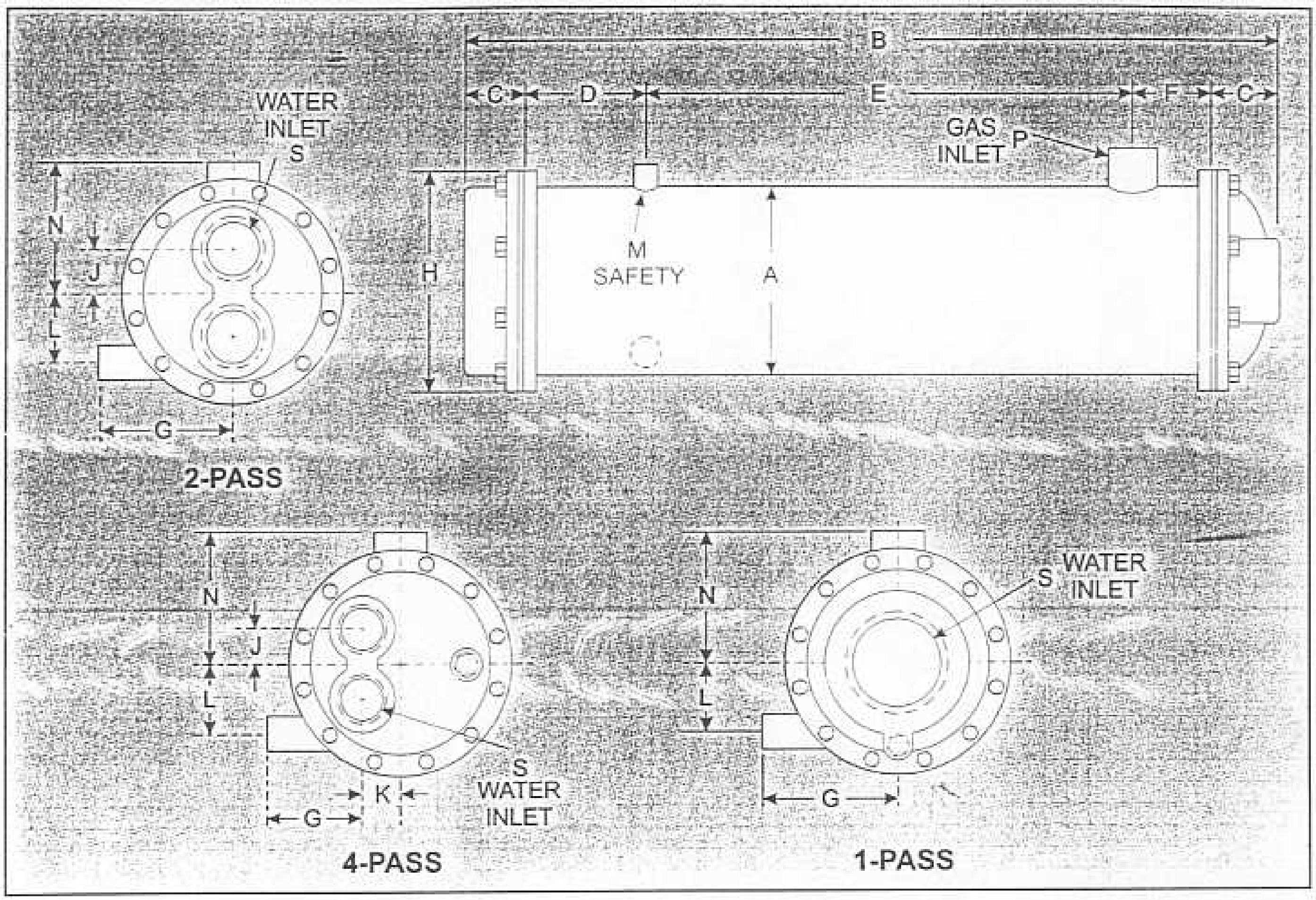
• A refined, 2-piece shaft/seal assembly virtually eliminates seal leakage. Its carbon ring and neoprene bellows combine to provide a tight seal against a highly polished seat. An oil bath completely surrounds the seal assembly, yielding maximum reliability over a wide temperature range.

• Efficient crankcase heater design prevents both accumulation of liquid refrigerant in the crankcase during shutdown and the consequent dilution of the compressor's oil supply.



(1) Oil-Level Sight Glass
(2) Oil Drain
(3) Reversible Oil Pump
(4) Statically and Dynamically Balanced Crankshaft
(5) Unrestrictive Suction Gas Inlet
(6) Fine Mesh Suction Screen
(7) Precision-Ground Valve Plate Assembly with Swedish Steel Ring Valves
(8) Internal Capacity Control System
(9) Time-Proven Shaft Seal Assembly
(10) Removable Cylinder Liners
(11) Forged-Steel Connecting Rods with Replaceable Bearing Inserts

Dimensions of Standard ACME® AHX Models



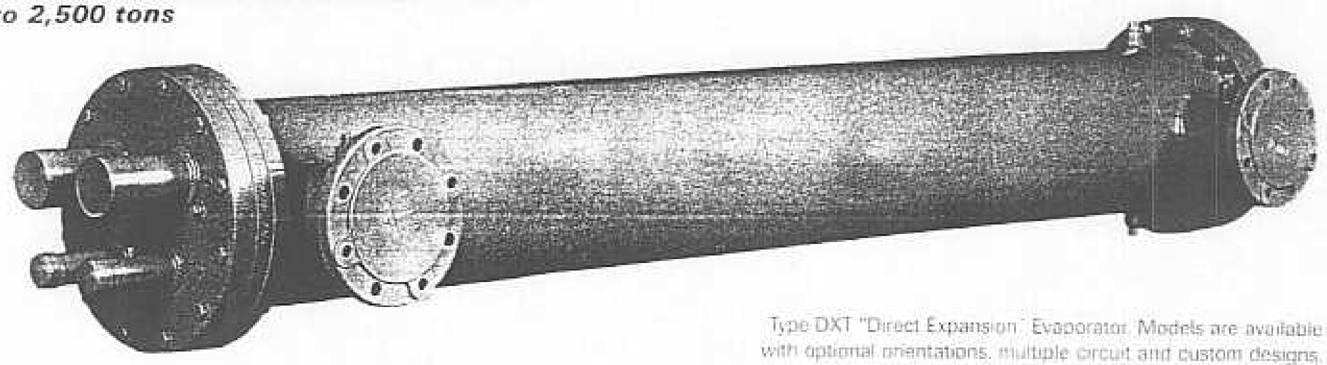
Capacity and Dimensions

MODEL AHX	NOM TON	A	B	C	D	E	F	G	H	J	R	P	M	S	L	K	N
CRX-3	7	6-5/8	27-13/16	2-7/32	3-1/4	17	3-1/2	4-13/16	7-1/2	1-13/16	5/8	1-3/8	1/2	1-1/2	2-13/16	1-1/16	6-5/16
CRX-5	9	6-5/8	27-13/16	2-7/32	3-1/4	17	3-1/2	4-13/16	7-1/2	1-13/16	7/8	1-3/8	1/2	1-1/2	2-3/4	1-1/16	6-5/16
CRX-7.5	14	6-5/8	39-13/16	2-7/32	3-3/8	28-3/4	3-5/8	4-13/16	7-1/2	1-13/16	7/8	1-3/8	1/2	1-1/2	2-3/4	1-1/16	6-5/16
CRX-10	18	6-5/8	51-9/16	2-7/32	3-3/8	28-3/4	3-5/8	4-13/16	7-1/2	1-13/16	7/8	1-3/8	1/2	1-1/2	2-3/4	1-1/16	6-5/16
CRX-15	19	6-5/8	51-9/16	2-7/32	3-3/8	28-3/4	3-5/8	4-13/16	7-1/2	1-13/16	1-1/8	1-5/8	1/2	1-1/2	2-5/8	1-1/16	6-5/16
AHX-605C-2	26	6-5/8	63-13/16	2-1/32	3-1/2	52-3/8	3-7/8	4-13/16	7-1/2	1-13/16	1-1/8	1-5/8	1/2	2	2-5/8	-	6-5/16
AHX-605D-2	30	6-5/8	63-13/16	2-1/32	3-1/2	52-3/8	3-7/8	4-13/16	7-1/2	1-13/16	1-3/8	2-1/8	1/2	2	2	-	6-5/16
AHX-805A-2	43	8-5/8	66	3-1/8	3-1/2	52-3/8	3-7/8	5-13/16	9-11/16	1-7/8	1-3/8	2-1/8	1/2	2-1/2	3-13/32	-	7-5/16
AHX-806A-2	55	8-5/8	78	3-1/8	3-1/2	64-3/8	3-7/8	5-13/16	9-11/16	1-7/8	1-3/8	2-1/8	1/2	2-1/2	3-13/32	-	7-5/16
AHX-1005A-2	64	10-3/4	69-1/8	4-11/16	3-3/4	52	4	6-7/8	13-3/4	2-1/2	1-5/8	2-5/8	1/2	3	4-1/4	-	8-3/8
AHX-1006A-2	82	10-3/4	81-1/8	4-11/16	3-3/4	64	4	6-7/8	13-3/4	2-1/2	1-5/8	2-5/8	1/2	3	4-1/4	-	8-3/8
AHX-1205A-2	90	12-3/4	69	4-5/8	4-3/16	50-5/16	4-5/8	7-7/8	15-3/4	2-5/8	1-5/8	2-5/8	1/2	4	5-1/4	-	9-3/8
AHX-1206A-2	115	12-3/4	81	4-5/8	4-3/8	62-7/16	4-15/16	7-7/8	15-3/4	2-5/8	2-1/8	3-1/8	3/4	4	5-1/16	-	9-3/8
AHX-1208A-1	137	12-3/4	105	4-5/8	4-3/4	86-7/16	4-15/16	7-7/8	15-3/4	-	2-1/8	3-1/8	3/4	6‡	5-1-16	-	9-3/8
AHX-1405B-2	139	14	71	5-5/8	4-3/8	50-7/16	4-15/16	8-1/2	17-7/8	4-1/2	2-1/8	3-1/8	3/4	4‡	5-9/16	-	10
AHX-1208B-1	149	12-3/4	105	4-5/8	4-3/8	86-7/16	4-15/16	7-7/8	15-3/4	-	2-1/8	3-1/8	3/4	6‡	5-9/16	-	9-3/8
AHX-1406B-2	178	14	83	5-5/8	4-3/8	64-3/16	3-3/16	8-1/2	17-7/8	4-1/2	2-1/8	3-5/8	3/4	4‡	5-9/16	-	10
AHX-1605B-2	197	16	71	5-3/8	4-5/8	49-11/16	5-7/16	9-1/2	19-7/8	5	2-1/8	3-5/8	3/4	5‡	6-1/2	-	11
AHX-1210B-1	204	12-3/4	129	4-5/8	4-3/8	10-3/16	5-3/16	7-7/8	15-3/4	-	2-1/8	3-5/8	3/4	6‡	5-1/16	-	9-3/8
AHX-1606A-2	221	16	83	5-5/8	4-7/8	61-3/16	5-11/16	9-1/2	19-7/8	5	2-5/8	4-1/8	3/4	5‡	6-7/8	-	11
AHX-1408B-1	211	14	107	5-5/8	4-5/8	85-11/16	5-7/16	8-1/2	17-7/8	-	2-5/8	4-1/8	3/4	6	5-7/16	-	10
AHX-1606B-2	247	16	83	5-7/8	4-7/8	61-3/16	5-11/16	9-1/2	19-7/8	5	2-5/8	4-1/8	3/4	5‡	6-7/16	-	11
AHX-1410A-1	267	14	131	5-5/8	4-5/8	109-5/8	5-7/16	8-1/2	17-7/8	-	2-5/8	4-1/8	3/4	6	5-7/16	-	10
AHX-1410B-1	290	14	131	5-5/8	4-5/8	109-5/8	5-7/16	8-1/2	17-7/8	-	2-5/8	4-1/8	3/4	6	5-7/16	-	10
AHX-1608B-1	300	16	120-1/2	6-1/8	4-7/8	84-5/8	4-7/8	9-1/2	19-7/8	-	3-1/8	5-1/8	3/4	8	5-7/8	-	11
AHX-1610A-1	363	16	144-1/2	6-1/8	4-7/8	108-5/8	4-7/8	9-1/2	19-7/8	1	3-1/8	5-1/8	3/4	8	5-7/8	-	11
AHX-1610B-1	407	16	144-1/2	6-1/8	4-7/8	108-5/8	4-7/8	9-1/2	19-7/8	1	3-1/8	5-1/8	3/4	8	5-7/8	-	11

Capacity based 14,400 BTUH per ton, 85° condenser water, 10° range with R-22 service at 105° condensing temperature. ‡ = 125 Lb. FF Flange
Comprehensive rating tables are available for R-22, R-134a and R-404a. Windows 95™ selection software available.
Capacity includes .00025 additive fouling, .0005 total fouling factor.

ACME® Chiller Barrels

7.5 to 2,500 tons



Type DXT "Direct Expansion" Evaporator. Models are available with optional orientations, multiple circuit and custom designs.

Select from our extensive stock of standard models or custom units with short lead times.

Superior by Design

Modern Tube Materials

ACME® DXT evaporators utilize the latest technology tubing engineered specifically for refrigerant evaporation. Special enhancements on the outside and on the inside produce exceptional performance and efficiency. Refrigerant boils readily against the surface, reducing the overall vessel size and cost. The new generation of DXT vessels feature 3/4" OD tube materials with heavier wall construction than smaller diameter tubed vessels-most suitable for industrial-duty.

Modifications

Vessels are available in "Direct Expansion" or "Flooded" designs in standard or special materials and nozzle orientations. Evaporators can be made from all 316 stainless steel for directly cooling acids or other corrosive liquids. Vessels can be equipped with Cupro-Nickel or Titanium tubes and tube sheets for sea water duty. If your application calls for something special, just ask.

Controlled Velocities

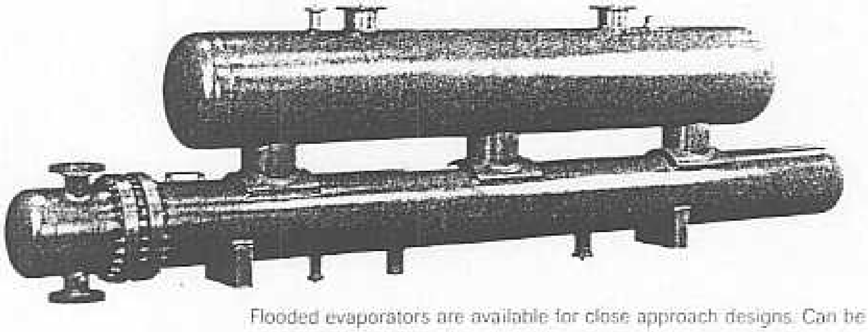
DX evaporators are carefully engineered to provide excellent heat transfer rates, effective refrigerant boiling and provide assured oil carry through. Shell circuits are engineered to provide high performance with a low pressure drop to conserve the required pumping power. Vessels can be engineered for very high chilled water flows for certain applications such as ice-rinks.

Multi-Circuit Flexibility

Vessels are available with up to four separate circuits, depending on diameter. Vessels can be engineered to have equal or unequal performance ratings with refrigerant connections on one end of the vessel or unequal ratings on opposite ends. Some chiller packagers prefer the unequal designs on each end for ease of piping and matched capacity for multiple compressor systems with unequal HP.

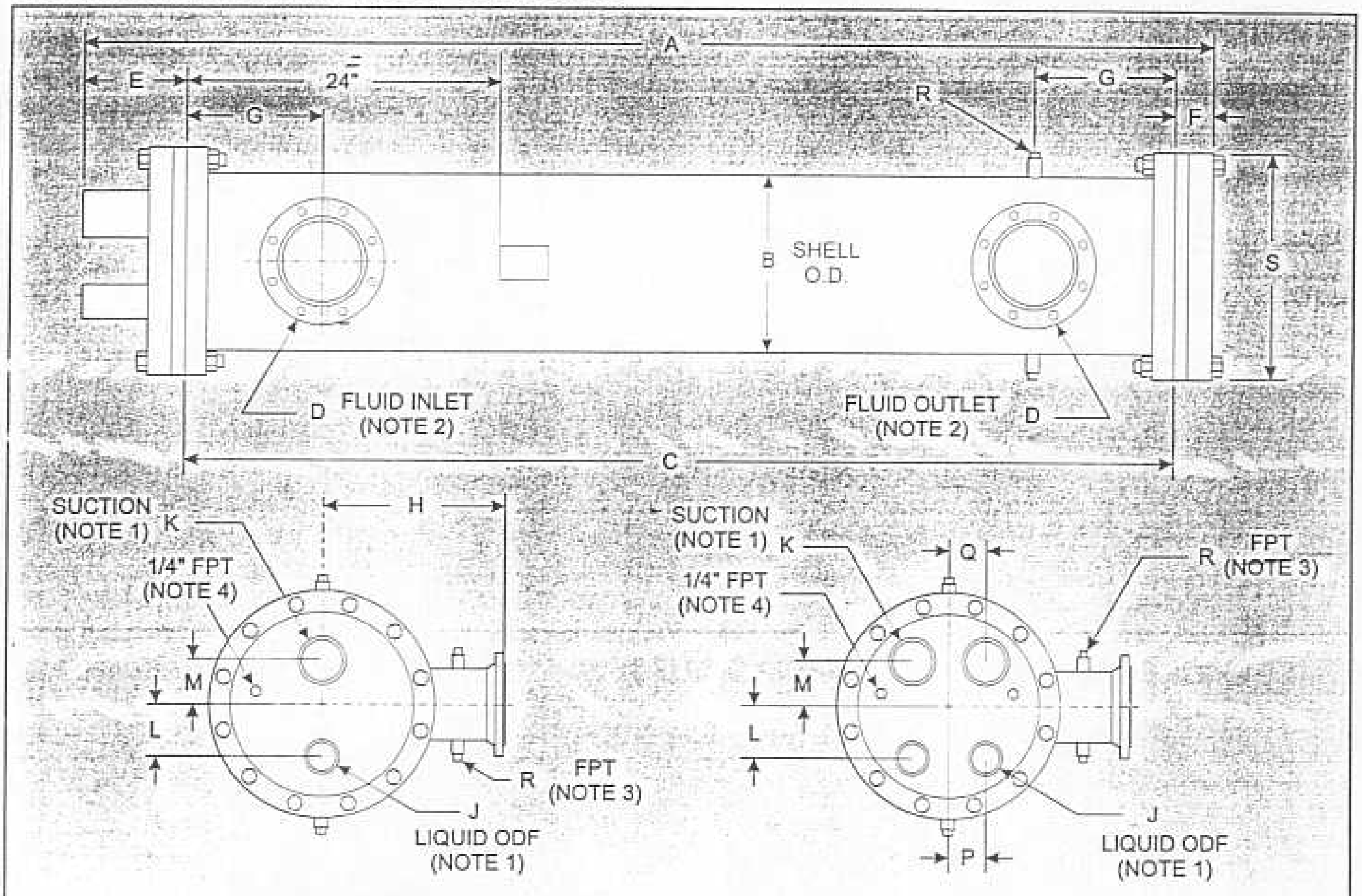
Standard Construction

- ***Shells*** - Steel pipe to ASME specification. Shells are shot blasted and cleaned prior to assembly.
- ***Tubes*** - Copper high performance enhanced design roller expanded into multiple-grooved tube sheet.
- ***Tube sheet*** - Flange quality steel to ASME specifications. Precision machined for excellent sealing.
- ***Baffles*** - Hot-rolled steel for enhanced strength and reliability. Engineered for correct fit to reduce tube wall damage from high velocity fluids.
- ***Heads*** - Fabricated to ASME specifications using steel ring and cover design with superior gas distribution.
- ***Connections*** - Flanges are 150 Lb. ANSI raised face. Refrigerant connections are steel and bored to ODS of copper tubing. Thermowell, vent and drain connections are provided.
- ***Codes*** - The refrigerant side is constructed to the latest edition of the ASME Section VIII Div. 1 code and stamped accordingly. Refrigerant side pressure is designed for 250 PSI at 100°F. Shell side design pressure is 150 PSI at 120°F. Both circuits are tested at 1.25 times the design pressure under water and dried prior to sealing.
- ***Finish*** - Exterior surfaces are cleaned and painted with a medium gray enamel paint.
- ***Insulation*** - Optional 3/4" Armaflex* insulation in single or double thickness is available.



Flooded evaporators are available for close approach designs. Can be beneficial for reduced kW draw in multiple compressor systems.

Dimensions of Standard ACME® DXT Models



1. Suction and liquid connections are steel
2. Fluid connections are MPT thru 3" diameter. Larger sizes are 150 Lb. raised face flanges.
3. Bottom connection only on 3" MPT and smaller fluid connection models.
4. External equalizer connection.
5. On units ordered with 3/4" insulation, add thickness to appropriate dimensions.
6. Port sizes in table are correct for model shown. Refer to factory for other circuits and port sizes.

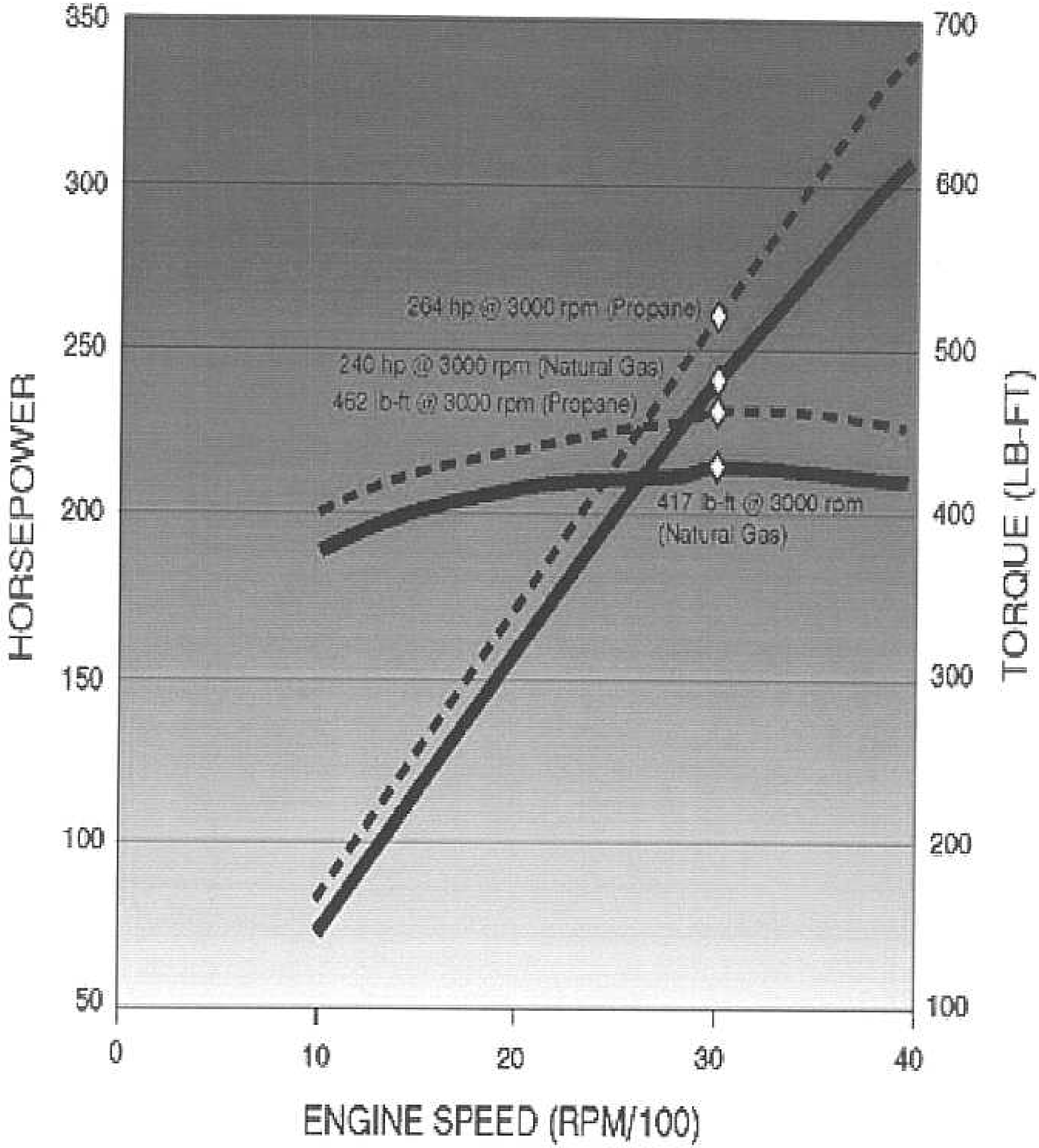
Capacity and Dimensions

MODEL DXT	NOM TON	A	B	C	D	E	F	G	H	J ODF	K ODF	L	M	P	Q	R	S
503-Q4-1C	2.9	44-5/8	5-1/2	35-5/8	2	7-9/16	1-7/16	3-3/16	8-5/8	5/8	1-1/8	1-3/4	1-3/4	-	-	3/4	8-1/2
504-Q4-1C	6.3	56-5/8	5-1/2	47-5/8	2	7-9/16	1-7/16	3-3/16	8-5/8	5/8	1-1/8	1-3/4	1-3/4	-	-	3/4	8-1/2
505-Q4-1C	8.6	68-5/8	5-1/2	59-5/8	2	7-9/16	1-7/16	3-3/16	8-5/8	5/8	1-1/8	1-3/4	1-3/4	-	-	3/4	8-1/2
605-Q4-1C	12.8	68	6-5/8	59-5/8	2-1/2	6-15/16	1-7/16	3-7/16	9-3/16	7/8	1-3/8	2-1/8	2-1/8	-	-	3/4	9-3/4
804-Q4-2C	17.9	56-7/8	8-5/8	47-5/8	3	7-11/16	1-9/16	3-7/8	10-3/16	1-1/8	1-3/8	3	3	1-25/64	1-25/64	3/4	11-3/4
805-Q4-2C	23.4	68-7/8	8-5/8	59-5/8	3	7-11/16	1-9/16	3-7/8	10-3/16	1-1/8	1-3/8	3	3	1-25/64	1-25/64	3/4	11-3/4
806-R2-2C	26.2	80-1/4	8-5/8	71-5/8	3	7-1/16	1-9/16	3-7/8	10-3/16	1-3/8	2-1/8	2	1-5/8	1-3/4	1-3/4	3/4	11-3/4
807-R2-2C	36.1	92-7/8	8-5/8	83-5/8	3	7-1/16	1-9/16	3-7/8	10-3/16	1-3/8	2-1/8	2	1-5/8	1-3/4	1-3/4	3/4	11-3/4
1007-S2-2C	45.3	93	10-3/4	83-5/8	4	7-7/16	1-15/16	4-1/2	11-5/8	1-3/8	2-5/8	2-3/4	1-3/4	2	2-1/2	3/4	14-3/8
1008-S2-2C	58.4	105	10-3/4	95-5/8	4	7-7/16	1-15/16	4-1/2	11-5/8	1-3/8	2-5/8	2-3/4	1-3/4	2	2-1/2	3/4	14-3/8
1009-S2-2C	69.4	117	10-3/4	97-1/2	4	7-7/16	1-15/16	5-1/16	11-5/8	1-3/8	2-5/8	2-3/4	1-3/4	2	2-1/2	3/4	14-3/8
1208-S2-2C	93.2	105-3/8	12-3/4	95-5/8	5	7-3/4	2-3/16	5-3/4	12-5/8	1-5/8	2-5/8	3-1/4	1-3/4	2-1/2	2-3/4	3/4	16-3/8
1410-S2-2C	117.6	130-1/2	14	119-5/8	6	8-1/4	2-11/16	5-3/4	13-1/4	1-5/8	3-1/8	2-5/8	3	2-5/8	2-7/8	3/4	17-1/2
1610-S2-2C	147.2	131-1/2	16	119-5/8	8	8-7/8	3-3/16	7-1/16	14-1/4	2-1/8	3-1/8	4	3	3	3-1/4	3/4	19-1/2
1810-RS2-2C	196.2	131-1/2	18	119-5/8	8	8-11/16	3-3/16	7-1/16	15-1/4	2-1/8	3-5/8	4-3/4	3-1/2	3-1/4	3-3/4	3/4	21-1/2
2010-RS2-2C	248.8	132-1/2	20	119-5/8	10	9-3/16	3-11/16	8-3/8	16-1/4	2-1/8	3-5/8	5	4-1/4	3-1/2	4-3/8	3/4	23-1/2

Nominal tons capacity based 12,000 BTUH per ton, 44° leaving water temperature, 10° range with R-22 service at 35° evaporating temperature
Comprehensive rating tables are available for R-22, R-134a and R-404a. Windows 95™ selection software available.
Capacity includes .00025 additive fouling, .0005 total fouling factor

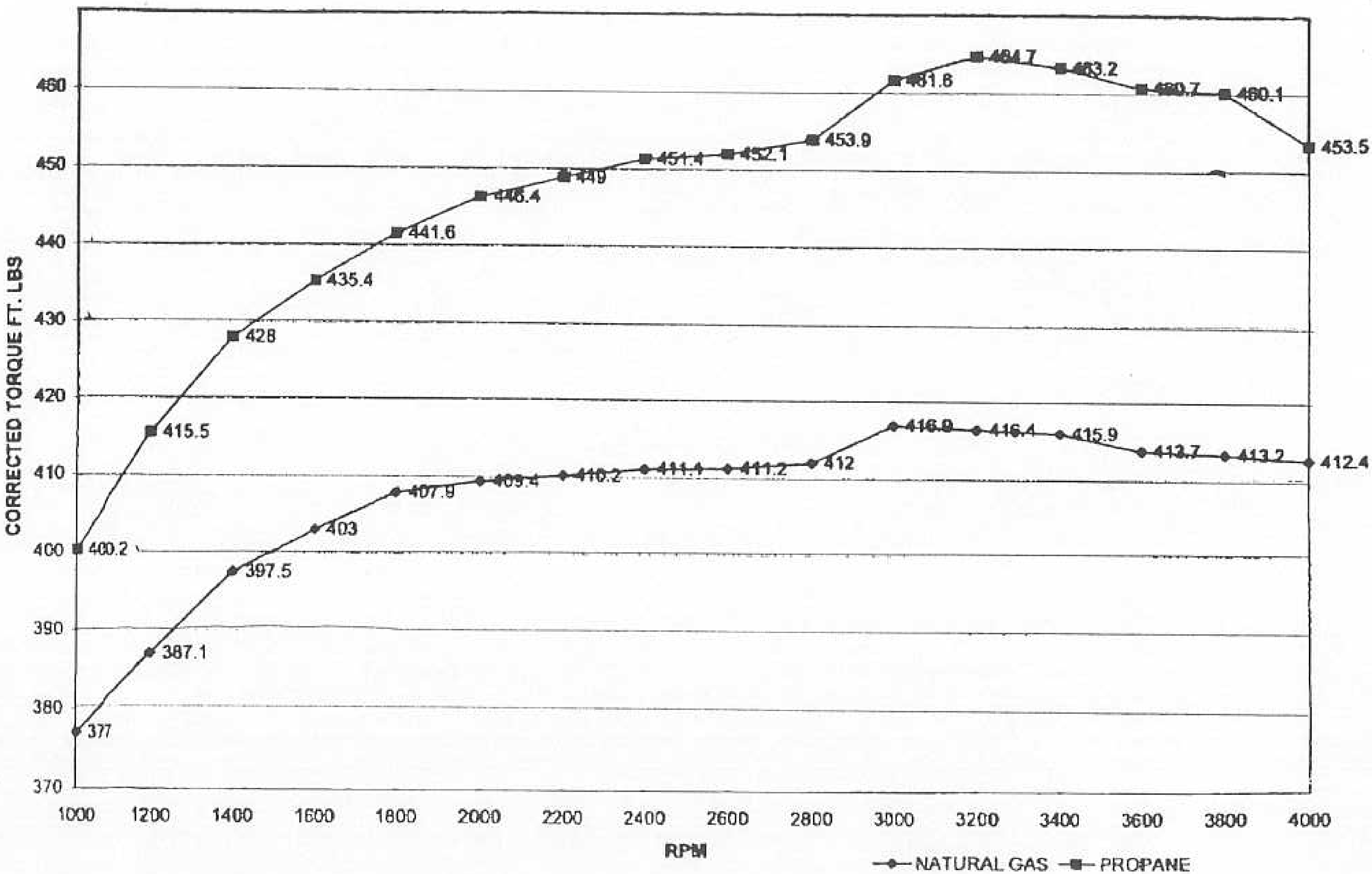
Appendix B

Torque Curves



General Motors Vortec 8100 Series Industrial Engine Torque Curve

8.1L ALTERNATE FUEL COMPARISON
WOT POWER
CORRECTED TORQUE VS. RPM



INDUSTRIAL ENGINE SYSTEMS

Appendix C

Feasibility Report

gti

Feasibility Report

Hybrid Gas/Electric Chiller/Cogenerator

Prepared for:

National Energy Technology Laboratory
Morgantown, West Virginia

Contract No. DOE-FC26-99FT40641

Prepared by:

Gary A. Nowakowski
Gas Technology Institute
Chicago, Illinois

October 2000

Table of Contents

1. Introduction

The intention of this report is to evaluate the technical and economic feasibility of developing and commercializing the hybrid natural gas/electric chiller/cogenerator product. The report discusses the state of the technology, looks at different product designs, estimates product cost and pricing, projects performance and operating costs and summarizes overall economics.

2. Evaluation Criteria

Various hybrid chiller/cogenerator combinations were evaluated based on a set of three key criteria: (a) Need for interconnection requirements, (b) Hybrid chiller operation and (c) Ability to operate as an emergency generator.

a) Need for Interconnection Requirements: A drawback of induction generators is that they require interconnection to the grid. Synchronous generators can be either interconnected to the grid or to a specific electric load. Electric utilities have significant control over permitting interconnection requirements as well as standby/back-up rates and stranded cost recovery (competitive transition charges, CTC). The utility can strongly discourage the interconnection of electric generation equipment to their distribution system using both means. If there were no interconnection barriers, use of induction generators for reducing a building's electric demand would be ideal due to a simple grid interconnect and the fact that the demand reduction is transparent to the individual building loads (i.e. lighting, chillers, refrigeration systems, mainframe computers). A brief description of synchronous and induction generators is given below.

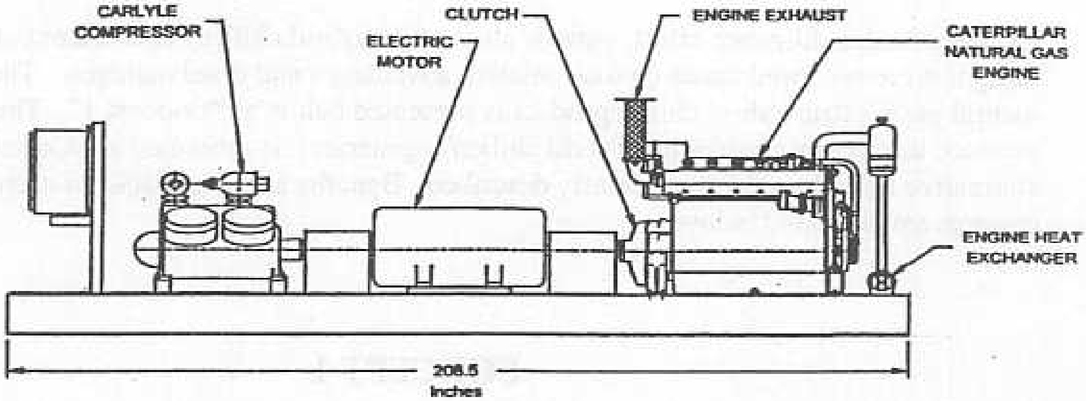
Synchronous generators are used in emergency or standby generator sets. They are able to generate electricity when the electric grid is down. They can be connected to individual equipment or interconnected to the grid. A synchronous generator must operate at a synchronous speed of either 1,800 rpm or 3,600 rpm.

An ***induction generator*** is basically a standard electric motor operated in reverse. Induction generators are relatively inexpensive and highly durable. Today, most industrial motors greater than one horsepower are three-phase induction machines. Induction generators are commonly used in co-generation equipment. They operate at a speed slightly more than their synchronous speed of 1,800 rpm. At exactly 1,800 rpm, no current is generated. As speed is increased above the synchronous speed, 1800 rpm, the generator power increases up to full capacity. Because the generator's electric field is developed by an externally supplied magnetizing current, the generator output will be synchronized with that external source. Induction generators are relatively simple to interconnect to the electric utility grid. They offer single-point building load control. Multiple unit installations are straightforward. Interconnection requirements to the electric grid are generally less than that for a synchronous generator due to the fact that a synchronous generator can operate even if the electric grid is down whereas an induction generator requires an excitation current from the grid in order to generate electricity. Therefore, an electric company technician could shut down the electric grid in order to repair or install a piece of equipment or electric lines and unknowingly be electrocuted by electricity generated from a synchronous generator. The same would not be true of an induction generator which could not function without the electric grid.

(b) Hybrid Chiller Operation: Hybrid chiller operation refers to air conditioning using both natural gas and electricity as primary fuels. A hybrid chiller plant would provide the building owner with the flexibility to minimize cooling operating costs irrespective of energy rates by using the lowest cost fuel (either natural gas or electricity). If real time pricing rates become more the norm, hybrid chiller operation will become increasingly valuable. In addition, for "single chiller buildings", the hybrid chiller offers prime mover redundancy, i.e., if the engine is being serviced or maintained, the electric chiller can still be operated.

(c) Ability to operate as an Emergency Generator: An advantage of an engine-driven chiller hybrid product is the ability to provide cooling or emergency power generation as part of a single package utilizing a single engine. Companies involved in manufacturing and selling engine chillers haven't yet taken advantage of this feature. However, as deregulation unfolds, electric reliability will become more of an issue and a single product capable of providing cooling and emergency power generation should gain greater value in the market place.

3. Candidate Hybrid Design Concepts



The original hybrid product design concept (shown above) was based on a hybrid natural gas/electric chiller developed through GRI funding with Alturdyne as the manufacturing partner. The chiller is capable of providing cooling with either natural gas or electricity as the primary fuel. The driveline consists of an engine, a clutch, an electric motor and a compressor all in series on the same shaft. With the clutch engaged, the engine drives the compressor. If electric operation is preferred, the clutch is disengaged and the electric motor drives the compressor. The rationale for this product are the electric rate structures around the country which essentially penalize electric customers for high demand during "peak demand periods", but provide attractive rates during "off-peak" demand periods. On-peak demand periods, as defined by local utilities, are generally coincident with maximum demand for cooling (summer season and day time hours) and inversely, off-peak demand periods are associated with low demand for cooling (evening hours and winter season). The hybrid chiller provides the fuel flexibility needed to provide the lowest cost cooling possible during any period of time. For periods of time with high electric demand charges, the building operator would use the engine fueled by natural gas (driving through the electric motor) to drive the refrigeration compressor. During periods with low electric rates, the electric motor would be used to drive the compressor. An added advantage of this product is the redundancy of the prime movers, thus providing an inherently more reliable cooling product.

The latest product design is an advancement of the product described above. With this design, the motor doubles as a synchronous generator thus providing the energy customer with an added feature, emergency power. In addition, with a larger engine, air conditioning and electricity could be generated simultaneously thus significantly reducing building peak electric demand. The generator could offer variable speed, constant frequency operation in order to exploit the variable speed capability of the engine-driven chiller. For building owners with a need for both emergency power (excluding hospitals where there is a requirement for a generator set dedicated for emergency power) and air conditioning, this new product would offer a lower first cost premium and an improved economic justification over engine-driven chillers.

Besides substituting a motor/generator in place of the electric motor, an extra clutch is incorporated between the motor/generator and the compressor. The second clutch is required to disengage the compressor during emergency power operation.

As part of a due diligence effort, various alternative hybrid chiller/cogenerator combination designs were reviewed based on their relative advantages and disadvantages. The original natural gas/electric hybrid chiller product is presented below as "Concept 1". The proposed product, the natural gas/electric hybrid chiller/cogenerator, is presented as "Concept 2". Other alternative hybrid products are briefly described. Benefits and drawbacks of each product concept are discussed below.

CONCEPT 1

ENGINE – CLUTCH – MOTOR – COMPRESSOR

This was the original product design. The primary objective of this concept was to eliminate the customer risk and apprehension associated with purchasing an engine-driven chiller for a building which requires only one chiller. The building owner concerns would include product reliability and availability. These concerns do have some merit since engine chillers are more complex than their electric counterparts. In addition, there is always the concern regarding down time associated with service and maintenance. A second selling feature of this product is the fact that the chiller can be operated using either natural gas or electricity as the primary fuel. This feature provides building owners with the flexibility to minimize operating costs (based on dual-fuel capability) regardless of current and future energy rates.

One unit was installed at Plastic Graphics in Los Angeles. The unit accumulated 1,000 operating hours, but is in the process of being removed due to a poor site application, a process cooling application requiring 20 tons of cooling on a sharp, rapid on/off duty cycle.

CONCEPT 2

ENGINE – CLUTCH – SYNCHRONOUS MOTOR/GENERATOR – CLUTCH – COMPRESSOR

(Variable Speed, Constant Frequency Power Controls Required)

A Los Angeles motor/generator consultant has an invention on a controller adapter, which when used in conjunction with an off-the-shelf vector controller, would enable variable speed, constant frequency generator operation at lower cost than competing designs (above 150 kW). This invention is currently being utilized in wind turbine generators by a division of Enron Corporation involved with wind turbine installations. The controller adapter only requires one-third of the power generated and is, therefore, lower in cost than conventional units. Enron is interested in eventually moving to a brushless generator to eliminate the maintenance and service associated with replacement of the slip rings and brushes. GRI's proposed hybrid chiller/cogenerator intended to incorporate this invention into the design. A second clutch is needed so that the engine can drive the synchronous generator (providing emergency power) without driving the compressor. The engine operates in a variable speed mode thus providing variable capacity and high efficiency chiller operation. The variable speed, constant frequency generator allows the unit to generate electricity while the engine speed modulates. Consequently, the engine can operate fully loaded and at a high efficiency at all times.

The product design was intended to expand on the original GRI design with the following two features:

(1) The engine would be able to generate electricity while simultaneously providing chilled water.
(2) The unit could also function as a standby generator for emergency purposes.

This product was determined to offer increased value to the building owner by allowing maximum electric demand reduction and emergency electric generation. The emergency electric generation is a key added feature which improves the overall economics of the product significantly. The buyer of this equipment would essentially be purchasing a hybrid chiller and an emergency generator.

Based on discussions, it was determined that the generator brushes would have to be replaced, probably on an annual basis. This would represent an added maintenance task. However, the brushes could be located on the outside of the generator (with a special design) to allow for easy replacement. The cost of this motor/generator would be quite expensive, estimated at $25,000.

CONCEPT 3

ENGINE – CLUTCH – INDUCTION MOTOR/GENERATOR – CLUTCH -- COMPRESSOR

This concept is identical to the previous one with the exception that an induction motor/generator replaces the synchronous motor/generator. This product design allows the engine to operate at roughly one speed, between 1,800 rpm and 1,850 rpm, while driving the compressor and generator simultaneously. Variable speed, constant frequency power controls are not required. Whatever power is not needed to drive the compressor is used to generate electricity which is fed to the electric grid, thus reducing the building's electric consumption. In this way, the engine can always be fully loaded and operate at its maximum efficiency. The induction motor is simpler and less costly to interconnect than the synchronous generator. This concept has three drawbacks:

1. Emergency power generation is not possible with this product design, a significant value-added feature.
2. This concept requires interconnection to the grid, albeit with an induction generator for which interconnection requirements can often be less demanding than a synchronous generator.
3. This operating strategy does not take advantage of the high efficiency, variable speed chiller operation inherently possible with an engine-driven product.

CONCEPT 4

ENGINE – SYNCHRONOUS GENERATOR – CLUTCH – INDUCTION MOTOR/GENERATOR – CLUTCH – COMPRESSOR

This design concept provides the same functionality as concept 2, but it is expected to cost less and uses off-the-shelf components. When the engine is intended to drive the compressor and the induction generator simultaneously, the synchronous generator is disconnected from its load and its brushes are also disconnected to eliminate unnecessary wear. The induction generator is utilized for electric peakshaving purposes while the synchronous generator is utilized for emergency electric power generation only. Both the induction generator and synchronous generator are off-the-shelf components are readily available and priced reasonably ($1,800 and $2,400, respectively, for 75 kW output). The drawbacks include the following:

1. The length of this product will deter product sales since "foot print" is often limited by the space in the mechanical room, especially for replacement applications.
2. The product also requires interconnection with the grid

CONCEPT 5

ENGINE – SYNCHRONOUS GENERATOR – INDUCTION GENERATOR

This design concept does not function as a chiller, only as a generator. The concept involves an engine generator set producing electricity for one of two purposes: (1) The engine drives the induction generator generating electricity. The induction generator is interconnected to the electric grid and reduces the building electric demand during peak periods. The electric demand reduction is transparent to the electric consuming equipment. While the synchronous generator is on the same shaft as the induction generator, it would be disconnected from its electric load during peak shaving. An advantage of this design is that the building doesn't require a chiller in order to achieve savings from peak shaving. (2) The engine drives the synchronous generator which provides emergency electricity to predetermined loads. While the induction generator is on the same shaft as the synchronous generator, it would be disconnected from its load during emergency power operation.

The benefit of this product design is the fact that it is applicable to all buildings weather or not a chiller is installed. Consequently, the market potential is tremendous.

The drawback of this design concept is the necesssity to interconnect the output from the induction generator with the grid.

CONCEPT 6

ENGINE– SYNCHRONOUS GENERATOR--wired to – SEMI-HERMETIC COMPRESSOR (Electric Driven)

This concept is similar to the Trane's "Enginator" product. It is essentially a synchronous generator set which is dedicated to providing electricity to power an electric chiller. However, unlike the Trane product which simply integrates a Waukesha generator set with a high efficiency Trane centrifugal chiller, the opportunity exists to integrate the required hardware as part of a single piece of equipment. It's advantages include:

1. The engine generator set can be located separately from the electric chiller
2. The engine generator set can be integrated with existing chillers
3. The engine generator set can be utilized as an emergency generator
4. Hybrid operation: Cooling can be provided using either natural gas or electricity as the primary fuel

The disadvantage is that there is an efficiency conversion penalty involved with generating the electricity for the electric motor-driven chiller. Also, the generator must be sized 20 to 30% larger than the electric motor that it powers in order to handle the motor's starting power surge requirements.

CONCEPT 7

ENGINE—SYNCHRONOUS GENERATOR—CLUTCH--COMPRESSOR

This product provides natural gas cooling along with the ability to generate emergency power. The drawback is that it is not a hybrid product and therefore cannot provide electric cooling.

4. The Top Two Hybrid Designs

The two top Concepts which satisfied all three key criteria were Concept 2, the originally proposed product design and Concept 6, a synchronous generator hardwired to a semi-hermetic compressor on one skid or alternatively, a separately-installed synchronous generator supplying power to an electric chiller.

The table below was created to aid in evaluating the various hybrid designs. The hybrid products were evaluated on three principle criteria: (1) Hybrid natural gas/electric chiller operation, (2) no Electric grid interconnect requirements and (3) Ability to provide emergency power. The interconnect requirements of an induction generator was considered a significant commercial barrier. While an induction generator is an attractive means of reducing building electric demand irrespective of individual electric consuming equipment, electrical interconnection requirements as specified by the local electric utility can often be onerous. The ability to operate the product as a hybrid chiller and an emergency generator were considered quite important to the product's commercial viability. Emergency power generation greatly enhances the commercial viability of an engine-driven chiller through increased utility and consequently improved economics. The ability to operate the chiller using either natural gas or electricity provides the building owner with the flexibility to always use the most cost effective fuel for any period of time and for any schedule of energy rates. It also provides inherently greater cooling system reliability due to the redundancy in prime movers.

No.	Combination	Interconnect	Hybrid Operation	Emergency Gen	Other Issues
1	E-Cl-M-C	No	Yes	No	
2	E-Cl-SM/G-Cl-C	No	Yes	Yes	
3	E-Cl-IM/G-Cl-C	Yes	Yes	No	
4	E-SG-Cl-IM/G-Cl-C	Yes	Yes	Yes	Length
5	E-SG-IG	Yes	No	Yes	
6	E-SG wired to HC	No	Yes	Yes	
7	E-SG-Cl-C	No	No	Yes	

Abbreviations: E (Engine), Cl (Clutch), M (Electric Motor), SM/G (Synchronous Motor/Generator), IM/G (Induction motor/generator), C (Compressor), SG (Synchronous Generator), HC (Semi-hermetic compressor), IG (Induction generator)

5. Technical Feasibility

A hybrid natural gas/electric chiller/cogenerator can be developed utilizing existing technology including reversible synchronous machines capable of operating as motors or generators. Two major manufacturers of motors, AVK and WEG have successfully built them before and are willing to build them for this application. The machines are designed for self starting without load. All compressor cylinders will be unloaded to minimize the startup torque.

The original concept was to develop a wound rotor machine with slip rings short circuited. This is an excellent low-slip, high efficiency induction machine whose motor performance can be tailored to develop as much as 175% of rated torque to start the compressor. The wound rotor machine is also an excellent synchronous generator when the short-circuit is removed from the slip rings and DC power is applied to the slip rings. Since slip rings and brushes would need to be replaced on an annual basis, a decision was made to specify a reversible synchronous machine (without slip rings and brushes) capable of operating as a synchronous motor or generator. The selection was based on the need to develop the most commercially acceptable product possible.

Part of the originally proposed product design concept involved the simultaneous operation of the compressor and a variable speed, constant frequency generator. Since the average compressor load for an air conditioning duty cycle is roughly 50%, a variable speed, constant frequency (VSCF) generator would enable the engine to continuously operate at full load, the best efficiency point. VSCF technology is utilized for wind turbines. The two drawbacks with the VSCF generator are (a) cost and (b) utilization of the generated electricity. A variable speed, constant frequency motor/generator would cost about $25,000 for 75 kW output, roughly three to five times the cost for a constant speed machine. Based on applying this technology to wind turbines, the economic breakeven point is around 400 kW. Besides the high price of the VSCF generator, utilization of varying amounts of generated electricity represents another issue. The only practical way to utilize varying amounts of generated power would be to feed the electricity back to the electric grid. Given that local utility interconnection requirements (cost and time) are often a significant deterrent to interfacing with the grid, economically applying VSCF would be difficult. In fact, if interconnection to the grid is possible, a single speed product could more economically be applied to supply cooling and generate electricity. Compressor cylinder unloading would control cooling output. Engine horsepower not used to cover the cooling load would be utilized to generate electricity. In this way, the engine could be fully loaded (and operate at a maximum efficiency) during peak demand periods when electric rates are highest.

Industrial gasoline-derivative engines have proven to be highly reliable in the market place for engine chiller applications. Tecogen has successfully applied them for engine-driven chiller applications in the market place. The engine service life is estimated at a nominal 20,000 hours. Gasoline-derivative engines have a significant cost advantage (3:1) over diesel-derivative engines. Given these advantages, the Project Team decided to specify a GM7.4 L gasoline derivative engine rather than a Caterpillar diesel-derivative engine.

The compressor is a Carrier Carlyle reciprocating compressor with a long track record for reliability and durability. Unloading of the 12 cylinder compressor can be done in pairs.

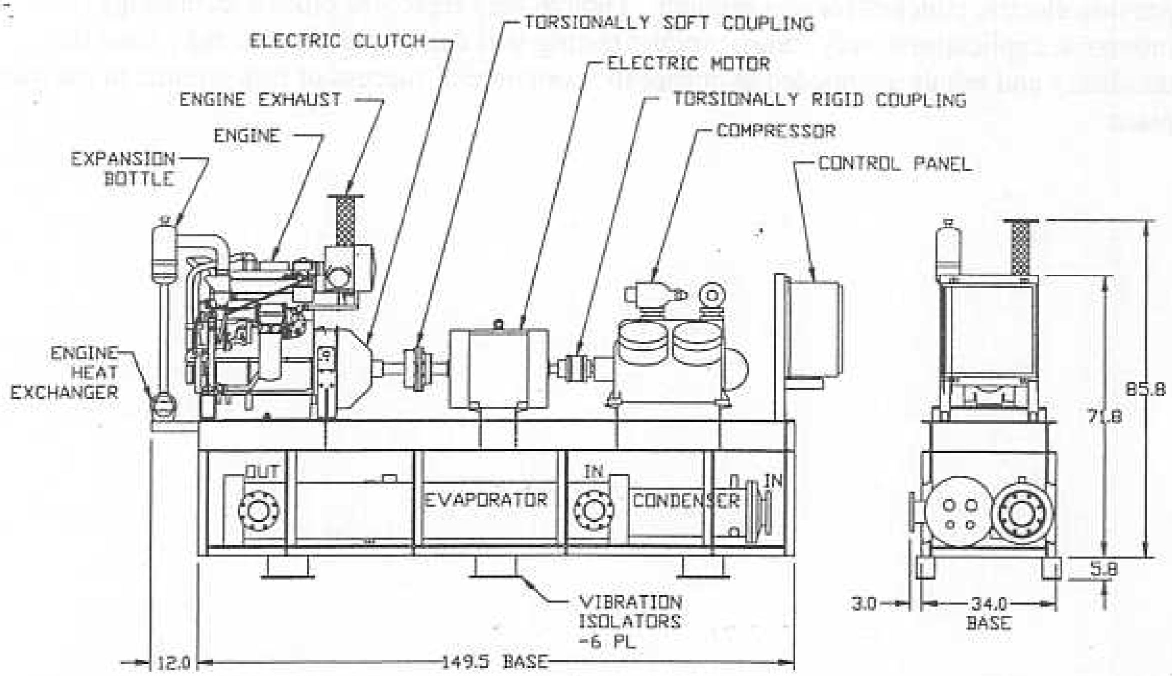
The control hardware has been developed and the software programming is underway. There should be no technical showstoppers with regards to controls. The controller is a microprocessor-based custom design which will be significantly lower in cost than purchasing a generic industrial grade controller. It will include diagnostic and remote monitoring capability.

Proper speed matching of the engine, motor/generator and compressor is critical. The speed limitation for the reciprocating compressor is 1,800 rpm. The synchronous generator can be operated at either 1,800 rpm or 3,600 rpm. The gasoline-derivative engine can operate between a range of speeds from 1,500 rpm to 3,200 rpm. Operating the engine at a constant 1,800 rpm would satisfy the compressor and the generator and portend to very long engine life. It would also allow the eventual specification of a diesel-derivative engine such as a Caterpillar or Waukesha model as a substitute for the gasoline-derivative GM engine.

The current hybrid chiller/cogenerator design requires two clutches. Warner electric will provide electric clutches for this product. Though they represent proven technology for industrial applications, only future product testing will determine whether they have the durability and reliability needed to ensure the commercial success of this product in the market place.

6. Commercial Feasibility

One of the goals of this project was to design a commercially-viable product. Hence, emphasis in the design process was placed on minimizing costs as much as possible, but also specifying components which have the durability and high reliability needed for a chiller application. As an example, a decision was made to locate the engine drive-line above the condenser/evaporator. Both York International and Tecogen essentially utilize the evaporator/condenser tube bundles as the support frame, thus eliminating the cost for an added support structure. This design feature also results in a compact chiller with a footprint comparable to electric units, a key factor in the replacement market.



6.1 Manufacturing Cost and Pricing Analysis

Several major decisions were made concerning the chiller design which impact cost and more importantly price.

- An industrial automotive (gasoline-derivative) engine would be specified. The automotive derivative engine is roughly $10,000 less than a comparable 100 HP diesel-derivative engine.
- We will specify R134-A as the refrigerant. While the cost increases significantly due to a larger compressor and evaporator and condenser tube bundles, the refrigerant is environmentally friendly and is considered the top replacement candidate for R22.

- Due to Alturdyne's extensive experience with reciprocating compressors, we will use a 100-ton Carlyle reciprocating compressor. A screw compressor would provide a better speed match for a gasoline-derivative engine. Reciprocating compressors are limited to 1800 rpm while a GM engine can operate up to 3,200 rpm. However, the engine should achieve very long life operating at low speeds (1,200 to 1,800 rpm)
- A decision was made not to include a variable speed, constant frequency feature as part of the motor/generator primarily because it would be too costly (roughly $25,000 for a 75 kw machine).
- As part of the GRI-funded Hybrid project, Alturdyne, has designed and developed a custom microprocessor-based controller. This controller will be utilized in Alturdyne's engine chillers, hybrid chillers and the current advanced hybrid chiller.

A manufacturing cost and pricing estimate was completed and shown below for two cases: (a) Use of R22 as a refrigerant and (b) Use of R134A as a refrigerant. Technically speaking, the product could be designed with either refrigerant. However, R22 will be phased out during the next ten years. Large manufacturers such as Trane and York have already redesigned their complete chiller lines with alternate refrigerants including R123 and R134A, respectively. The cost associated with specifying R134A versus R22 for this chiller design is quite significant, more than $20,000. The estimated product price increases from $76,000 to $98,000. The cost increase is directly related to the larger condenser, evaporator and compressor required for R134A. R134A has a lower specific density than R22. These manufacturing cost estimates assume annual sales volume of 50 units. At larger volumes, the manufacturing cost can be reduced by 10 to 20%.

Purchased parts and materials make up approximately 88% of the product's manufacturing cost with the remainder for labor and factory overhead. The gross margin for the product is 35%, fairly typical for small HVAC manufacturers.

The price of this equipment (100-ton/75 kW unit) compares with equivalent electric chillers and an emergency generator set as follows:

Hybrid Chiller/Cogenerator -- $98,000
Engine Chiller -- $88,000
Electric Chiller -- $40,000
Emergency Generator -- $19,000

The chiller/cogenerator will have about a 11% price premium over a conventional engine chiller. The first cost premium between a 100-ton engine chiller and an electric chiller is $48,000. The first cost premium between the hybrid chiller/cogenerator and a separate electric chiller and 75 kW emergency generator is $39,000. These price premiums will change considerably depending on the size of the equipment. However, it is important to note the lower price premium of the hybrid chiller/cogenerator than an engine chiller.

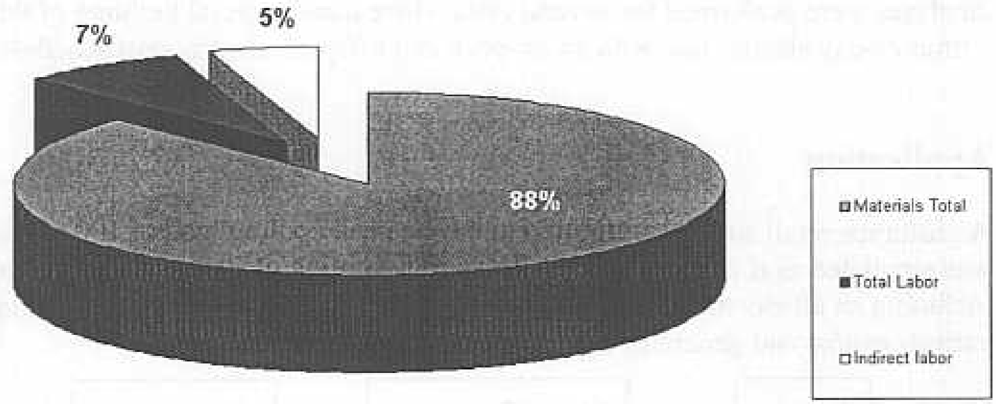
Manufacturing Cost and Pricing Estimate

Materials	*Quantity*	*Cost, Each*	*R22 Cost, total*	R134A Cost, total
GM Engine	1	$4,779.00	$4,779.00	$4,779.00
Clutch	2	$2,045.00	$4,090.00	$4,090.00
Bearing	2	$82.00	$164.00	$164.00
Motor/Generator	1	$2,369.00	$2,369.00	$5,000.00
Carrier 5H86 Compressor	1	$8,652.00	$8,652.00	$12,700.00
Flex Coupling	1	$456.00	$456.00	$456.00
Oil Cooler Package	1	$245.00	$245.00	$245.00
Motor Fastening	1	$147.00	$147.00	$147.00
Crankcase Heater	1	$55.00	$55.00	$55.00
Ketema Evaporator	1	$5,265.00	$5,265.00	$9,654.00
Ketma Condenser	1	$2,869.00	$2,869.00	$5,750.00
Engine Heat Exchanger	1	$686.00	$686.00	$686.00
Frame and Brackets	1	$750.00	$750.00	$750.00
Other Materials	1	$11,759.00	$11,759.00	$11,759.00
Materials Total			$42,286.00	$56,235.00
Materials Handling			$1,691.44	$2,249.40
Materials Total			$43,977.44	$58,484.40

Labor	*Hours*	*Rate, $/hr*	*Cost*	*Cost*
Project Engineer	35	27	$945.00	$945.00
Electrical Engineer	15	27	$405.00	$405.00
Draftsman	6	11	$66.00	$66.00
ILS Data	8	17	$136.00	$136.00
Foreman	4	19	$76.00	$76.00
Quality Control	2	12.8	$25.60	$25.60
Machinist	12	19	$228.00	$228.00
Sheet Metal	8	9.36	$74.88	$74.88
Welder	24	12.25	$294.00	$294.00
Assembler	60	9.36	$561.60	$561.60
Electrician	60	10.25	$615.00	$615.00
Painter	24	9.17	$220.08	$220.08
Test Technician	8	12.8	$102.40	$102.40
Total Labor			$3,749.56	$3,749.56
Indirect labor			$2,512.21	$2,512.21
Manufacturing Cost			$50,239.21	$64,746.17
G&A			$16,729.66	$21,560.47
Manufacturing Cost & G&A			$66,968.86	$86,306.64
Profit			$8,036.26	$10,356.80
Manufacturing Cost, G&A, Profit			$75,005.12	$96,663.43
Warranty			$1,500.10	$1,933.27
Estimated Price			$76,505.23	$98,596.70

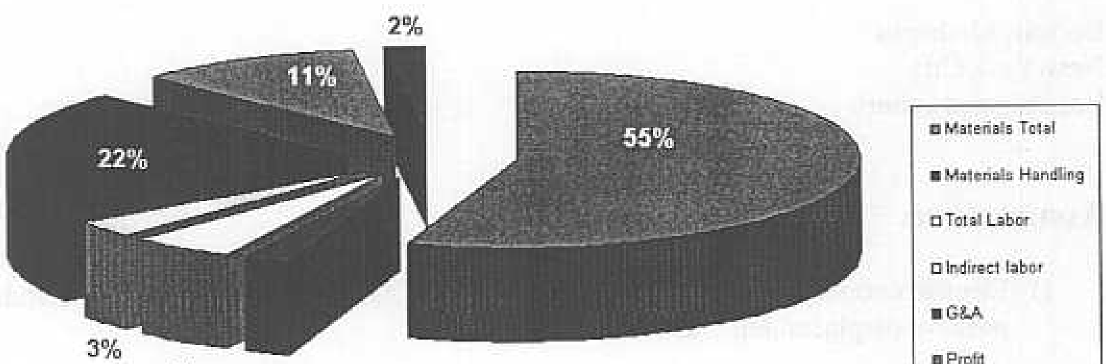
Manufacturing Cost Breakdown

Alturdyne Advanced Hybrid Chiller/Generator



Product Price Breakdown

Alturdyne Advanced Hybrid Chiller/Generator



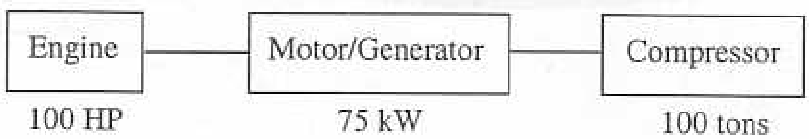
6.2 Operating Economics

Approach

Energy cost savings analyses were performed using the DOE-2 building energy analysis program to simulate the application of various cooling plant configurations to a prototype building. Analyses were performed for several cites 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.

Application

A prototype retail store was configured to have a peak cooling load of 100 tons in each city and was simulated as if it were equipped with various cooling plant equipment configurations including an all electric cooling plant, an all gas cooling plant and with hybrid cooling plants of various engine and generator capacities like that shown below.



For comparison purposes, the retail store was also analyzed with an engine generator set available to run interconnected with the electric utility grid to satisfy a portion of the building's electric load. One additional case simulated an engine generator set dedicated to the electric chiller with the generator operating only when there was a cooling load.

Locations

Detroit, Michigan
New York City
Los Angeles suburb

Assumptions

1) Electric cooling efficiency, 0.79 kW/ton (4.45 COP) based on ASHRAE Standard 90.1, positive displacement water cooled chiller

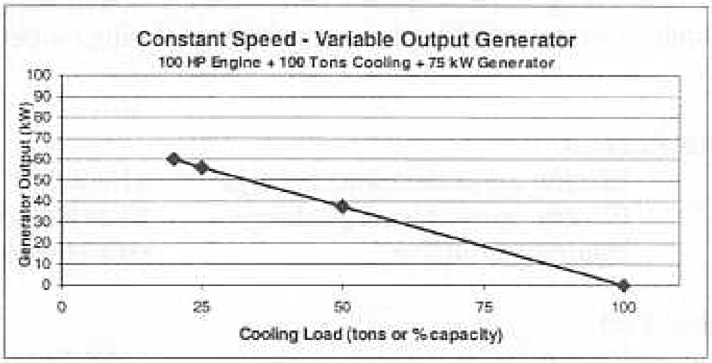
2) Gas cooling efficiency, 1.46 COP with 0.02 kW/ton electric parasitics based on water cooled engine driven chiller

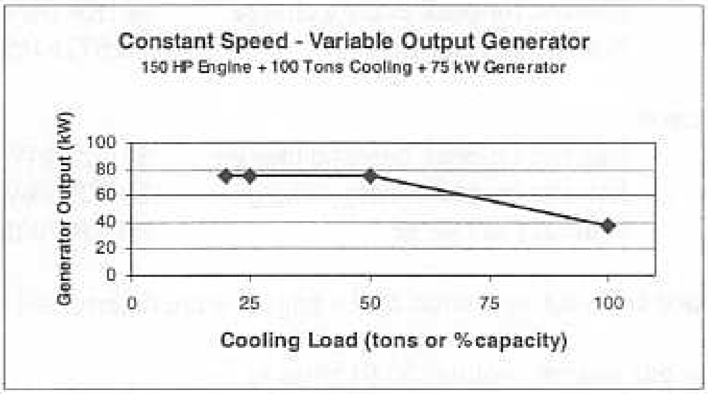
3) For hybrid chiller/cogenerator, gas engine runs at constant speed and fuel consumption anytime cooling is needed during the on-peak electric period which is different for each city

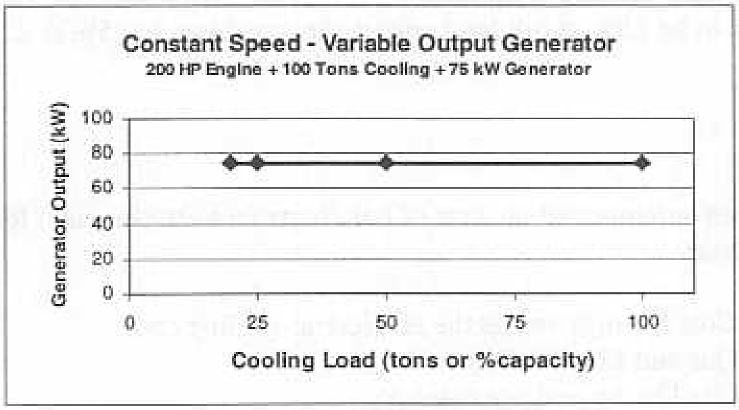
4) Generator runs at constant speed with variable output when gas engine runs

5) Generator set was assumed to be interconnected to the utility electric grid and allowed to operate during the on-peak period hours to reduce the building's dependency on the grid.

6) After satisfying cooling load for any hour, unused engine HP is used to operate generator; generator output varies as shown below with for three engine sizes







7) Two different operating scenarios were investigated:

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

b) Generator allowed to operate during all on-peak hours even below 20% cooling capacity by falsely loading compressor. This allowed generator to peak shave and produce kWh during on-peak hours when it normally not be operating.

8) Annual electric and gas costs for each case were calculated using rate schedules for each city that applied to this retail application. Savings during on-peak hours were determined as follows:

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

9) Maintenance costs for operation of the engine were determined as follows:

For gas engine cooling, \$0.015/ton-hr
For engine generator, \$0.015/HP-hr of generator output

10) For the cases utilizing a conventional engine generator set, the fuel input efficiency was assumed to be 25% at full load output varying down to 15% at 25% of full load output.

Results

Results have been summarized on a set of bar charts (see attachments) for each of the 3 cities to show for each case:

Annual Cost Savings versus the all electric cooling case
Annual Gas and Electric Costs
Annual Gas Use by end use category

The 15 cases analyzed include:

1) All electric cooling plant

2) 75 kW engine generator set operating at full capacity during on-peak hours

3) 112 kW engine generator set operating at full capacity during on=peak hours

4) 75 kW engine generator dedicated to running electric chiller; generator operates only when cooling required

5) All gas cooling plant

6) Hybrid cooling plant operating in gas cooling mode during on-peak hours and electric cooing mode during off-peak hours

7) Hybrid chiller/cogenerator with 100 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

8) Hybrid chiller/cogenerator with 100 HP engine, 100 ton compressor, 75 kW generator operating during all on-peak hours

9) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

10) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 75 kW generator operating during all on-peak hours

11) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 93 kW generator operating during on-peak hours when cooling required

12) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 93 kW generator operating during all on-peak hours

13) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

14) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 112 kW generator operating during on-peak hours when cooling required

15) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 112 kW generator operating during all on-peak hours

Conclusions

An all gas cooling plant saves $6,000 - $10,000 annually (engine maintenance costs included) versus an all electric cooling plant for the three cities analyzed

For the hybrid chiller/cogenerator cases analyzed:

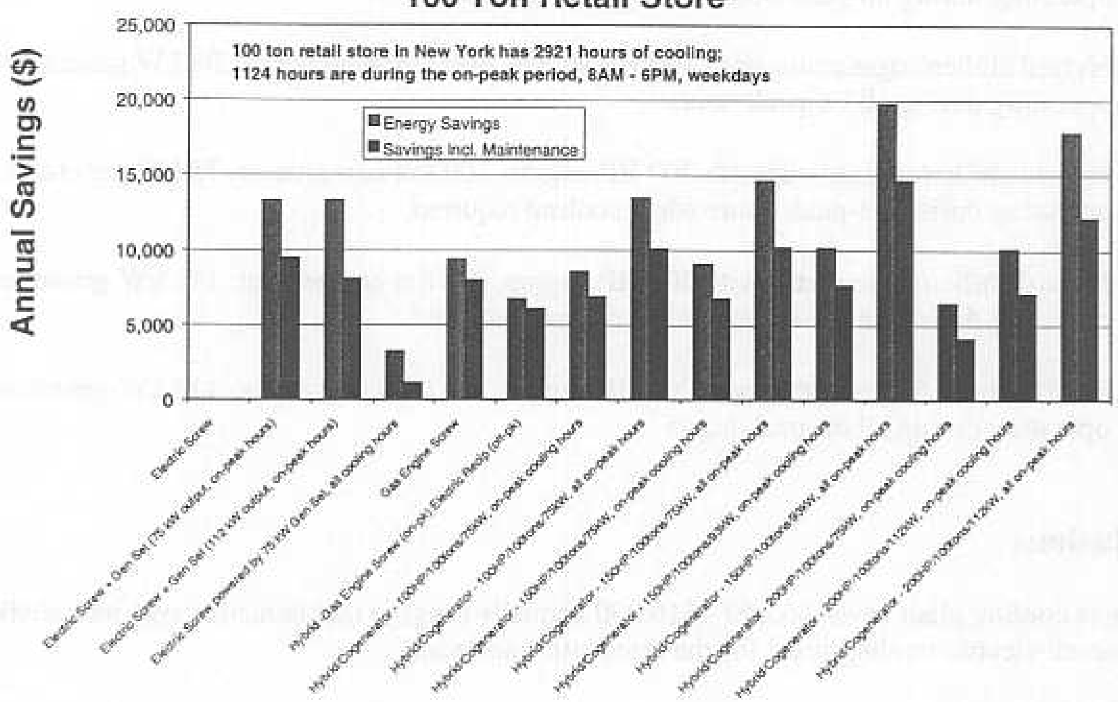
a) Annual savings can be maximized if the chiller/cogenerator is allowed to operate during all on-peak hours even when no cooling is needed.

b) The optimum chiller/cogenerator configuration based on the alternatives analyzed appears to be the system with a 150 HP gas engine, 100 ton compressor and 93 kW generator operating all on-peak hours. This configuration produces annual savings including maintenance versus the all electric cooling plant of $9,000 - $15,000.

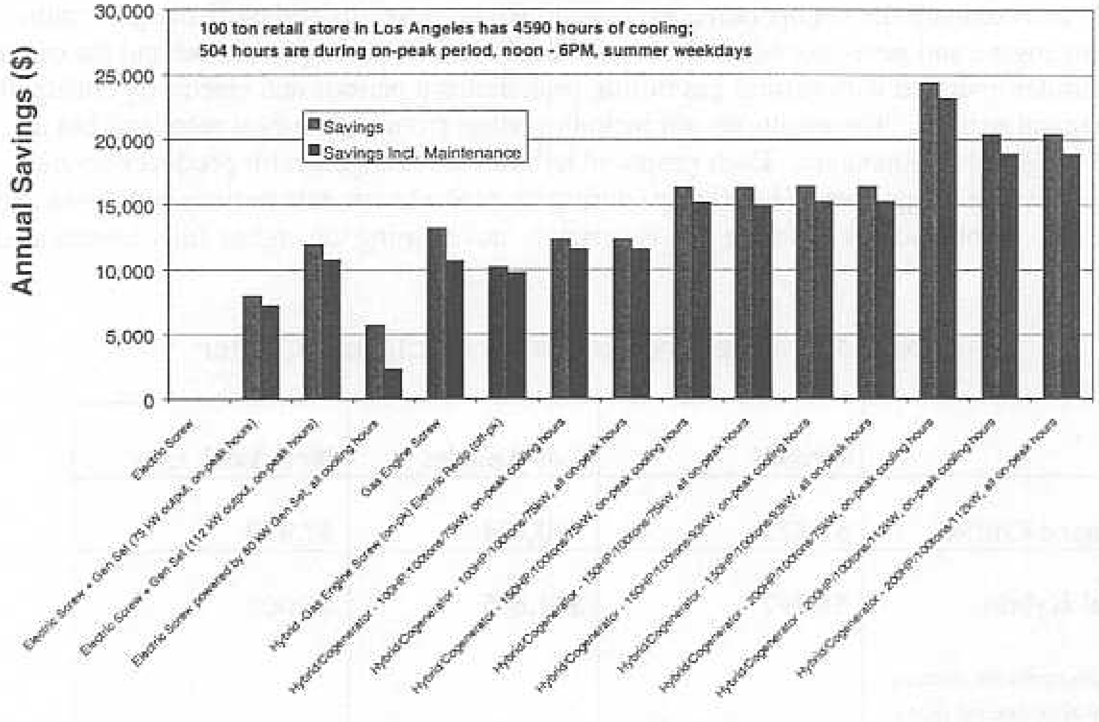
c) Greater annual savings are possible in Los Angeles due to the long cooling season but only at the expense of installing a larger 200 HP engine.

d) The hybrid chiller/cogenerator makes most sense in cities and applications that have time-of-use electric rates with on-peak and off-peak schedules where electric demand and energy charges are higher during on-peak periods. For cities in which time of use rates don't apply, but electric rates are high, an engine-driven chiller would generally provide the best economics.

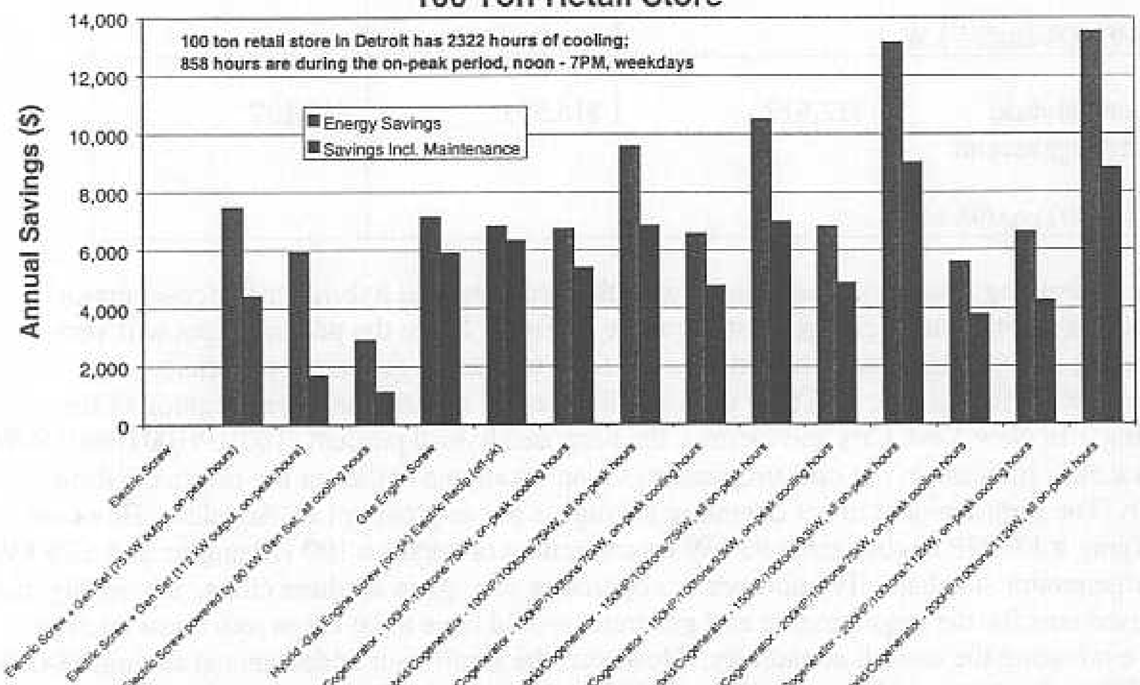
New York Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store



Los Angeles Savings Versus All Electric for various Cooling Plant Scenarios 100 Ton Retail Store



Detroit Annual Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store



6.3 Economics

The table below summarizes the results from the DOE-2 hour-by-hour analysis performed to evaluate and compare the net operating savings of two proposed hybrid chiller/cogenerators (different engine and generator size) versus an electric chiller, an engine chiller and the original hybrid chiller operated with natural gas during peak demand periods and electricity during off-peak demand periods. The results do not include savings from engine heat recovery, but do include a cost for maintenance. Each proposed hybrid chiller/cogenerator product operates continuously at a single speed (1,800 rpm) during on-peak electric rate periods supplying and generating a combination of cooling and electricity, thus keeping the engine fully loaded at all times.

Net Operating Savings versus an Electric Chiller

	Detroit	**Los Angeles**	**New York City**
Gas Engine Chiller	$5,873	$10,674	$7,979
Original Hybrid (Natural gas operation on-peak, Electricity operation off-peak)	$6,297	$11,885	$6,063
Proposed Hybrid Chiller/Cogenerator 100HP/100Tons/75 kW	$9,036	$11,885	$12,821
Proposed Hybrid Chiller/Cogenerator 150HP/100Tons/93 kW	$12,612	$15,951	$19,132

A key underlying assumption associated with the two proposed hybrid chiller/cogenerator products is that the electricity generated can be utilized. Since the power output will vary depending on the chiller load, the only way to fully utilize the generated electricity is to interconnect to the electric grid thus reducing the electric demand and consumption of the building. In New York City and Detroit, the proposed hybrid product (100HP/100Tons/75kW) offers a 50% increase in net operating savings over an engine chiller or the original hybrid chiller. The improvement in net operating savings is not as great in Los Angeles. However, specifying a 150 HP engine and a 93 kW motor/generator versus a 100 HP engine and a 75 kW motor/generator substantially improves the operating savings in all three cities. Obviously, the increased cost for the larger engine and generator would have to be taken into consideration when evaluating the overall economics. However, the significant added annual savings ($4,000 to $6,000 per year) would seem to offer a rapid payback on the incremental investment.

The pay back periods for the proposed Chiller/Cogenerator versus a separate electric chiller and emergency generator in New York City, Los Angeles and Detroit range from 3.0 to 4.3 years. Commercial building owners are generally willing to consider the purchase of engine-driven chillers if the payback period is less than five years. For reference, the simple payback periods for an engine chiller versus an electric chiller range from 4.5 to 8 years. The analysis is for a retail store. Previous engine chiller analyses has shown that other building applications like hospitals often result in improved economics.

Product Prices
Hybrid Chiller/Cogenerator -- $98,000
Engine Chiller -- $88,000
Electric Chiller -- $40,000
Emergency Generator -- $19,000

Price Premium

Engine chiller versus Electric Chiller First Cost Premium: $48,000

Hybrid Chiller/Cogenerator versus Electric Chiller and Emergency Generator First Cost Premium: $39,000

Economic Simple Payback (Hybrid Chiller/Cogenerator versus an electric chiller & Emergency Generator) :

New York City : $39,000/$12,821 = 3.0 years

Detroit: $39,000/$9,036 = 4.3 years

Los Angeles: $39,000/$11,885 = 3.3 years

Economic Simple Payback (Engine Chiller versus an Electric Chiller)

New York City: $48,000/$7,979 = 6.0 years

Detroit: $48,000/$5,873 = 8.0 years

Los Angeles: $48,000/$10,674 = 4.5 years

7. Conclusions

Technically, there do not appear to be any showstoppers with regards to developing a product which functions as an emergency generator and an engine chiller. A reversible synchronous machine can be operated as a motor or a generator. The one limitation is that the machine, when operated as a motor, cannot start under a load. This does not appear to be a problem as the compressor can be fully unloaded before the motor is started. A variable speed, constant frequency generator would enable the generation of power coincident with variable speed chiller operation. However, in order to utilize varying levels of power generation, interconnection to the electric grid would be necessary. Grid interconnection/permitting requirements along with standby/backup rates, as specified by the local electric utility, often discourage on-site power generation. Because of this fact, as well as the high cost for a VSCF motor/generator, a decision was made not to incorporate A VSCF feature into the prototype under development. As a single speed machine, the product is capable of providing cooling and generating electricity simultaneously. The chiller would match the cooling load through cylinder unloading and utilize refrigerant gas bypass rather than cycling. Consequently, the machine would still generate varying output power levels (constant speed, but varying torque), thus necessitating interconnection with the grid in order to utilize the electricity.

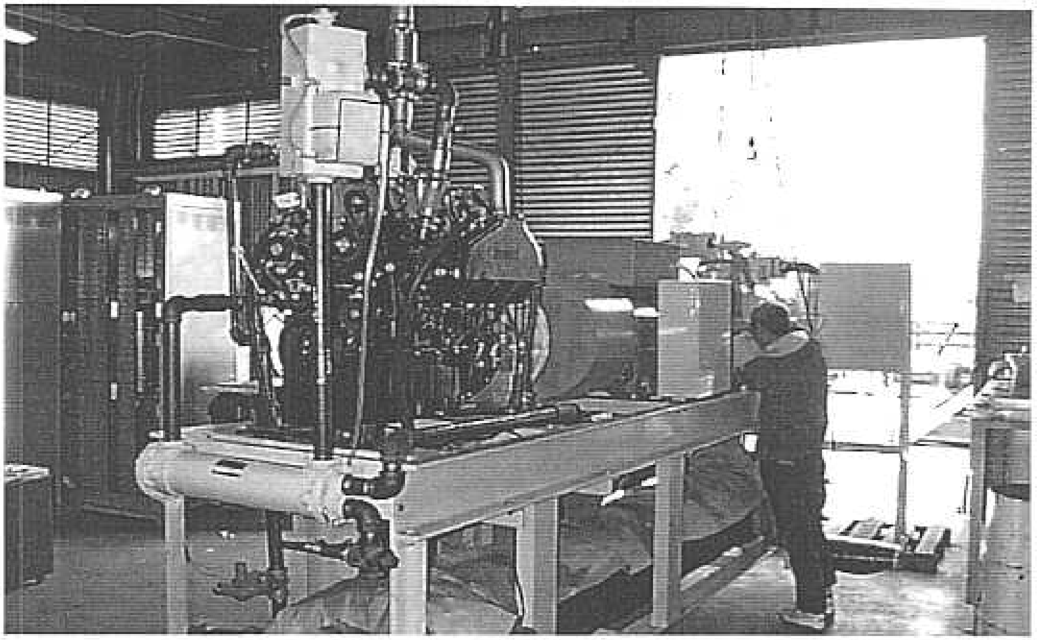
From a commercial perspective, the product will be economically competitive in many high electric-rate areas of the country including Detroit, New York City, and Los Angeles. The product offers a lower first cost premium over a competing electric chiller/emergency generator than would an engine chiller versus an electric chiller. Due to the flexibility to generate electricity simultaneously while supplying cooling, it offers improved operating savings assuming grid interconnection is possible. Payback periods ranged from 3 to 4.5 years in those cities for retail applications. Other applications such as hospitals would be expected to yield even shorter payback periods. Recovering heat from the engine has the potential of improving the economics even further (10% to 30% depending on the application).

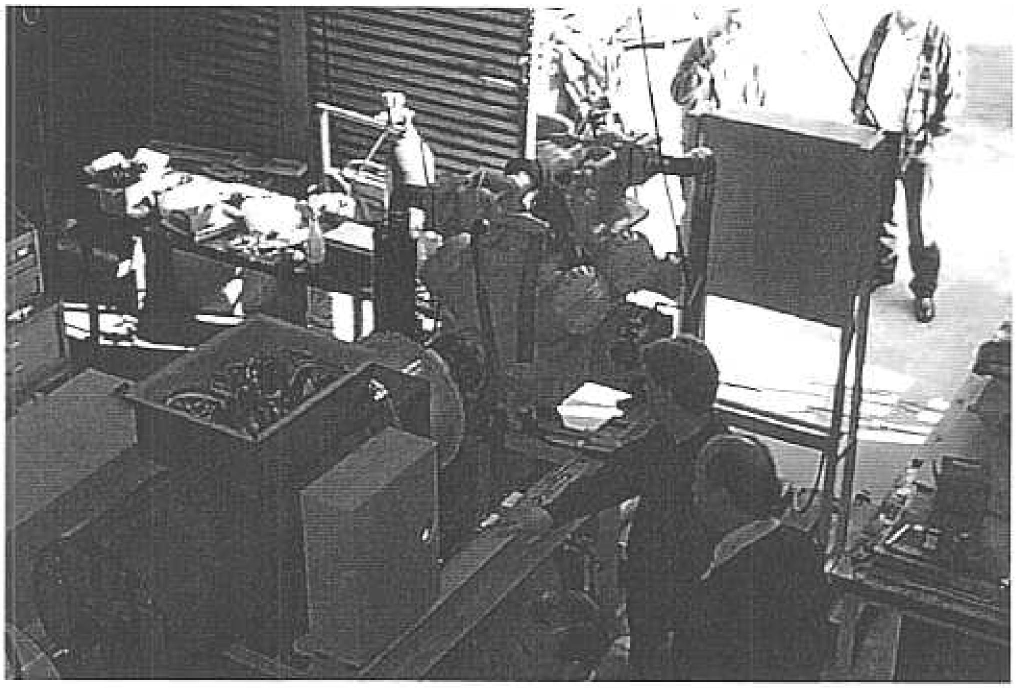
In total, the hybrid/co-generator represents a technically and commercially-viable product capable of serving as a chiller, peak shaver and emergency generator.

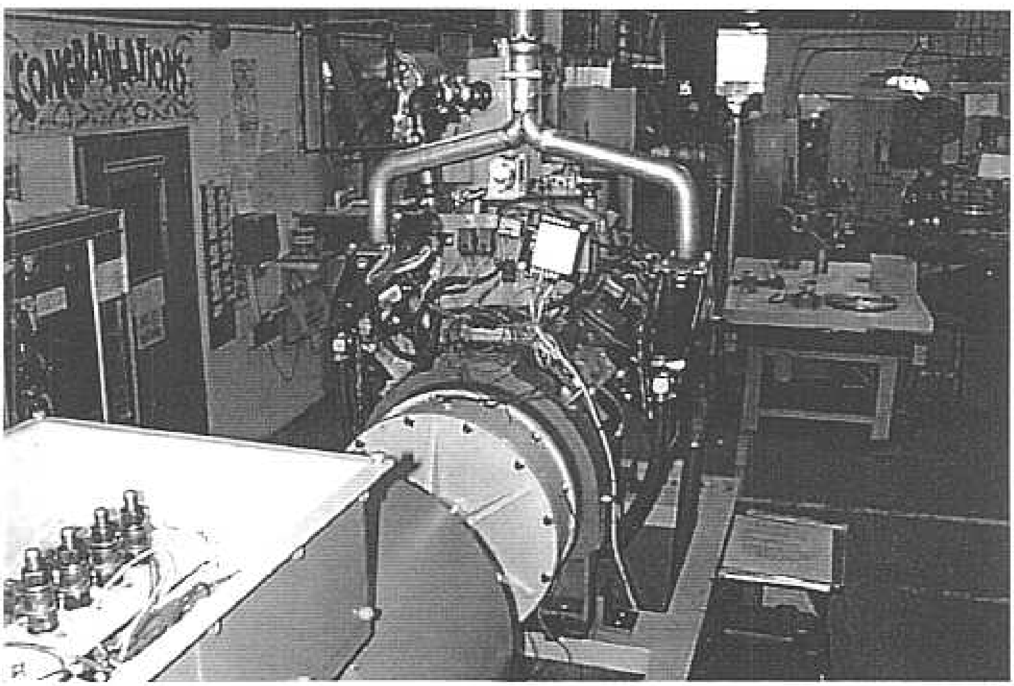
Appendix D

Photographs of the Unit

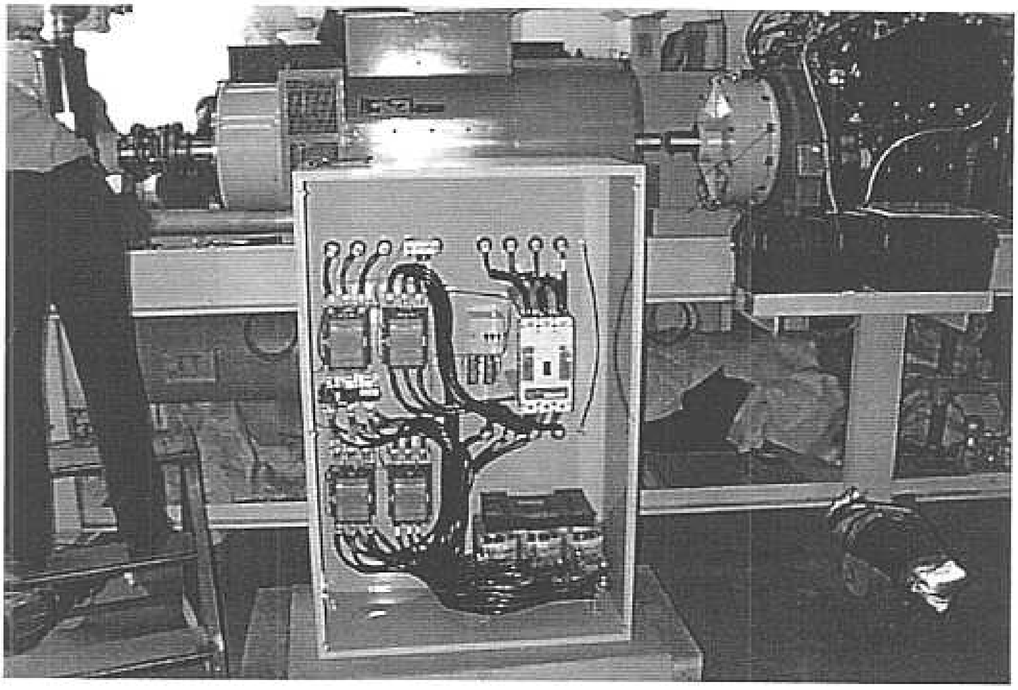
The first four pictures are an overall view of the unit. The covers are off the electrical boxes to show the wiring and relaying within the panels.



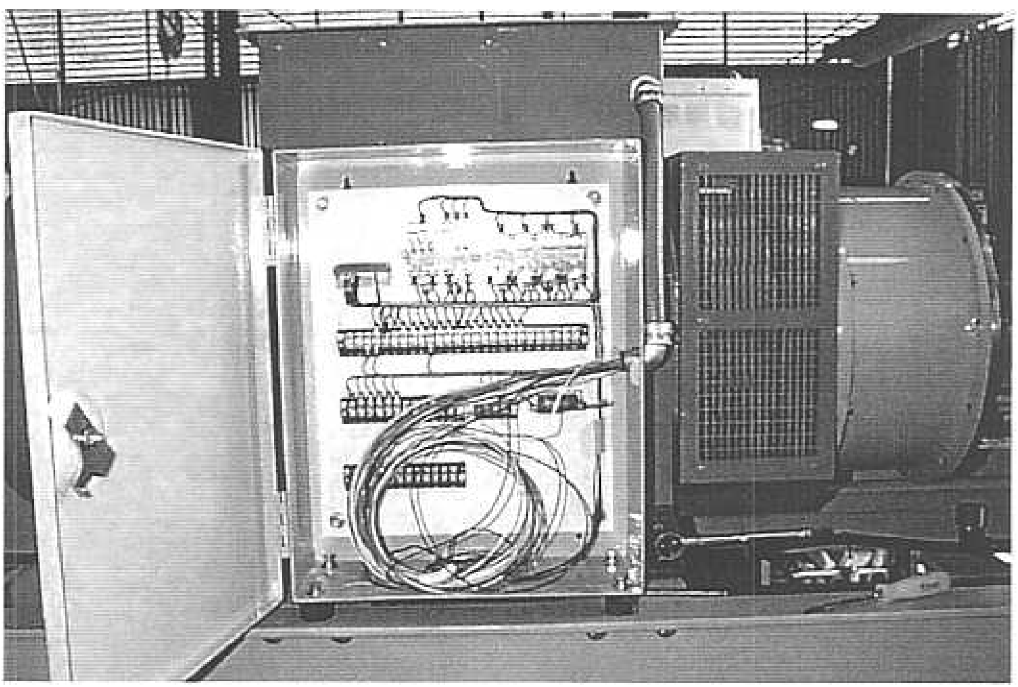



CONGRATULATIONS

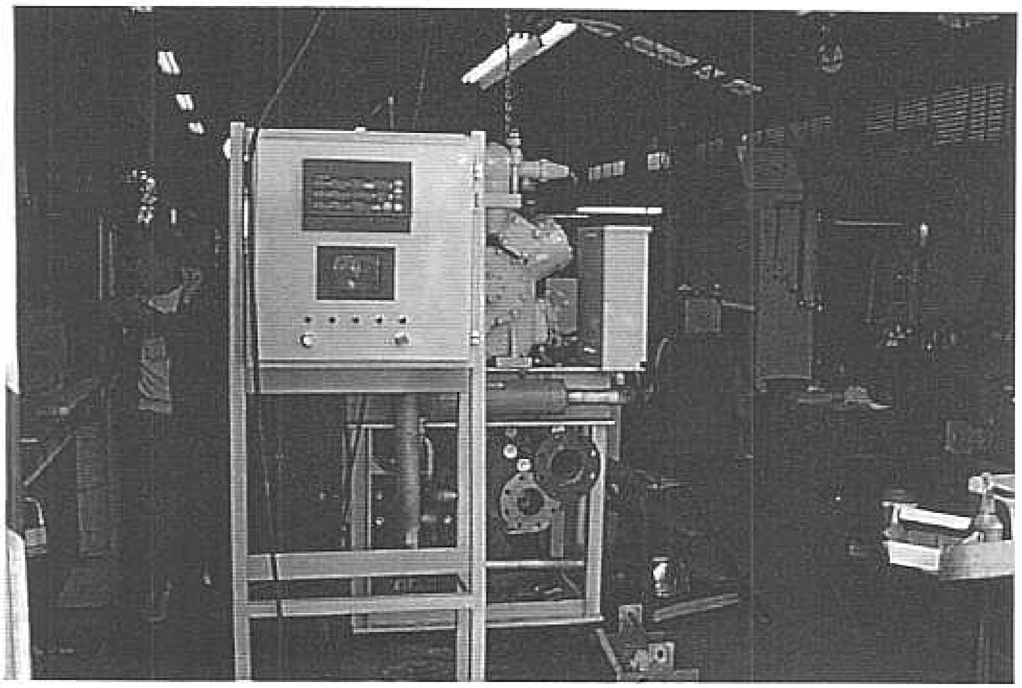
View of power transformer and related protective relays panel.



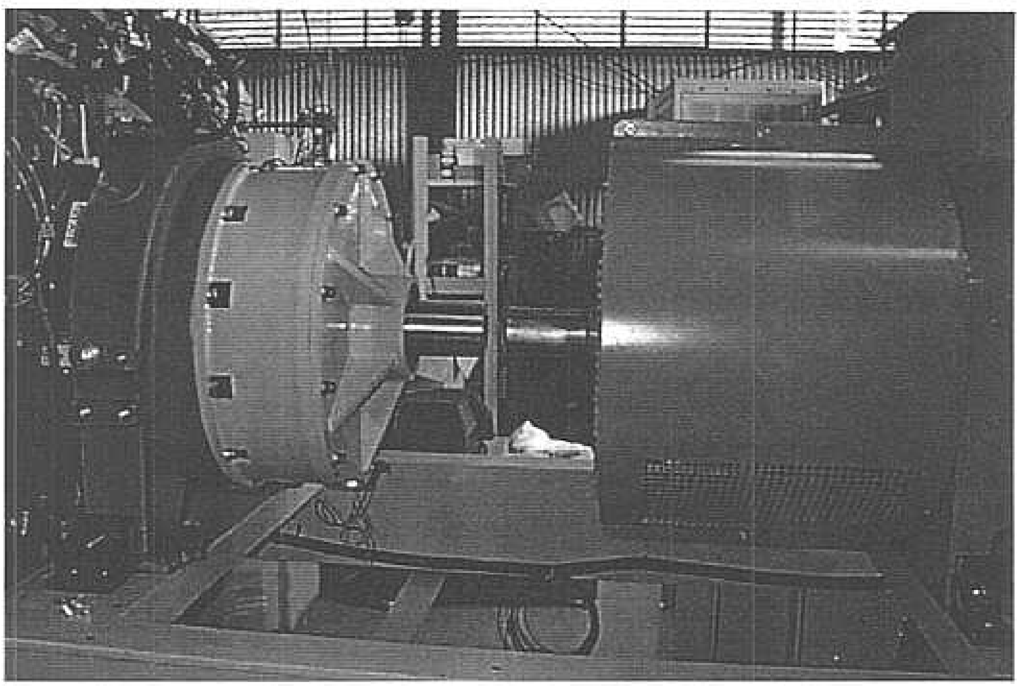
Controls and termination panel for synchronous generator/motor.



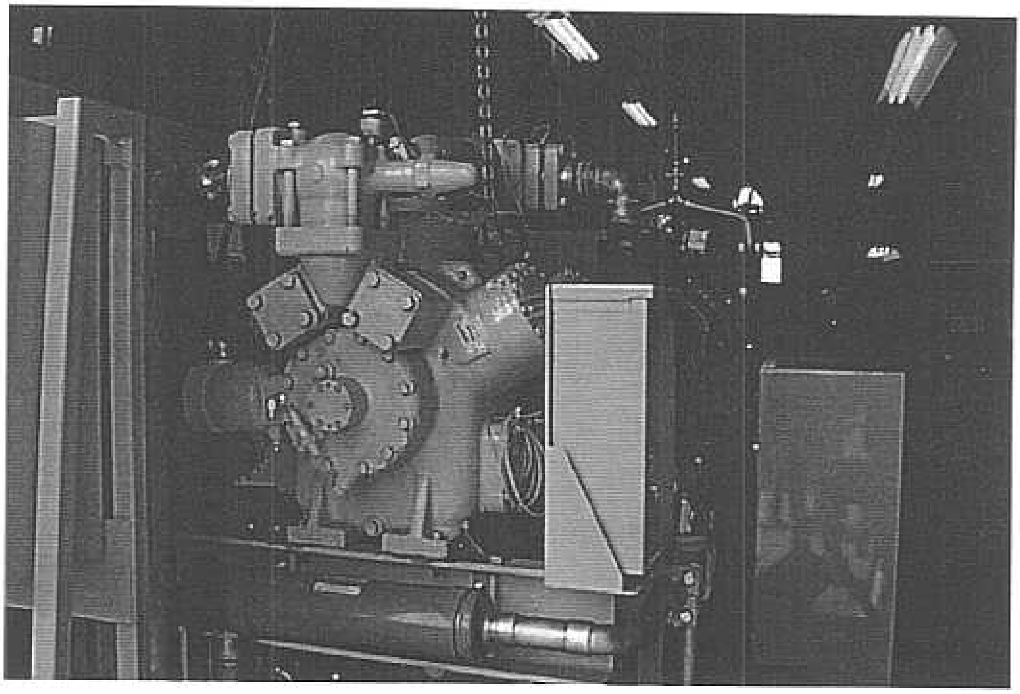
View of Controls panel and annunciator board.



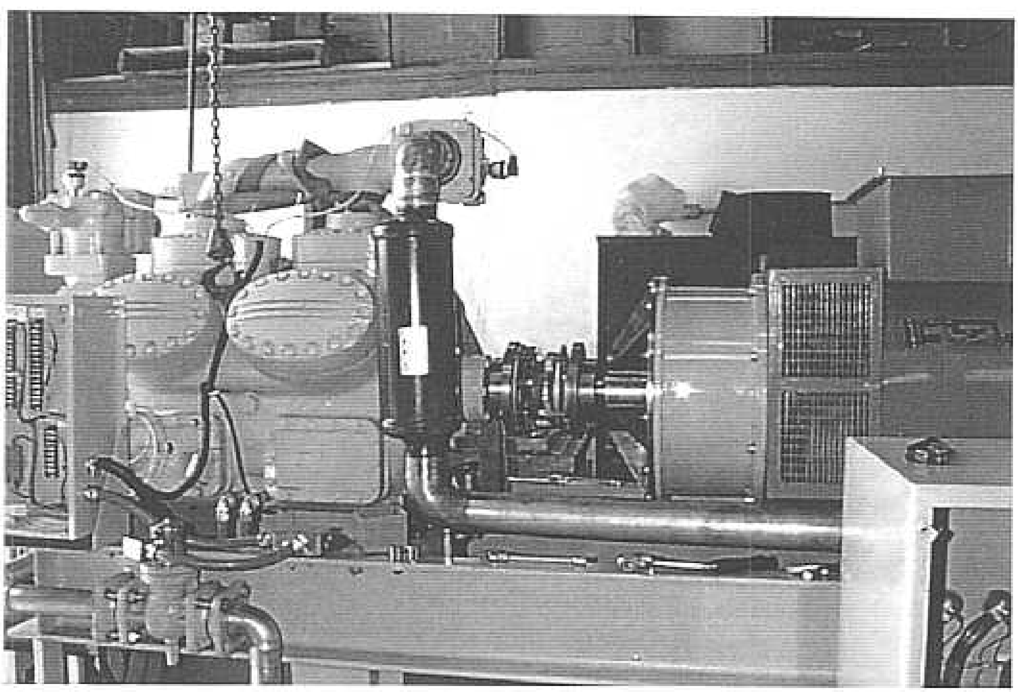
View of clutch housing and missing coupling between engine and synchronous generator/motor (coupling added in February 2001 – picture not available)



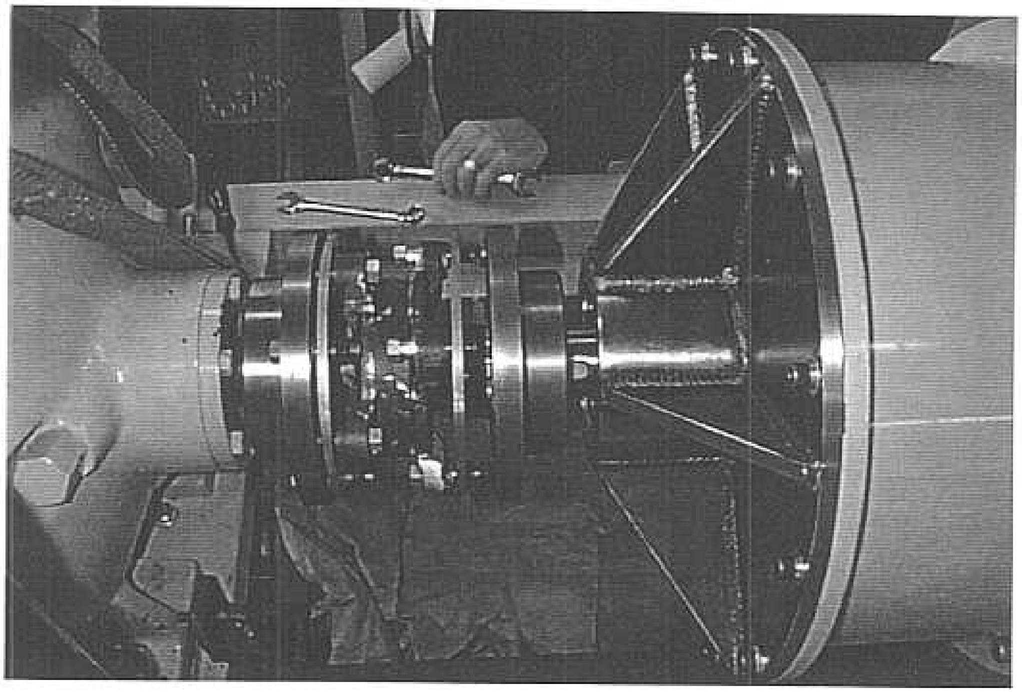
Compressor end of skid with all associated piping connected

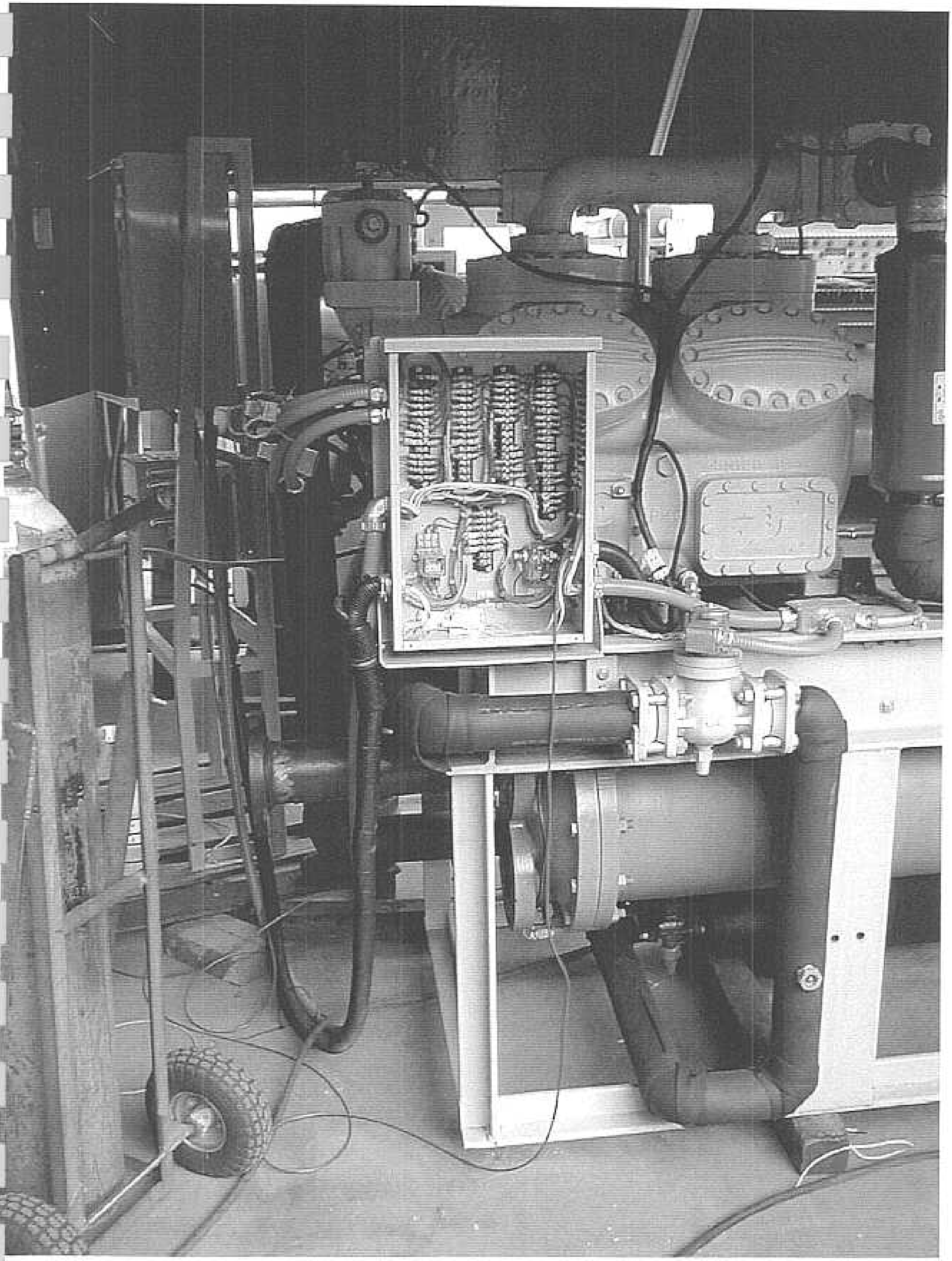


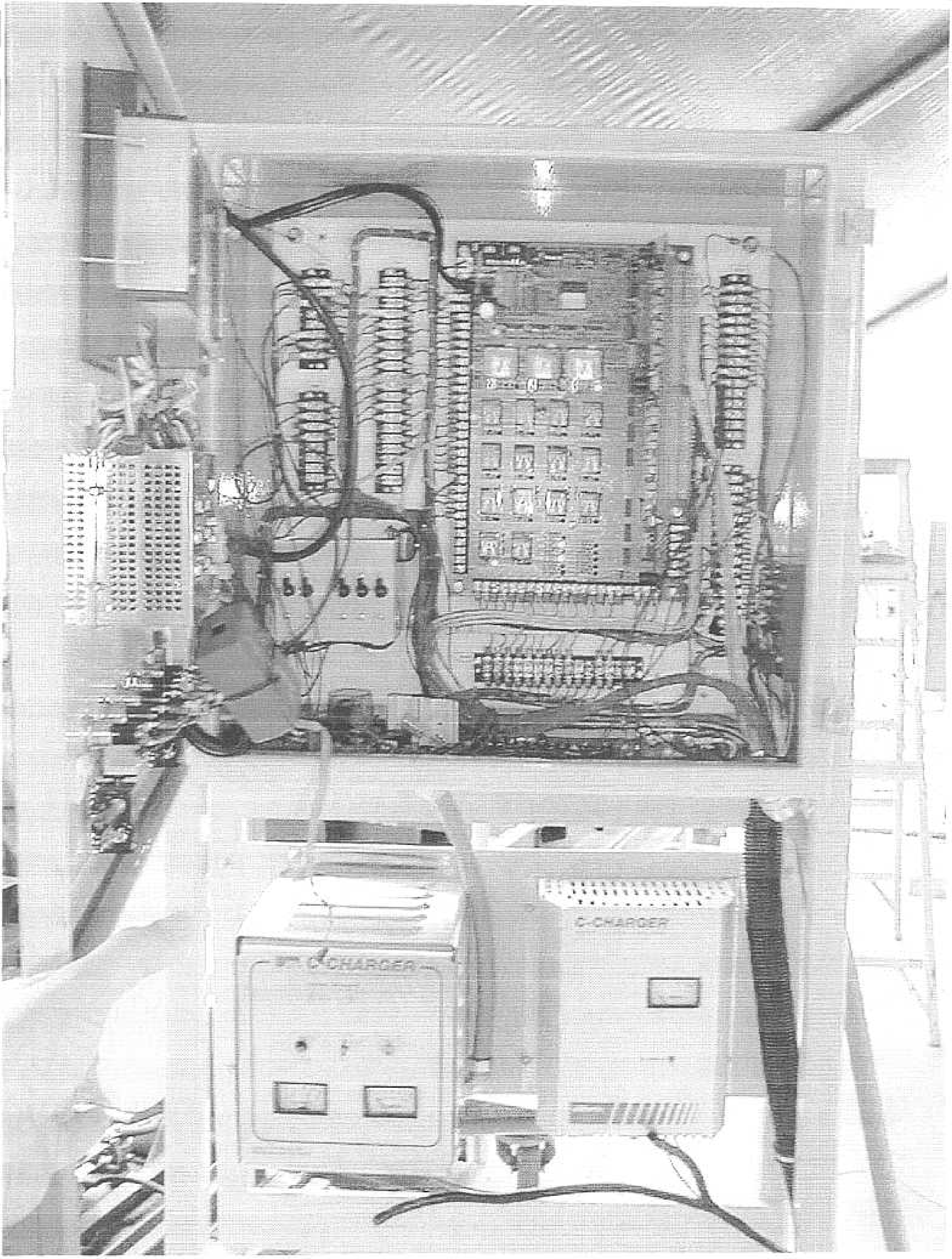
Side view of coupling between compressor and synchronous generator and associated clutch



Closer view of coupling and clutch housing



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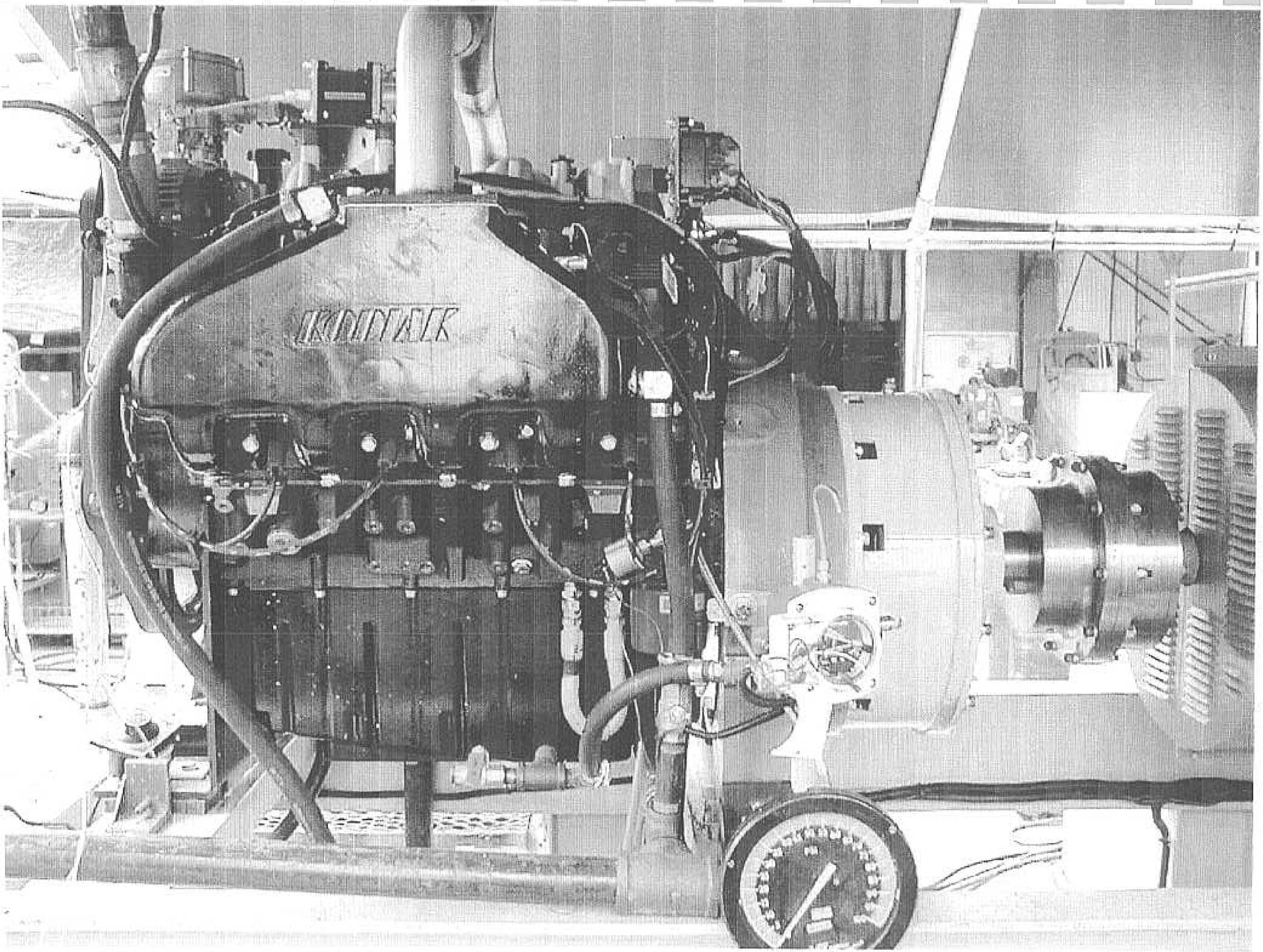
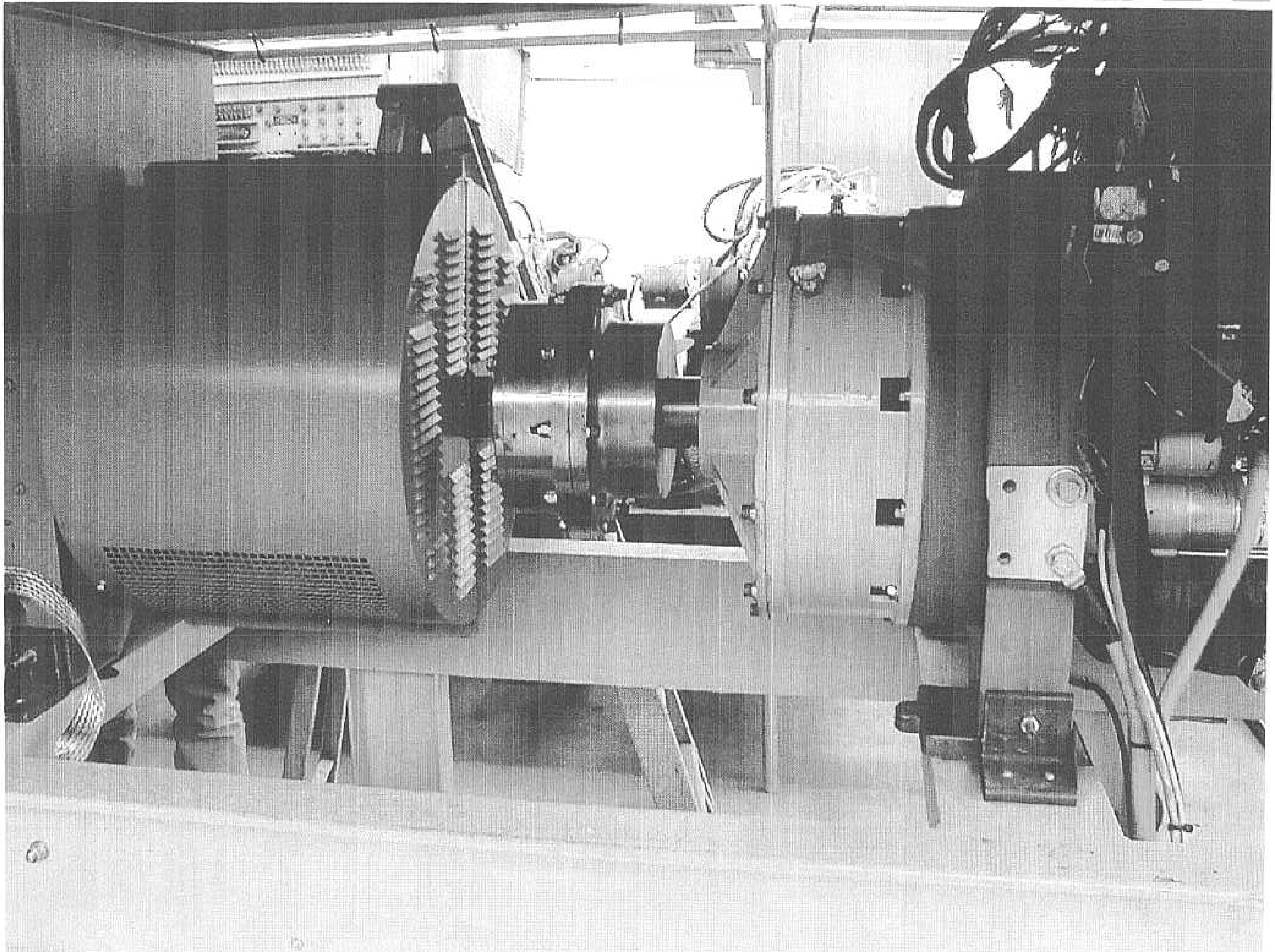
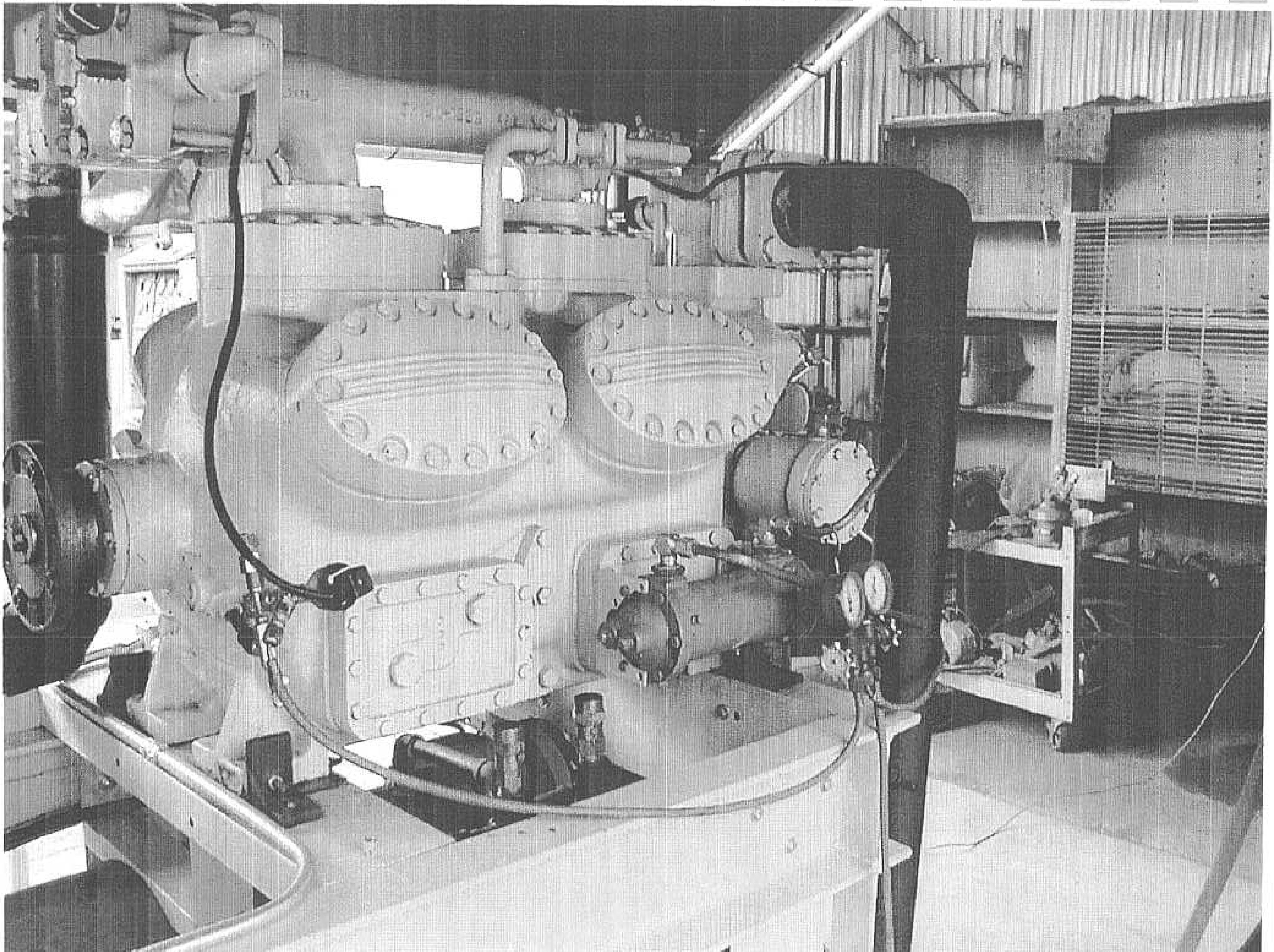






Appendix E

Timeline of Events

Hybrid Chiller/Generator Project Timeline

January 2000 –

A kickoff meeting was held on January 21 at Alturdyne's facility. The group decided that Hallidyne Corporation's proposal had two shortcomings: the high first cost of the motor/generator and the maintenance/service required to replace the slip rings and brushes. Three design concepts were proposed. The first was incorporating a synchronous generator and induction generator in line with the engine and compressor. The drawback is the length of the skid, the positive point is the low equipment costs. The second design involves using an engine/induction motor/generator and compressor in series. This unit could not provide emergency power generation. The last concept was an engine generator set with both a synchronous and induction generator on one shaft. The benefits of this design include induction generator "peak shaving" and emergency power generation at a reasonable price.

February 2000 –

Decision was made to proceed with a motor/generator capable of serving as the electric prime mover for the compressor as well as the generator for emergency power needs. The decision not to proceed with a variable speed, constant frequency design was based on costs.

Work was started to develop product specifications including engine and product layout. Initial decision was to use a Cummins diesel derivative because a) the low-cost General Motors 7.4 liter engine was being discontinued and the 8.1 liter was not yet available and b) the Caterpillar engine Alturdyne used in the past was too expensive ($ 15,000).

Energy and economic analysis using DOE-2 was planned for March 2000 using the following cases: a) baseline conventional cooling plant, b) hybrid cooling plant (gas cooling only), c) hybrid cooling plant (gas and electric cooling available),d) hybrid cooling plant (gas and electric cooling and cogenerator available) and e) hybrid cooling plant with ice storage. The hybrid cooling plant with cogen available was to be looked at using three different sizes of engine (100, 150 and 200 h.p.), three different sizes of motor/generator (75 and 112.5 kW) and a 100 ton compressor.

April 2000 –

Meeting was held on April 12, 2000 attended by members of GRI, DOE, OnSite and Alturdyne. One of the issues discussed was the prototype's redesign to reduce the overall width. The evaporator and condenser would be located under the engine. The decision was made to use a Reuland Electric motor with double end shafts. The following technical issues were also decided upon: a) a GM engine would be specified as the prime mover, b) a Carrier reciprocating compressor would be specified, c) that the motor/generator would provide two functions (as an induction motor and as a synchronous generator) and d) that the refrigerant to be used would be R134-A.

By the end of April it was reported that cumulative net outlays were $ 34,945.02. The Federal share was $ 27,956.02 and GRI's cost share was $ 6,989.00

In a memo from Alturdyne to GRI, Alturdyne stated that they would build a synchronous motor test stand 'to prove the concept of using a synchronous generator as a motor'. The test stand was to be constructed of two 12 kW generators with a coupling and was to be assembled in three to four weeks.

May 2000 –

Alturdyne successfully located two sources to build the motor/generators: AVK (Germany) and WEG Electric Motor (Brazil). The AVK unit was available at 208 VAC, the dual voltage unit takes longer. Several motor/generator manufacturers were contacted by Alturdyne this month including Marathon, Stamford Newage, AVK, WEG, Baylor and Lima.

Alturdyne hired a programmer for the system controls who starts work in June.

It was believed that the compressor would have to be enlarged to accommodate R134-A and the 8.1 GM engine.

A major goal for the month of June is the completion of the Bill of Materials. The long lead time items such as the compressor, clutches, evaporator, condenser and engine need to be ordered. The lead time for most of these items is six to eight weeks.

June 2000 –

All of the detail data on both the AVK and WEG motor/generators was obtained. The AVK unit was scheduled to be delivered by October 15, 2000. The WEG unit was scheduled to be delivered by August 30, 2000. The compressor, evaporator and condenser were ordered and had a delivery date of September 18, 2000.

It was anticipated that the clutch, couplings and engine would be purchased in July.

Torsional analysis work which was scheduled for June was not completed, but was anticipated to start next month.

Notes from AVK ("after a short time the machine, now operated as a synchronous motor, may be mechanically loaded") raises a concern about the AVK motor's ability to start under load. There is an implication that the motor must be started with no load on its shaft. However, for the motor to go from asynchronous to synchronous operation, the motor has to over come 129 ft-lb of torque from the compressor. The pull-in torque of the AVK is 306 ft-lb. The pull-in torque of the WEG is 287 ft-lb.

July 2000 –

The clutches were ordered in July, but the engine was not. GRI had advised using the 7.4 liter engine. Couplings were not ordered due to the lack of torsional data.

The controls programming were scheduled to be completed by Oct. 1, 2000. Although the package design was not completed, the product specification was 90 % completed by the end of July.

Alturdyne was given approval to hire an OnSite consultant for support on design, assistance on engine issues, testing and ETL certification.

The major components were identified. Engine – GM Vortec 8100 V8, factory equipped using natural gas as fuel which can operate from 550 to 4,800 RPM. Motor/Generator – a AVK DSU 43 M1-4, which has a synchronous speed of 1,800 RPM, a generator output of 100 kVA and a motor output of 100 h.p. Compressor – a Carrier/Carlyle model 5H126, 12 cylinder reciprocating unit. Evaporator – an API/KETEMA model DXT-1610-S2-2C. Condenser – an API/KETEMA model AHX-1406B-2. Electric clutches – Warner Electric model 1525-HT

August 2000 –

A review meeting was held on August 2, 2000 between GRI and Alturdyne. The agenda for the meeting was as follows: a) major production design and delivery status (motor/generator, GM 8.1 liter gas engine, Carrier compressor, clutches, couplings, vessels and controls), b) minor product/system design status (valves, piping, system design, torsional analysis), c) fabrication schedule, d) development testing, e) ETL certification, f) pricing/costs, g) market and h) discussion about the Omni Metals (an earlier prototype being tested) controls.

October 2000 –

During October 2000, a large portion of time was spent receiving the various parts needed for final construction of the skid at Alturdyne's facility in San Diego, California. All components were received with the exception of the synchronous generator/motor being shipped from AVK in Germany. This component was expected to arrive in November 2000. The controller is supposed to be ready by December 2000.

Gard Analytics' market report is expected to be ready by December 2000.

On October 10, a production schedule was supplied by Alturdyne to GRI. The schedule listed that the clutch would be completed by Nov. 13, the engine would be delivered by Nov. 6, the WEG motor/generator would be delivered by Nov. 10 and that the entire assembly would be completed and ready for testing by ETL by Dec. 18, 2000.

November 2000 –

The month of November saw a lot of progress and a few setbacks. The synchronous generator/motor from AVK arrived as expected. Alturdyne began constructing the final skid assembly. The evaporator and condenser were mounted into the body of the skid, but that was the extent of the progress. The skid assembly was expected to be 90 % completed by the end of the month, but delays in parts delivery as well as assembly problems with the skid lowered the completion level to approximately 70 %.

The GTI Project Manager associated with this project, Mr. Gary Nowakowski, resigned from the company at the end of November. Mr. Todd Kollross has assumed responsibility for this project.

December 2000 –

During this month, much progress was made on the completion of the first phase of this project. All of the needed components were delivered to Alturdyne prior to December 1, 2000. The construction of the skid assembly remained the main focus of the project.

A status meeting was held on December 6, 2000 at Alturdyne's headquarters in San Diego, California. The main purpose of this meeting was to assess the progress on the construction of the Hybrid Gas/Electric Chiller and Emergency Generator project. It was determined that construction of the skid was approximately 85 % completed. The structural steel enveloping the evaporator and condenser had been welded in place and was awaiting final paint. The major rotating components (compressor, motor and engine) of the system had been installed.

95 % of the controls were completed and was ready for direct wiring onto the skid.

Tasks which needed to be completed in January included: finishing clutch housing construction, installation of clutches, final wiring, functional testing, painting, shakedown runs of engine, uncoupled motor runs, final piping installation and pressure check of refrigerant.

January 2001 –

A status meeting was held on January 23 at Alturdyne's headquarters in San Diego. The meeting concentrated on the construction progress made on the hybrid unit since last month. The shakedown runs were delayed due to the late arrival of the coupling connecting the synchronous generator and the engine. The coupling was received and installed by January 29. Phase 1 is scheduled to be completed by March 31, 2001.

Functional testing was also concentrated upon this month. After discussing the feasibility and available time frames with Intertek (formerly ETL in Courtland, NY), it was determined that many of the functional tests will be performed at Alturdyne's manufacturing facility in San Diego. Intertek was unable to test the unit at their Courtland, NY facility until July 2001, due to a large backlog of work. Intertek was interested and actually preferred to perform the final functional tests of the entire assembly at the installation station. The onsite testing they perform would include the Standard Chiller Safety and Performance test in accordance with ARI Standard 550.

Testing at Alturdyne was scheduled to begin the week of February 12, 2001 and to be completed by March 9, 2001.

Skid wiring was completed as was piping and refrigerant pressure tests.

The budget amount spent to date is $ 360,019.08. This amount includes GTI labor as well as all subcontracted support.

February 2001 –

The month of February was spent testing the unit at Alturdyne's facilities in San Diego and preparing the Phase 1 Report. Uncoupled motor runs took place on Feb. 6. As of the end of February, 100 % of the Phase 1 budget had been spent. Although cost overruns are expected, GTI will incur these overruns.

March 2001 –

During the month of March, the unit was tested by Alturdyne. Since it was not possible to load the chillers during these tests, chiller testing (involving loading) will occur during the field tests.

In addition to the factory performance testing, the Phase One Final Report was written.

Appendix F

Test Data

FACTORY TEST PROCEDURE

FOR

ENGINE DRIVEN HYBRID CHILLERS

NOTE

Procedure is for chillers using R-134a as a refrigerant,
General Motors engine, and Alturdyne Microprocessor controls

PREPARED BY David LeCren Date 3/16/01
David LeCren

APPROVED BY ____________________ Date _______
Frank Verbeke

TABLE OF CONTENTS

PROCEDURE

1.0 SCOPE

This procedure describes the steps necessary to factory test an assembled hybrid chiller. The procedure is written for a WW (watercooled condenser, water chilling evaporator) packaged unit. It is also applicable to AW, EW or AA units.

The procedure is applicable to units using R-134 as a refrigerant and Alturdyne Microprocessor controls.

2.0 EQUIPMENT AND SUPPLIES

a. Certified oxygen-free gaseous nitrogen in pressure bottle

b. Inert gas pressure regulator with bottle and outlet gages

c. Vacuum gage with 0-29.99 in Hg range and 0.5 in Hg accuracy

d. Vacuum pump capable of 25 microns or better ultimate vacuum, and 3 cfm minimum air displacement (5 cfm preferred)

e. Vacuum pump oil

f. Manometer capable of resolving 6-8 inches of water with an accuracy of .2 inches of water

g. Refrigeration gages with four valve manifold and hoses

h. Thermocouple thermometer capable of 1°F accuracy at 40°F

i. Digital multimeter with frequency counter (separate tachometer OK) with Probes.

j. Heavy-duty, low silicate, ethylene glycol-based antifreeze. See Table I in Appendix B for quantities.

k. Supplemental coolant additive and test kit. Caterpillar NALCO 3000 suggested.

l. Distilled or de-ionized water. Quantity equal to antifreeze.

m. Natural Gas Engine Oil (SAE 40). Engine is shipped filled with oil. Provide enough to fill 30 or 55 gallon reservoir included with chiller. Specification is TBN 4-6, sulfated ash less than 0.49%. Recommend Caterpillar NGO or Mobil Pegasus 80.

n. Refrigeration oil suitable for R-22 service

o. Tools to measure alignment of engine and compressor, and correct as necessary

p. Shims for re-alignment of engine and compressor

q. Load Bank.

r. Commercial Power source to Match Motor Voltage.

3.0 PROCEDURE

3.1 RECORD PRODUCT DATA

Record data in Section 1 of Appendix E

3.2 STATIC TEST

3.2.1 GENERATOR STATIC TEST

3.2.1.1 Set controls to Digital Inputs.

3.2.1.2 Connect Terminal #1 and Terminal #2 and verify that the controller correctly reads inputs.

	Terminal #1	Terminal #2
Chilled Water Freeze	TB103-1	TB103-2
Chilled Water Flow	TB103-3	TB103-2
High Coolant Temp	S307-WK	GND
Over Voltage	MT101-17	MT101-18
Under Voltage	MT101-19	MT101-20
Over Current	MT101-24	MT101-25

3.2.1.3 Drain Coolant and verify that the controller correctly reads inputs.

3.2.1.4 Trigger Low oil level and verify that the controller correctly reads inputs.

3.2.1.5 Disconnect Magnetic Pickup and verify that the controller correctly reads inputs.

3.2.1.6 Set Generator Magnetic Pickup frequency to 441 Hz and verify 92% Input.

3.2.1.7 Set Generator Magnetic Pickup frequency to 480 Hz and verify 100% input.

3.2.1.8 Connect frequency generator to Engine Magnetic Pickup input and set to 50 Hz.

3.2.1.9 Connect frequency generator to Generator Magnetic Pickup input and set to 5 Hz.

3.2.1.10 Disable fuel solenoid and Engine starter.

3.2.1.11 Crank Engine in MAN/GEN.

3.2.1.12 Verify and record the time of the three crank cycles and 2 wait cycles.

3.2.1.13 Verify Over crank.

3.2.1.14 Set Engine Magnetic Pickup frequency to 5040 Hz and Gen Magnetic Pickup frequency to 480 Hz.

3.2.1.15 Crank Engine in MAN/GEN and verify Low Oil Pressure.

3.2.1.16 Reset Engine Alarm timer to 30 sec.

3.2.1.17 Increase Engine Magnetic Pickup frequency to 5330 Hz, crank engine and verify Over Speed and Over speed warning.

3.2.1.15 Set Engine Magnetic Pickup frequency to 5465 Hz, crank engine and verify Critical Over Speed.

3.2.1.16 Reset Engine Magnetic Pickup frequency to 5040 Hz, crank engine, ground High Coolant Temp and verify High Coolant Temp shutdown.

3.2.1.17 Crank engine, push Emergency Stop and verify Emergency Stop.

3.2.1.18 Crank engine, lower coolant level and verify Low Coolant Level shutdown.

3.2.1.19 Crank engine, trip oil level switch and verify Low Oil Level shutdown.

3.2.1.20 Decrease Engine Magnetic Pickup to 4760 Hz, crank engine and verify Engine Under speed and Under speed warning.

3.2.1.21 Crank engine and verify that the engine clutch is engaged.

3.2.1.22 Crank engine, short high voltage input and verify High Voltage shutdown.

3.2.1.23 Crank engine, short low voltage input and verify Low Voltage shutdown.

3.2.1.24 Crank engine, short high current input and verify High Current shutdown.

3.2.1.25 Crank engine, reduce generator speed to below 95% and verify Engine Clutch engage failure.

3.2.2 GAS CHILLER STATIC TEST

3.2.2.1 Verify Chilled water, Condessor water, and Compressor Temperatures.

3.2.2.2 Connect three pressure regulators to dry nitrogen bottle and connect to suction pressure, discharge pressure, and compressor oil pressure.

3.2.2.3 Set Suction pressure to 65 psi.

3.2.2.4 Set Discharge pressure to 100 psi.

3.2.2.5 Set Compressor Oil pressure to 90 psi.

3.2.2.6 Set Engine Magnetic Pickup frequency to 5040 Hz, crank engine in GAS/MAN, short Chilled Water Freeze switch and verify Chilled Water Freeze shutdown.

3.2.2.7 Crank engine in GAS/MAN, short Chilled Water No-Flow and verify Chilled Water No-Flow shutdown.

3.2.2.8 Crank engine in GAS/MAN, set Suction Pressure to 54 psi and verify Low Suction Pressure shutdown.

3.2.2.9 Crank engine in GAS/MAN, set Discharge pressure to 276 psi and verify High Discharge pressure shutdown.

3.2.2.10 Crank engine in GAS/MAN, set Compressor Oil pressure to 10 psi above suction pressure and verify Low Compressor Oil pressure shutdown.

3.3.10.7 Verify that the pressure has dropped below .002 inches of mercury (50 microns) absolute. Shut the vacuum pump valve, turn off the pump. Backseat the compressor inlet and discharge valves.

3.3.10.8 Check the moisture and liquid indicator(s). It should be green, indicating no moisture in the system. If it indicates yellow for moisture present, note this for possible replacement.

3.3.10.9 Connect the nitrogen bottle to the access valve at the filter/drier and fill the system with 2-5 psig of dry nitrogen.

3.3.10.10 Recheck the moisture and liquid indicator(s). If it still indicates yellow for moisture present, replace it and repeat the evacuation process from the beginning.

3.3.10.11 Isolate the filter/drier housing by manually closing the solenoid valves and closing the King valve (angle valve at outlet of condenser)

*3.3.10.12 Open the access valve on the filter/drier, equalize the pressure, then unbolt the flange. Check the flange gasket for damage and replace it if necessary (there is a fresh gasket in the can with each filter/drier element). Install the elements and re-bolt the flange.

Open the access valve on the filter/drier, then manually open the solenoid valves and the King valve to purge the filter drier.

A listing of the required filter/drier elements is provided in Appendix A, Table II.

3.3.10.13 Repeat 3.1.3.1 and 3.1.3.2.

3.3.10.14 Verify that all valves internal to the system are opened (see paragraph 3.1.3.3)

3.3.10.15 Verify that the vacuum pump is full of clean vacuum pump oil, open ballast valve, start pump, and open access valve on filter/drier (close ballast valve at .04-.08 in of Hg).

3.3.10.16 Pump system down to .004 inches of mercury (100 microns) absolute pressure minimum. Close access valve on filter/drier and valve on vacuum pump. Turn off vacuum pump.

3.3.10.17 Connect R-~~22~~ 134A cylinder to access valve at filter/drier. Open access valve, then "Liquid" valve on R-~~22~~ cylinder. Let vacuum draw R-~~22~~ into system. When first cylinder is empty, change cylinders and repeat until system is full or vacuum will draw no more liquid into the system. Close bottle and access valves, but leave attached during startup.

---

* Sometimes the solenoid valve will leak slightly. If so provide some makeup nitrogen through the expansion valve reference line access valve(s) so there will be enough nitrogen left in the system to purge the filter/drier. Only about a 2 psig residual pressure is necessary.

3.4 PRELIMINARY TESTING
Record following steps in section IV

3.4.1 Connect power to Water Jacket Heater (If so equiped).

3.4.2 Connect power to Engine Oil Heater (If so equiped).

3.4.3 Connect power to Battery Heater (If so equiped).

3.4.4 Set Engine and Generator magnetic pickup. (Bottom out on tooth and back out ¼ turn).

3.4.5 Measure Control current draw.

3.4.6 Measure Field resistance.

3.5 INITIAL ENGINE START_UP
Record following steps in Section V

3.5.1 Disable voltage regulator.

3.5.2 Open all AC Breakers.

3.5.3 Disable Fuel.

3.5.4 Disable Engine Clutch.

3.5.5 Crank Engine in MAN/GEN and verify Engine Oil Pressure.

3.5.6 Enable Fuel.

3.5.7 Disconnect ILS Connection on Barber Coleman.

3.5.8 Crank Engine in MAN/GEN.

3.5.9 Set Governor to 1100 RPM.

3.5.10 Shutdown engine.

3.5.11 Re-connnect ILS Connection on Barber Coleman.

3.5.12 Start Engine in MAN/GEN Mode.

3.5.13 Set Governor to 1800 RPM.

3.5.14 Stop Engine.

3.5.15 Enable Engine Clutch.

3.6 GENERATOR START-UP
Record following steps in Section VI

3.6.1 Start engine in MAN/GEN.

3.6.2 Record Residual Voltage.

3.6.3 Stop engine.

M. Decrease Generator voltage to < 187 VAC and verify Under Voltage.

N. Increase Compressor Oil Pressure to 0-5 psi above suction pressure and verify Comp Clutch Dis-engage fail.

3.8.2 Start Chiller in MAN/GAS with coupling disconnected.

A. Lower pressure at suction pressure transducer to < 45 Psi and verify Low Suction Pressure.

B. Connect Dry nitrogen bottle to Discharge Pressure Transducer. Set pressure regulator to > 275 Psi and verify High Discharge Pressure.

C. Bleed Pressure from Compressor Oil Pressure sender to > 5 and < 12 and verify Low Compressor Oil Pressure.

D. Open Jumper on Chilled Water Flow Switch and verify Chilled Water No-Flow.

E. Bleed Pressure from Compressor Oil Pressure to 0-5 Psi and verify Compressor Clutch engage Fail.

3.8.3 Start Chiller in MAN/ELEC with coupling disconnected.

A. Connect Ocsilator to engine magnetic pickup and set to 500 Hz and verify Engine Clutch Dis-Engage Fail.

3.9 Minor Malfunctions Verification.

3.9.1 Start Generator in MAN/GEN and verify the following minor alarms. Reset Generator and restart for next alarm.

A. Manually increase speed at Mixer to 1900 rpm and verify Over speed warning.

B. Manually decrease speed at Mixer to 1750 RPM and verify Under speed warning.

3.9.2 Start Chiller in MAN/GAS and verify the following minor alarms.

A. Decrease Suction Pressure to < Low Suction Pressure Warning level and verify Low Suction Pressure Warning.

B. Set Discharge Pressure to > High Discharge Pressure Warning Level and verify High Discharge Pressure Warning.

C. Decrease Low Oil Pressure to < 20 Psi and verify Low Oil Pressure Warning.

3.10 Verification ot Auto Start.

3.10.1 Set Controls to AUTO/OFF and Short Auto Start Contacts. Verify Generator Start.

3.11 Generator Cold Start. Start Generator after Unit has set for more than 10 Hours and record information in Section X.

3.12 Generator Heat Run.

3.12.1 Connect Load Bank to Generator Output.

3.12.2 Connect Instrumentation to Generator.

3.12.3 Start Unit and Let Warmup for 2 Minutes.

3.12.4 Apply 100% load to Generator.

3.12.5 Take data every 15 Min.

3.12.6 Record Data in Section XI.

3.13 Perform Hot Start Test and record data in Section XIII.

3.14 Perform Transient Response Data and record data in Section XIV.

3.15 Perform Cool Down, Maximum Load Verification and record data in Section XV.

APPENDIX A

TABLE I

Approximate R-22 Load by Model
(Use "Nominal" Charge for Loading)

MODEL NUMBER	MINIMUM CHARGE (lb)	NOMINAL CHARGE (lb)	MAXIMUM CHARGE (lb)
WW030	15.1	56.0	74.0
WW050	23.0	90.0	119.4
WW080	39.3	155.0	204.8
WW100	53.0	200.0	263.4
WW120	56.2	195.0	254.7
WW150	71.6	255.0	334.5
***WW200**	106.0	400.0	526.8
***WW240**	112.4	390.0	509.4
***WW300**	143.2	510.0	669.0

* Dual units, charge is divided equally between the two refrigerant loops.

APPENDIX A

TABLE II

Filter/Drier Elements by Model Number

MODEL	QUANTITY	SPORLAN PART NUMBER
AW030/WW030	1	RC-4864
AW045/WW050	2	RC-4864
AW070/WW080	4	RC-4864
WW100	4	RC-4864
AW100/WW120	4	RC-10098
AW130/WW150	4	RC-10098

APPENDIX B

TABLE I

Anti-Freeze Requirement by Model Number

MODEL NUMBER	ANTI-FREEZE (gallons)
WW030	1.0
WW050	1.5
WW080	2.5
WW100	2.5
WW120	3.0
WW150	3.0
***WW200**	5.0
***WW240**	6.0
***WW300**	6.0

* Dual units, divide equally between two engines.

APPENDIX B

TABLE II
Cooling Water Flows and Pressure Drops by Model Number

MODEL NUMBER	CONDENSER (85°F in/-95°F out)		ENGINE Hx (85°F in/-95°F out)		OIL COOLER (85°F in/-95°F out)	
	FLOW (gpm)	PRESS DROP (psi)	FLOW (gpm)	PRESS DROP (psi)	FLOW (gpm)	PRESS DROP (psi)
WW030	86	3.1	20	0.9	--	--
WW050	144	3.4	31	1.4	4	**
WW080	214	4.5	45	1.4	--	--
WW100	296	1.6	59	1.8	4	**
WW120	365	1.8	68	2.1	--	--
WW150	425	2.8	88	3.3	6	**
*WW200	588	1.6	118	1.8	8	**
*WW240	738	1.8	117	1.8	--	--
*WW300	857	2.9	142	2.6	12	**

* Dual units, divide between two engine-compressor modules.
** Not currently available.

APPENDIX B

TABLE III

Chilled Water Flow and Pressure Drop by Model Number

MODEL NUMBER	FLOW (gpm)	PRESSURE DROP (psi)	INLET TEMP (°F)	OUTLET TEMP (°F)
WW030	68	4.2	55	45
WW050	114	2.5	55	45
WW080	180	4.5	55	45
WW100	226	6.6	55	45
WW120	274	5.5	55	45
WW150	338	5.0	55	45
WW200	449	7.2	55	45
WW240	554	4.4	55	45
WW300	682	4.6	55	45

APPENDIX C

TABLE I

Frequency vs. RPM by Model Number

Engines: GM881 Models: WW100	
RPM	FREQUENCY (Hz)
500	1400
700	1960
900	2520
1050	2940
1080	3024
1100	3080
1120	3136
1150	3220
1200	3360
1300	3640
1400	3920
1500	4200
1600	4480
1700	4780
1750	4900
1780	4984
1800	5040
1820	5096
1850	5180
1900	5320

APPENDIX C

TABLE II

R-134a Pressure vs. Temperature

Pressure, psi	Temperature, F	Pressure, psi	Temperature, F
15 inHg	-40	110	93
10 inHg	-30	120	98
5 inHg	-22	130	103
0	-15	140	107
5	-3	150	112
10	7	165	118
15	15	180	123
20	22	195	129
25	29	210	134
30	35	225	139
35	40	240	143
40	45	255	148
45	50	270	152
50	54	285	156
55	58	300	160
60	62		
65	66		
70	69		
75	73		
80	76		
85	79		
90	82		
95	85		
100	88		

APPENDIX D

TABLE I
Pressure Look-Up Table

psi	in. of H_2O	in. of Hg	mm of H_2O	mm of Hg
0.1	2.768	0.2036	70.31	5.171
0.2	5.536	0.4072	140.62	10.342
0.3	8.304	0.6108	210.93	15.513
0.4	11.072	0.8144	281.24	20.684
0.5	13.84	1.018	351.55	25.855
0.6	16.608	1.2216	421.86	31.026
0.7	19.376	1.4252	492.17	36.197
0.8	22.144	1.6288	562.48	41.368
0.9	24.912	1.8324	632.79	46.539
1	27.68	2.036	703.1	51.71
2	55.36	4.072	1406.2	103.42
3	83.04	6.108	2109.3	155.13
4	110.72	8.144	2812.4	206.84
5	138.4	10.18	3515.5	258.55
6	166.08	12.216	4218.6	310.26
7	193.76	14.252	4921.7	361.97
8	221.44	16.288	5624.8	413.68
9	249.12	18.324	6327.9	465.39
10	276.8	20.36	7031	517.1
14.7	406.896	29.9292	10335.57	760.137
15	415.2	30.54	10546.5	775.65
20	553.6	40.72	14062	1034.2
25	692	50.9	17577.5	1292.75
30	830.4	61.08	21093	1551.3
40	1107.2	81.44	28124	2068.4
50	1384	101.8	35155	2585.5
100	2768	203.6	70310	5171
150	4152	305.4	105465	7756.5
200	5536	407.2	140620	10342
250	6920	509	175775	12927.5
300	8304	610.8	210930	15513
350	9688	812.6	246085	18098.5
400	11072	814.4	281240	20684
450	12456	916.2	316395	23269.5
500	13840	1018	351550	25855

psi	mbar	microns	Pascals	lb/ft^2
0.1	6.895	5.172E+03	6.895E+02	14.4
0.2	13.79	1.034E+04	1.379E+03	28.8
0.3	20.685	1.551E+04	2.069E+03	43.2
0.4	27.58	2.069E+04	2.758E+03	57.6
0.5	34.475	2.586E+04	3.448E+03	72
0.6	41.37	3.103E+04	4.137E+03	86.4
0.7	48.265	3.620E+04	4.827E+03	100.8
0.8	55.16	4.137E+04	5.516E+03	115.2
0.9	62.055	4.654E+04	6.206E+03	129.6
1	68.95	5.172E+04	6.895E+03	144
2	137.9	1.034E+05	1.379E+04	288
3	206.85	1.551E+05	2.069E+04	432
4	275.8	2.069E+05	2.758E+04	576
5	344.75	2.586E+05	3.448E+04	720
6	413.7	3.103E+05	4.137E+04	864
7	482.65	3.620E+05	4.827E+04	1008
8	551.6	4.137E+05	5.516E+04	1152
9	620.55	4.654E+05	6.206E+04	1296
10	689.5	5.172E+05	6.895E+04	1440
14.7	1013.565	7.602E+05	1.014E+05	2116.8
15	1034.25	7.757E+05	1.034E+05	2160
20	1379	1.034E+06	1.379E+05	2880
25	1723.75	1.293E+06	1.724E+05	3600
30	2068.5	1.551E+06	2.069E+05	4320
40	2758	2.069E+06	2.758E+05	5760
50	3447.5	2.586E+06	3.448E+05	7200
100	6895	5.172E+06	6.895E+05	14400
150	10342.5	7.757E+06	1.034E+06	21600
200	13790	1.034E+07	1.379E+06	28800
250	17237.5	1.293E+07	1.724E+06	36000
300	20685	1.551E+07	2.069E+06	43200
350	24132.5	1.810E+07	2.413E+06	50400
400	27580	2.069E+07	2.758E+06	57600
450	31027.5	2.327E+07	3.103E+06	64800
500	34475	2.586E+07	3.448E+06	72000

AP ENDIX E

STATIC CHECK-OFF SHEET

Alarm	Input			Setting	Warning			Setting	
	Gen	Gas Chiller	Elec Chiller		Gen	Gas Chiller	Elec Chiller		Shutdown
Chilled Water Freeze	✓		NA						✓
Low Coolant Level	✓		NA						✓
Chilled Water Flow	✓		NA						✓
Low Engine Oil Pressure	✓	✓	NA						✓
High Engine Coolant Temp	✓		NA						✓
Over Voltage	✓		NA						✓
Under Voltage	✓		NA						✓
Over Current	✓		NA						✓
92% Motor Speed	✓								
100% Motor Speed	✓								
Under Speed	✓			1750 RPM 4925 Hz	✓	NA	NA	1700 RPM 4925 Hz	✓
Over Speed	✓			1850 RPM 5176 Hz	✓	NA	NA	1900 RPM 5321 Hz	✓
Critical Over Speed	✓		✓					1950 RPM 5469 Hz	✓
Emergency Stop	✓								✓
Engine Clutch Engage Fail	✓								
Engine Clutch Dis-engage Fail									
Low Suction Pressure		✓							
High Discharge Pressure									
Low Comp Oil Pressure		✓							

		Digital Inputs		Setting		Warning		Setting	Shutdown
	Gen	Gas Chiller	Elec Chiller		Gen	Gas Chiller	Elec Chiller		
Comp Clutch Engage Fail									
Comp Clutch Dis-engage Fail									
Motor Over Current									
Low Comp Oil Temp									

CRANK CYCLES

Crank			Wait		
1	12	Sec	1	12	Sec
2	12	Sec	2	12	Sec
3	12	Sec			

ANALOG INPUTS

Input		
Chilled Water Inlet Temp	63	Deg F
Chilled Water Outlet Temp	62	Deg F
Suction Temp	63	Deg F
Discharge Temp	64	Deg F
Condenser Water Inlet Temp	63	Deg F
Condenser Water Outlet Temp	63	Deg F
Compressor Oil Sump Temp	64	Deg F
Chilled Water Flow	NA	GPM
Suction Pressure	21	Psi
Discharge Pressure	21	Psi
Compressor Oil Pressure	~~21~~ 0	Psi
Kilowatt	-112	KW
Oil Pressure	-2	Psi
Water Temperature	92	Deg F
Generator Speed	0	RPM
Engine Speed	0	RPM

APPENDIX F

SATEC PM290 SETUP PROCEDURE

1. Power Satec Module with drop cord to terminal 13 and terminal 14.
2. Press **SELECT** key to put it in Definition Mode.
3. Use the UP/DOWN ARROW keys to select CnF and set 4L-n.

	VOLTAGE		CURRENT		POWER FACTOR		APPARENT POWER
1		4		7		10	
	VOLTAGE		CURRENT		ACTIVE POWER		FREQUENCY
2	CnF	5		8	4L-n	11	
	VOLTAGE		CURRENT		CONSUMPTION		
3		6		9			

4. Select Pt. And set 1.0

	VOLTAGE		CURRENT		POWER FACTOR		APPARENT POWER
1		4		7		10	
	VOLTAGE		CURRENT		ACTIVE POWER		FREQUENCY
2	Pt.	5		8	1.0	11	
	VOLTAGE		CURRENT		CONSUMPTION		
3		6		9			

5. Select Ct. And set 300.

	VOLTAGE		CURRENT		POWER FACTOR		APPARENT POWER
1		4		7		10	
	VOLTAGE		CURRENT		ACTIVE POWER		FREQUENCY
2	Ct.	5		8	300	11	
	VOLTAGE		CURRENT		CONSUMPTION		
3		6		9			

6. To choose set points, follow the RELAY ENTER sequence below.

7. Once in the Definition Mode, scroll to the desired relay by using the UP/DOWN Arrow keys. When the dewired relay is reached, the relay number will be displayed in Window 2. At the stage, the relay number will be followed by a decimal point.

8. Press the SELECT key again so that the decimal point following the relay number disapears, 'On' will appear in Window 5. The High Voltage set point value (or dots) will remain and all other values will disapear. This will allow the user to change or set High Voltage ON relay value.

9. Set High Voltage at 229 on relay #1.

	High Voltage		High Current		Low Power Factor		High Apparent Power
1	229	4		7		10	
					High Accumulated Max Demand		High Unbalanced Current
2	1	5	ON	8		11	
	Low Voltage				Pulsing/ High reacitve Power		
3		6		9			

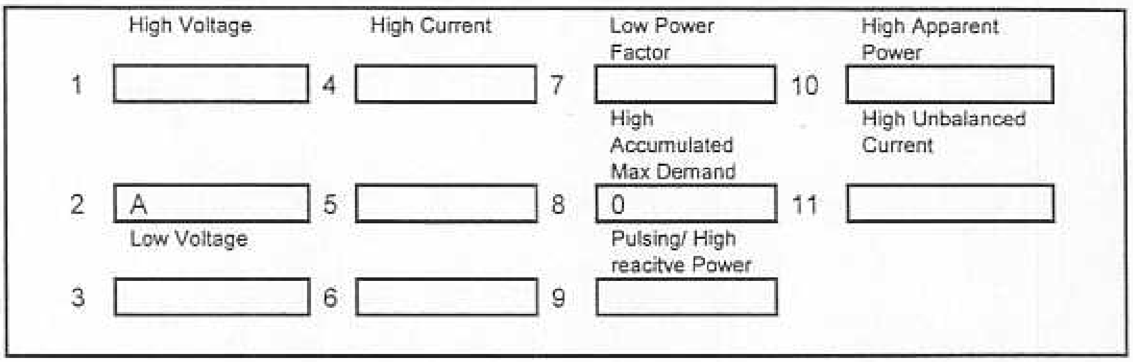
9. Set Low Voltage at 187 on relay #2.

	High Voltage		High Current		Low Power Factor		High Apparent Power
1		4		7		10	
					High Accumulated Max Demand		High Unbalanced Current
2	2	5	ON	8		11	
	Low Voltage				Pulsing/ High reacitve Power		
3	187	6		9			

10. Set High Current at 300 amps on relay #4.

	High Voltage		High Current		Low Power Factor		High Apparent Power
1		4	300	7		10	
					High Accumulated Max Demand		High Unbalanced Current
2	4	5	ON	8		11	
	Low Voltage				Pulsing/ High reacitve Power		
3		6		9			

11 Set Analog Output Channel. Use Select to enter configuration mode. Use Up/Down Arrows to get an A in window 2 which represents the Analog Output Parameter. Press the Select Button to make the decimal after the A disappear. Use arrow keys to get blinking Dots in box 8. Use select key to get a 0 in box 8. Press Energy Reset to enter parameter.



APPENDIX G

DATA SHEET - TEST REQUIREMENTS

NATURAL GAS ENGINE/GENERATOR SET

PACKAGE DATA
(PROJECT ENGINEER)

SERIAL (JOB) No.: 2462 AC/DC SCHEMATIC: 21324

CUSTOMER: GTI AC/DC WIRING DIAGRAM: 21325

CUST. JOBSITE: ______ REMOTE ANNUNCIATOR PANEL: N/A

CONTRACT (PO) No: ______ ______

PROJECT ENGINEER: DAVID LECREW

GENERATOR RATING

MODEL NUMBER: ______

VAC 120/208 kW 75 PHASE 3 AMPS 208

PF .8 CONFIGURATION 4W Hz 60Hz KVA 94

CONTROL VOLTAGE 24 VDC SYSTEM LOGIC X 2 WIRE LOGIC
______ 12 WIRE LOGIC

MOTOR RATING

VAC 120/208 HP 100 PHASE 3 AMPS 280

COMPRESSOR RATING

TONAGE 100 REFRIGERENT R134A

TEST REQUIREMENTS

25%	18.7	kW	1	PF	52	AMPS	.25	HOURS (.25 NOM)
50%	37.5	kW	1	PF	104	AMPS	.25	HOURS (.25 NOM)
75%	56.25	kW	1	PF	156	AMPS	.25	HOURS (.25 NOM)
100%	75	kW	1	PF	208	AMPS	.25	HOURS (.25 NOM)
110%	NA	kW		PF		AMPS		HOURS (1.0 NOM)
OTHER	NA	kW		PF		AMPS		HOURS

USING CHART RECORDER: RECORD TRANSIENT VOLTAGE AND FREQUENCY RESPONSES FOR EACH LOAD CHANGE REFLECTED, AND FOR DURATION OF HEAT RUN.

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APPENDIX G

DATA SHEET - TEST REQUIREMENTS

NATURAL GAS ENGINE/GENERATOR SET

PACKAGE DATA
(PROJECT ENGINEER)

SERIAL (JOB) No.: 2462 AC/DC SCHEMATIC: Z1324

CUSTOMER: ______ AC/DC WIRING DIAGRAM: Z1325

CUST. JOBSITE: ______ REMOTE ANNUNCIATOR PANEL: NA

CONTRACT (PO) No: ______ ______

PROJECT ENGINEER: David LeCren ______

GENERATOR RATING

MODEL NUMBER: ______

VAC 120/208 kW 75 PHASE 3 AMPS 208

PF .8 CONFIGURATION 4W Hz 60 KVA 94

CONTROL VOLTAGE 24 VDC SYSTEM LOGIC ✓ 2 WIRE LOGIC
______ 12 WIRE LOGIC

MOTOR RATING

VAC 120/208 HP 100 PHASE 3 AMPS 286

COMPRESSOR RATING

TONAGE 100 REFRIGERENT R134A

TEST REQUIREMENTS

25%	______	kW	______	PF	______	AMPS	______	HOURS (.25 NOM)
50%	______	kW	______	PF	______	AMPS	______	HOURS (.25 NOM)
75%	______	kW	______	PF	______	AMPS	______	HOURS (.25 NOM)
100%	75	kW	1	PF	209	AMPS	1	HOURS (.25 NOM)
110%	______	kW	______	PF	______	AMPS	______	HOURS (1.0 NOM)
OTHER	______	kW	______	PF	______	AMPS	______	HOURS

USING CHART RECORDER: RECORD TRANSIENT VOLTAGE AND FREQUENCY RESPONSES FOR EACH LOAD CHANGE REFLECTED, AND FOR DURATION OF HEAT RUN.

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SPECIAL INSTRUCTIONS

1. WITNESS TEST REQUIRED: YES______ DATE_____ NO_______

2. EQUIPMENT ACCESSORIES:

A. WATER JACKET HEATER:	YES_____	NO X
B. OIL HEATER:	YES_____	NO X
C. REMOTE PANEL:	YES_____	NO X
D. BATTERY CHARGER:	YES X	NO_____
E. AUXILIARY LOAD BANK:	YES_____	NO X
F. SHUNT TRIP:	YES_____	NO X
G. AIR BOX SHUTDOWN:	YES_____	NO_____
J. ________________	YES_____	NO_____
K. ________________	YES_____	NO_____
L. ________________	YES_____	NO_____
M. ________________	YES_____	NO_____

3. SPECIAL INSTRUCTIONS:

________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________
________________________________ (TECH)________

[signature]
PROJECT ENGINEER

3/1/2001
DATE RELEASED

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SECTION 1

PRODUCT DATA

TEST TECH David Delica DAL QA STAMP/INITIAL
NAME

	MFG	MODEL	SN
ENGINE	GM	GMG 891	0757 110 8800
GENERATOR	AVK	DSU 43M1-4	6423999A001
COMPRESSOR	CARRIER	5H126-399	1800 J00177
GOVERNOR ACTUATOR	BARBER Coleman	DYNC-10502-24	30040432
GOVERNOR CONTROLLER	BARBER Coleman	DYN1-10754-24	501F355
BATTERY CHARGER	Charles	43-C1241DE	B0041900091EB
REGULATOR	AVK	COSIMAT N+	B0014002-030
PF CONTROLLER	AVK	COS	B0014014-046
CONTROL BOARD	Alturdyne	20932-A	001
ANALOG BOARD 1	Alturdyne	21224-1	002-1
ANALOG BOARD 2	Alturdyne	21224-2	002-2
EVAPORATOR	Ketema	~~1406~~ 1610-S-2P-2C	4001920-101
CONDENSOR	Ketema	1406-2P	4001920-301
ENGINE HEAT EXCHANGER	Ketema	MHT-2-A-CT	40011423-101
TRANSFORMER	OLSun		30902-109458

NOTE: SHOULD ANY COMPONENT FAIL DURING TESTING PROCEDURE, RECORD INITIAL AND FINAL SERIAL NUMBERS BELOW:

COMPONENT FAILURE/REPLACEMENT LOG

ITEM	DESCRIPTION	SN	HOURS	REMARKS	TECH
1.					
2.					
3.					
4.					
5.					

SECTION II

STATIC TEST

THE CONTROL BOX, REMOTE BOX, ENGINE HARNESS, AND ALL OTHER ELECTRICAL SUBASSEMBLIES WERE STATIC CHECKED BY:

DA
TECH

2-27-01
DATE TESTED

SECTION III

ENGINE TEST CELL PREPARATION/INTERCONNECTION

INSTALL LABELED TIE WRAPS ON SWITCHES (LOP, PLOP, HWT, PHWT)			TECH NA
COOLANT (50/50 GLYCOL):	GALLONS	4	TECH BCH
LUBE OIL:	QUARTS	8	TECH DAL
	API SPEC		TECH
	WEIGHT	10w30	TECH DAL
CONT BATTERY (31 SIZE):	VDC	24	TECH DAL
ENGINE BATTERY (31 SIZE):	VDC	12	TECH DAL
FUEL LINES:			TECH DAL
BATTERY CHARGER:			TECH DAL
CONNECT TEST CELL OIL PRESSURE GAUGE:			TECH DAL
CONNECT EXHAUST SYSTEM:	END PRODUCT EQUIPPED		TECH NA
	TEST CELL TEMPORARY		TECH DAL

GENERATOR TEST CELL PREPARATION / INTERCONNECTION

CONNECT TEST CELL LOAD BANK:		TECH DAL
CONNECT STRIP RECORDER:		TECH DAL
CONNECT THERMOCOUPLES: (THESE ARE MINIMUM REQUIRED READINGS)	OIL	TECH DAL
	WATER	TECH DAL
	ALT AIR IN	TECH DAL
	ALT AIR OUT	TECH DAL
	AMBIENT	TECH DAL

MOTOR TEST CELL PREPARATION / INTERCONNECTION

CONNECT COMMERCIAL POWER SOURCE:	TECH DAL
CONNECT STRIP RECORDER:	TECH DAL

SECTION IV

ENGINE PRELIMINARY TESTING

1. CONNECT 208/120 VAC TO WATER JACKET HEATER: AMPS_____ TECH NA
   MODEL__________ SN__________ THERMOSTAT SETTING____ °F
2. WATER HEATER ENG. RUN CUT-OUT CIRCUIT: TECH NA
3. WATER HEATER ELAPSED TIME: ___ HRS TECH NA
   FOR THERMOSTAT TO TURN OFF.
4. WATER HEATER OVERNIGHT TEST: ___> 70° F TECH NA
5. CONNECT 120 VAC TO OIL HEATER: AMPS_____ TECH NA
   MODEL__________ SN__________ THERMOSTAT SETTING____ °F
6. CONNECT 120 VAC TO BATTERY HEATER: AMPS_____ TECH NA
   MODEL__________ SN__________ THERMOSTAT SETTING____ °F
7. ENSURE PROPER ASSEMBLY OF MAGNETIC PICK-UP (BOTTOM ON TOOTH/BACK 1/4 TURN .010"). TECH DAC
8. CONTROL CURRENT DRAW 1 AMPS TECH DAC

GENERATOR PRELIMINARY TESTING

1. MEASURE FIELD RESISTANCE (25 TO 50 OHMS) OHMS 9.5 TECH DAC
2. ENSURE PROPER ASSEMBLY OF MAGNETIC PICK-UP (BOTTOM ON TOOTH/BACK 1/4 TURN .010"). TECH DAC

COMPRESSOR PRELIMINARY TESTING

MOTOR PRELIMINARY TESTING

SECTION V

INITIAL START-UP VERIFICATION

1. DISABLE VOLTAGE REGULATOR — TECH DAL
2. ENSURE ALL AC CIRCUIT BREAKERS ARE OPEN. — TECH DAL
3. PLACE SELECTOR SWITCH IN "MANUAL": CRANK ENGINE: — TECH DAL
   PRIME/BLEED FUEL SYSTEM: — TECH DAL
   SET GOVERNOR: — TECH DAL
   RECORD NO LOAD HERTZ: Hz 60 — TECH DAL
   (ISOC = 60Hz - DROOP = 62.2 Hz)
4. ALLOW ENGINE TO RUN AT RATED SPEED FOR 5 MINUTES — TECH DAL
5. RECORD YOUR METER READING: 60 HOURS — TECH DAL

SECTION VI

AC SET-UP

1. MEASURE AND RECORD RESIDUAL VOLTAGE ON EACH PHASE TO VERIFY PROPER VOLTAGES ARE PRESENT:
(SHOULD BE IN RANGE OF 10 VAC AND 50 VAC).

1Ø VAC: .7 TECH PAC

2Ø VAC: .7 TECH DAC

3Ø VAC: .7 TECH PAC

2. ENABLE VOLTAGE REGULATOR: TECH PAC

3. SET REMOTE (10 TURN) VOLTAGE ADJUST POT TO MID-SCALE POSITION, ADJUST VOLTAGE TO NOMINAL VIA REGULATOR:

RECORD NOMINAL VOLTAGE	208 VAC	TECH PAC
LOW ADJUSTMENT REMOTE POT	185 VAC	TECH PAC
HIGH ADJUSTMENT REMOTE POT	231 VAC	TECH PAC
CALCULATE AND RECORD MAX % ADJUSTMENT	12 %	TECH PAC

SECTION VII

MOTOR START TEST

1. Static test motor starter controls TECH DAC

1. Connect Chart Recorder to Generator Speed Signal at TB105-1,2 and Put 300:5 CT on phase A of Commercial power feed and connect to Chart Recorder.

2. Start Motor by shorting TB1-24 and TB1-25 and verify 480 Hz at Generator Magnetic Pickup

3. Record Time to start and Maximum Current at 60% and 100%

Current 60%	900	TECH DAC
Current 100%	750	TECH DAC
Start Time	1.3 Sec	TECH DAC

4. Record Motor running Voltage, Current, P.F., KW, KVA, FREQ

1.	VOLTAGE	210 VAC	TECH DAC
2.	CURRENT	205 AMP	TECH DAC
3.	KILOWATT	6 KW	TECH DAC
4.	KILOVOLTAMP	73 KVA	TECH DAC
5.	POWER FACTOR	.09	TECH DAC
6.	FREQUENCY	660 Hz	TECH DAC

SECTION VIII

COMPONENT SETTING VERIFICATION

1. ENTER APPROPRIATE DATA:
   A. FLYWHEEL TEETH 168

   B. 100% SPEED 5040 Hz

   C. CRANK DISCONNECT 1008 Hz 20 % SPEED (20%) TECH DAC

   D. CRITICAL OVERSPEED 2040 Hz 113 %SPEED (120%) TECH DAC
   2040 Rpm

   SATEC ALARMS

   E. OVER VOLTAGE 229 VAC 110 %NOM (115%) TECH DAC

   F. UNDER VOLTAGE 187 VAC 90 %NOM (85%) TECH DAC

   G. OVER CURRENT 250 AMP 120 %NOM (125%) TECH DAC

   H. LOW OIL PRESSURE (VDO) 11 PSI TECH DAC

   I. HIGH WATER TEMP 225 Deg F TECH DAC

   J. LOW WATER LEVEL 10 SEC DELAY TECH DAC

   K..Z-WORLD COMPONET SETTINGS

	MALFUNCTION	WARNING	TECH	SHUTDOWN	
	ENGINE				
A	OVERSPEED	1900	DAC	1950	D
B	LOW OIL PRESS	20	DAC	12	D
C	HIGH WATER TEMP	205	DAC	215	D
	GENERATOR				
D	UNDERSPEED	1750	DAC	1700	D
	MOTOR				
E	MOTOR OVER CURRENT	300	DAC	325	D
	COMPRESSOR				
F	LOW SUCTION PRESSURE	28	DAC	23	D
G	HIGH DISCHARGE PRESSURE	225	DAC	250	D
H	LOW COMP OIL PRESSURE	18	DAC	12	D
I	CHILL WATER FREEZE	37	DAC	35	D
J	LOW COMP OIL TEMP	90	DAC	80	D
K	ENGINE STALL	1000	DAC	900	D

L. Z-WORLD TIMER SETTINGS

	TIMER	TIME	UNITS	TECH
A	ENGINE ALARM DELAY	10	SEC	DAC
B	COMPRESSOR ALARM DELAY	10	SEC	DAC
C	ELECTRIC ALARM DELAY	14	SEC	DAC
D	GEN ALARM DELAY	14	SEC	DAC
E	PUMP DOWN TIMER	30	SEC	DAC
F	SUCTION START DELAY	30	SEC	DAC
G	GEN FIELD FLASH	4	SEC	DAC
H	MOTOR GEN ACC DELAY	4	SEC	DAC
I	MOTOR STEP DELAY	1.0	SEC	DAC

M. CHILLER OPERATIONAL SETTINGS

		SETPOINT	UNITS	TECH
A	CHILLED WATER SETPOINT	45	Deg F	DAC
B	CHILLED WATER START SETPOINT	55	Deg F	DAC
C	CHILLED WATER STOP SETPOINT	45	Deg F	DAC
D	PUMP DOWN PRESSURE	~~45~~ 20	PSI	DAC
E	SUCTION START PRESSURE	~~85~~ 55	PSI	DAC

SECTION VIII

MAJOR SAFETY SHUTDOWN/ALARM VERIFICATION

VERIFY AND RECORD ALL APPLICABLE MAJOR SAFETIES AND RELATED FUNCTIONS:

Table 8a.

	MALFUNCTION	PANEL VISUAL	TECH
	GENERATOR MAJOR ALARMS		
A	OVERSPEED	✓	DAC
B	EMERGENCY STOP	✓	DAC
C	OVERCRANK	✓	DAC
D	LOW OIL PRESS (VDO)	✓	DAC
E	LOW OIL PRESS (COMP)	✓	DAC
F	HIGH WATER TEMP (VDO)	✓	DAC
G	HIGH WATER TEMP (COMP)	✓	DAC
H	LOW WATER LEVEL	✓	DAC
I	MAG PICKUP LOSS	✓	DAC
J	ENGINE CLUTCH ENGAGE FAIL	✓	DAC
K	LOW OIL LEVEL	✓	DAC
L	CRITICAL OVERSPEED	✓	DAC
M	UNDERSPEED	✓	DAC
N	OVER VOLTAGE	✓	DAC
O	UNDERVOLTAGE	–	DAC
P	HIGH CURRENT	✓	DAC
Q	COMP CLUTCH DIS-ENGAGE FAIL	✓	DAC

Table 8b.

	ELECTRIC CHILLER MAJOR ALARMS		
A	MOTOR OVER CURRENT		
B	LOW SUCTION PRESSURE	✓	DAC
C	HIGH DISCHARGE PRESSURE	✓	DAC
D	LOW COMP OIL PRESSURE	✓	DAC
E	CHILL WATER FREEZE	✓	DAC
F	CHILL WATER NO FLOW	✓	DAC
G	LOW COMP OIL TEMP	✓	DAC
H	COMP CLUTCH ENGAGE FAIL	✓	DAC
I	ENGINE CLUTCH DIS-ENGAGE FAIL	✓	DAC

Table 8c.

	GAS CHILLER MAJOR ALARMS		
A	OVERSPEED	✓	DAC
B	EMERGENCY STOP	✓	DAC
C	OVERCRANK	✓	DAC
D	LOW OIL PRESS (VDO)	✓	DAC
E	LOW OIL PRESS (COMP)	✓	DAC
F	HIGH WATER TEMP (VDO)	✓	DAC
G	HIGH WATER TEMP (COMP)	✓	DAC
H	LOW WATER LEVEL	✓	DAC
I	MAG PICKUP LOSS	✓	DAC
J	ENGINE CLUTCH ENGAGE FAIL	✓	DAC
K	LOW OIL LEVEL	✓	DAC
L	CRITICAL OVERSPEED	✓	DAC
M	LOW SUCTION PRESSURE	✓	DAC
N	HIGH DISCHARGE PRESSURE	✓	DAC
O	LOW COMP OIL PRESSURE	✓	DAC
P	CHILL WATER FREEZE	✓	DAC
Q	CHILL WATER NO FLOW	✓	DAC
R	LOW COMP OIL TEMP	✓	DAC
S	COMP CLUTCH ENGAGE FAIL	✓	DAC
T	ENGINE CLUTCH DIS-ENGAGE FAIL	✓	DAC
U	ENGINE STALL	✓	DAC

C1. 1st CRK 12 SEC 1st WAIT 12 SEC 2nd CRK 12 SEC 2nd WAIT 12 SEC 3rd CRK 12 SEC ALARM

C2. CRANKING BAT VOLTS 11.1V CRANKING BAT AMPS 200

SECTION IX

MINOR MALFUNCTIONS INDICATION/ALARM VERIFICATION

5. VERIFY AND RECORD ALL APPLICABLE MINOR ALARMS AND RELATED FUNCTIONS:

Table 9a.

	MINOR ALARMS	PANEL VISUAL	TECH
	GENERATOR		
A	PRE OVER SPEED	✓	DAC
B	PRE HIGH COOLANT TEMP	✓	DAC
C	PRE LOW OIL PRESSURE	✓	DAC
D	PRE UNDER SPEED	✓	DAC
	ELECTRIC CHILLER		
E	PRE-HIGH MOTOR CURRENT		
F	PRE-LOW SUCTION PRESSURE	✓	DAC
G	PRE-HIGH DISCHARGE PRESSURE	✓	DAC
H	PRE-LOW COMP OIL PRESSURE	✓	DAC
	GAS CHILLER		
I	PRE-LOW SUCTION PRESSURE	✓	DAC
J	PRE-HIGH DISCHARGE PRESSURE	✓	DAC
K	PRE-LOW COMP OIL PRESSURE	✓	DAC
L	PRE-ENGINE-STALL	✓	DAC
M	PRE HIGH COOLANT TEMP	✓	DAC
N	PRE LOW OIL PRESSURE	✓	DAC
O	PRE UNDER SPEED	✓	DAC

2. VERIFY AND RECORD ALL APPLICABLE CUSTOMER CONNECTIONS FOR:

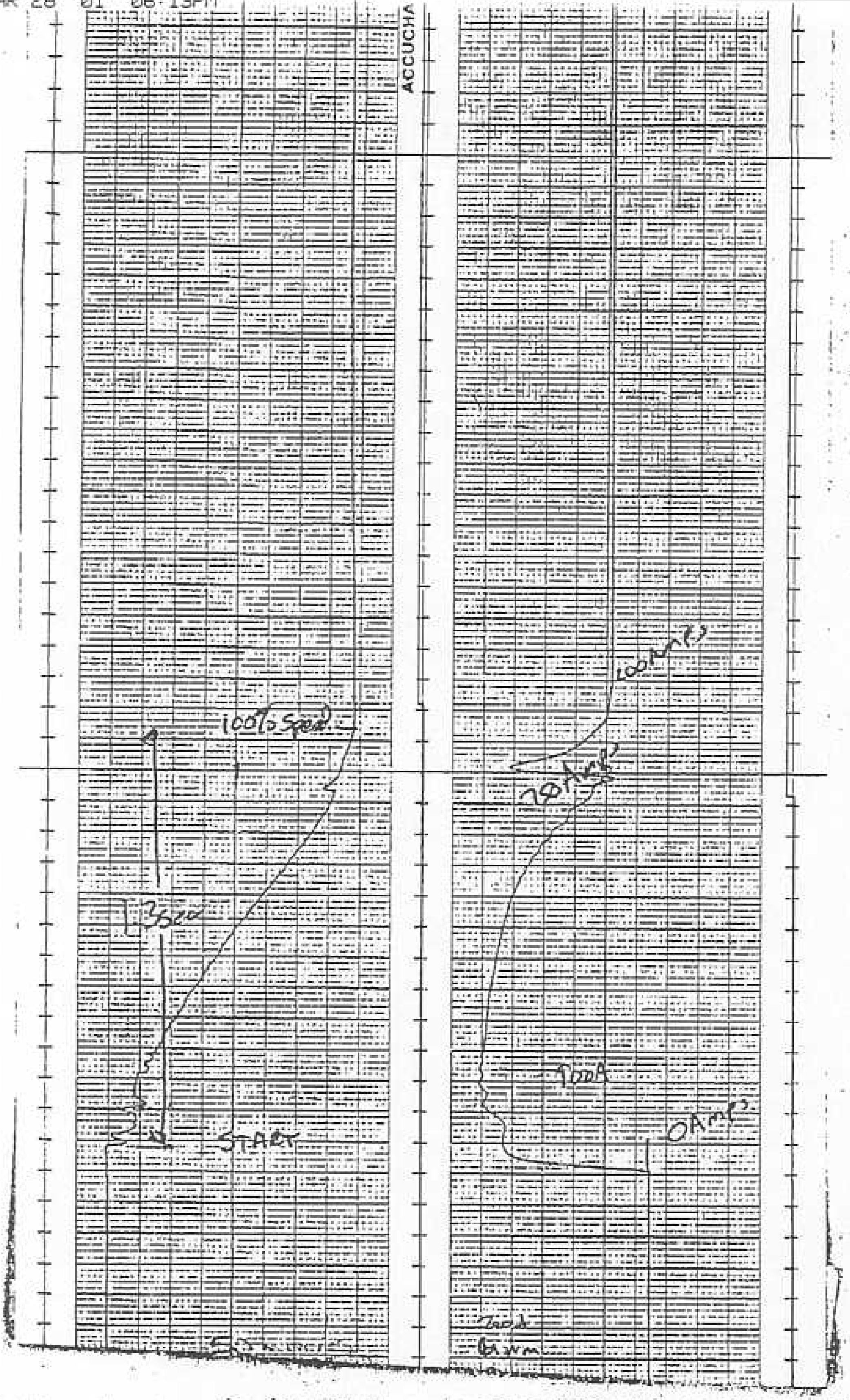
A. AUTO START — TECH DAC

B. ENGINE RUN — TECH NA

C. REMOTE EMERGENCY STOP — TECH NA

D. OTHER__________ — TECH______

E. OTHER__________ — TECH______



Motor Speed   Motor Current

SECTION X

COLD START - FACTORY TEST

1. AFTER SET HAS BEEN AT REST FOR A MINIMUM OF 10 HOURS, THE SYSTEM SHALL BE ENERGIZED AND THE FOLLOWING DATA RECORDED:
   NOTE: ENGINE CONSIDERED COLD WHEN OIL TEMPERATURE IS WITHIN 20 °F OF CURRENT AMBIENT).

   A. THE TIME INTERVAL FROM ENERGIZING THE STARTER MOTOR (STARTER ENGAGEMENT) TO WHEN UNIT REACHES 100% SPEED AT NO LOAD: 5 SEC (15 SEC MAX) TECH DAC

   B. INCLUDE CHART OF COLD START (recorder set for transient response) TECH NA

   C. VIBRATION DATA LOADED ______ (3MILS MAX) UNLOADED ______ (3 MILS MAX)

SECTION XI

HEAT RUN - FACTORY TEST

1. CONNECT, INSPECT, AND ADJUST (AS REQUIRED) APPROPRIATE LOAD BANK: TECH DAC

2. CONNECT, INSPECT, AND ADJUST (AS REQUIRED) APPROPRIATE STRIP CHART RECORDER AND LOG FULL SCALE READINGS ON CHART: TECH DAC

2a. LIST CCN NUMBRS OF ALL TEST EQUIPMENT USED DURING TEST:

a) CHART RECORDER ____________

b) MULTI METER 650

c) AMP CLAMP 693

d) VIBRATION EQUIPMENT ____________

e) SOUND METER ____________

f) OTHER ____________

3. ENERGIZE UNIT STARTING SYSTEM AND ALLOW SET TO RUN (NO LOAD) FOR A MINIMUM OF TWO (2) MINUTES: TECH DAC

4. APPLY 100% OF UNIT RATED LOAD (1.0 PF OR AS STATED), CENTER AND ADJUST STRIP CHART RECORDER FOR STABILITY PERFORMANCE THROUGHOUT HEAT RUN: TECH DAC

5. RECORD STARTING HOUR METER READING: 0.0 HOURS TECH DAC

6. RECORD TEST CELL BAROMETER: 30.1 IN/Hg TECH DAC

7. RECORD TEST CELL HUMIDITY 70 % TECH DAC

8. USING "FACTORY TEST LOG DATA SHEETS" TAKE TEST CELL AND UNIT READINGS AS REQUIRED (NORMAL 15 MINUTE INCREMENTS/2 HOUR DURATION): TECH DAC

9. ALL FACTORY TEST LOG DATA ENTRIES MUST FALL WITHIN THE ACCEPTABLE LIMITS OF INDIVIDUAL COMPONENT SETTINGS (REF SECTION VIII): TECH DAC

10. RECORD ENDING HOUR METER READING: 1.0 HOURS TECH DAC

11. REDUCE UNIT TO NO LOAD CONDITION AND ALLOW UNIT A COOL DOWN CYCLE OF NOT LESS THAN TWO (2) MINUTES:

12. SHUT OFF STRIP CHART RECORDER, VERIFY AND RECORD MAXIMUM EXCURSION FOR FULL 100% LOAD HEAT RUN:

A. FREQUENCY .3 HZ 5 % (± 1/4% MAX) TECH DAC

B. VOLTAGE 6 VAC 0 % (± 2% MAX) TECH DAC

13. VERIFY AND RECORD METER AND GAUGE ACCURACY AT END OF HEAT RUN/100% LOAD: TECH DAC

	TEST CELL	CONTROL PANEL	PERCENT ACCURACY	
AMMETER	207	199	7	(2% MAX)
VOLTMETER	204.6	206	1%	(2% MAX)
FREQUENCY	59.9	59.7	.1	(2% MAX)
KILOWATT	75	74	1%	(2% MAX)
OIL PRESSURE	43	44	2.3%	(5% MAX)
WATER TEMP				(5% MAX)
CONTROL VOLTS			N/A	
CONTROL AMPS			N/A	

SECTION XII

HOT START - FACTORY TEST

A. AFTER SET HAS OPERATED AT FULL LOAD FOR TWO (2) HOURS MINIMUM AND ALL TEMPERATURES HAVE STABILIZED, THE ENGINE SHALL BE SHUT DOWN AND RESTARTED. THE TIME REQUIRED FROM ENERGIZING THE STARTER MOTOR TO WHEN THE SET REACHES 100 PERCENT SPEED AT NO LOAD SHALL BE RECORDED:

12 SEC (10 SEC MAXIMUM) TECH DAC

B. INCLUDE CHART OF HOTSTART (recorder setup for transient response) TECH N/A

ATTACHMENT 1 JOB NUMBER 2402 DATE

FACTORY TEST LOG
RECIPROCATING DIESEL

TIME	3:28	3:45	4:00	4:15	4:30				
AMBIENT TEMP 74	~~68~~	71	71	75	71				
OIL TEMP	200	220	220	219	221				
WATER TEMP	203	203	203	203	203				
OIL PRESSURE	50	44	44	44	44				
ALTERNATOR INLET	72	74	74	~~83~~ 73	78				
ALTERNATOR OUTLET	78	78	78	83	83				
L1-L2 VOLTS	204.6	204.6	204.6	204.6	204.6				
L2-L3 VOLTS (1Ø L1-N)	206.1	206.1	206.1	206.3	206.2				
L3-L1 VOLTS (1Ø L2-N)	205.5	205.5	205.5	205.5	205.5				
AMPS L-1 Taken	(194.7	205	206	206	207				
AMPS L-2 Before	213	224	224	224	223				
AMPS L-3 Fan motor	194)	202	203	202	202				
KVA									
KW	71.2	75	75	75	75				
PF									
HZ	59.9	59.9	59.9	59.9	59.9				
CONTROL PANEL									
WATER TEMP									
OIL PRESSURE	49	44	43	43	43				
L1-L2 VOLTS	206	206	206	206	206				
L2-L3 VOLTS	208	209	209	209	209				
L3-L1 VOLTS	209	208	208	208	209				
AMPS L-1	199	199	199	199	199				
AMPS L-2	217	217	217	217	217				
AMPS L-3	198	198	198	198	199				
KVA	73	74	74	74	74				
PF	74	74	74	74	74				
HZ	59.8	59.7	59.7	59.7	59.7				

Cond water In 91 91 92 90 92
Cond water out 90 93 94 94 95

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DISCREPANCY LOG

Exh Cooler In R 102 107 102 102 100
Out R 110 110 110 110 114

Created on 03/13/01 4:37 PM

In 93 96 91 94
Out [illegible]

SECTION XIV

TRANSIENT RESPONSE PERFORMANCE DATA

1. OPERATE SET AT 100% SPEED LONG ENOUGH TO STABILIZE VOLTAGE AND FREQUENCY. TURN ON AND CENTER STRIP CHART AT NO LOAD. LOG FULL SCALE READING ON CHART. APPLY 100% OF FULL RATED OUTPUT IN ONE STEP (UNITY POWER FACTORY AND 0% GOVERNOR DROOP). SHED AND REAPPLY TWO MORE TIMES, ALLOWING TIME FOR THE TRACE TO STABILIZE AFTER EACH LOAD CHANGE. TECH DAL

2. APPLY 100% OF FULL RATED OUTPUT (UNITY PF AND 0% GOVERNOR DROOP) IN 1/4 LOAD STEPS. (I.E. INCREASING LOAD IN 1/4 LOAD STEPS FROM 1/4 TO 1/2, 3.4, FULL.) TECH DAL

3. SHED 100% OF FULL RATED OUTPUT (UNITY PF AND 0% GOVERNOR DROOP) IN 1/4 LOAD STEPS. (I.E. INCREASING LOAD IN 1/4 LOAD STEPS FROM FULL TO 3/4, 1/2, 1/4.) TECH DAL

4. REPEAT 1/4 LOAD TRANSIENTS (2 AND 3 ABOVE) TWO (2) MORE TIMES. TECH DAL

5. APPLY 100% OF FULL RATED OUTPUT IN ONE STEP AND SHED. SHUT UNIT DOWN USING MEANS OTHER THAN EMERGENCY STOP. TECH DAL

6. TURN OFF STRIP CHART RECORDER. TECH DAL

7. ANALYSIS

A. FREQUENCY REGULATION - TRANSIENT RESPONSE

MEASURE THE RESPONSE TIME IN MILLIMETERS FOR THE LAST FULL LOAD TRANSIENT FROM THE POINT WHERE THE TRACE LEAVES A STEADY STATE BAND TO THE POINT AT WHICH IT RETURNS TO, AND STAYS WITHIN, A BAND. LABEL THE TRACE ON THE CHART AND RECORD BELOW THE VALUES NOTED:

VERIFY AND RECORD MAXIMUM TRANSIENT CRITERIA (NO LOAD/FULL LOAD) FOR FREQUENCY RESPONSE:

	RESPONSE TIME	MAXIMUM DEPARTURE	
FREQUENCY	5 SEC (5 SEC MAX)	5 Hz (6 Hz MAX) (6 Hz MAX)	TECH DAL

B. VOLTAGE REGULATION - TRANSIENT RESPONSE

MEASURE THE RESPONSE TIME IN MILLIMETERS FOR THE LAST FULL LOAD TRANSIENT FROM THE POINT WHERE THE TRACE LEAVES THE STEADY STATE BAND TO THE POINT AT WHICH IT RETURNS TO, AND STAYS WITHIN, THE NEW STEADY STATE BAND. LABEL THE TRACE ON THE CHART AND RECORD THE VALUES NOTED:

VERIFY AND RECORD MAXIMUM TRANSIENT CRITERIA (NO LOAD/FULL LOAD) FOR VOLTAGE RESPONSE:

	RESPONSE TIME	MAXIMUM DEPARTURE	
VOLTAGE	.5 SEC (2 SEC MAX)	10 VAC (20% VAC MAX)	TECH [signature]

NOTE: THE PROJECT ENGINEER AND/OR THE QUALITY MANAGER ARE TO BE PRESENT FOR THE 100% LOAD TRANSIENT TEST.

APPROVED/PASSED:

TRANSIENT RESPONSE TEST: [signature]

PROJECT ENGINEER/PRODUCTION MANAGER

SECTION XV

COOL DOWN/MAXIMUM LOAD VERIFICATION

TECH DAC
MAXIMUM LOAD 84

1. WITH UNIT AT 0% RATED LOAD, INCREASE LOAD GRADUALLY TO FOR MAXIMUM KILOWATT OUTPUT. RECORD SAME.

2. DECREASE TO 0% RATED LOAD. ALLOW UNIT TO COOL PRIOR TO SHUTDOWN.
3. PERFORM ALL POST RUN CHECKS AND ADJUSTMENTS (I.E. BELTS, VALVE ADJUSTMENTS, LEAKS).

4. DISCONNECT AND PREPARE UNIT FOR TEST CELL REMOVAL UPON FINAL REVIEW BY TEST TECHNICIAN AND PROJECT MANAGER.

5. NOTE ANY KNOWN TEST OR EQUIPMENT FAILURES OR DISCREPANCIES REQUIRING CORRECTIVE ACTION PRIOR TO SHIPMENT:________

____

____

SECTION XVIII

ACOUSTICAL DATA

EQUIPMENT POSITION		DBA	OCTIVE BAND FREQUENCY 31.5	63	125	250	500	1K	2K	4K	8K
FRONT	NO LOAD	91									
	LOADED kW____										
LEFT SIDE	NO LOAD	91									
	LOADED kW____										
RIGHT SIDE	NO LOAD	92									
	LOADED kW____	~~92~~									
REAR	NO LOAD	89									
	LOADED kW____										

10 FT (RECORD READING DISTANCE FROM UNIT)

5 FT (RECORD READING ELEVATION)

70 DBA (AMBIENT LEVEL)

TECH DIAZ

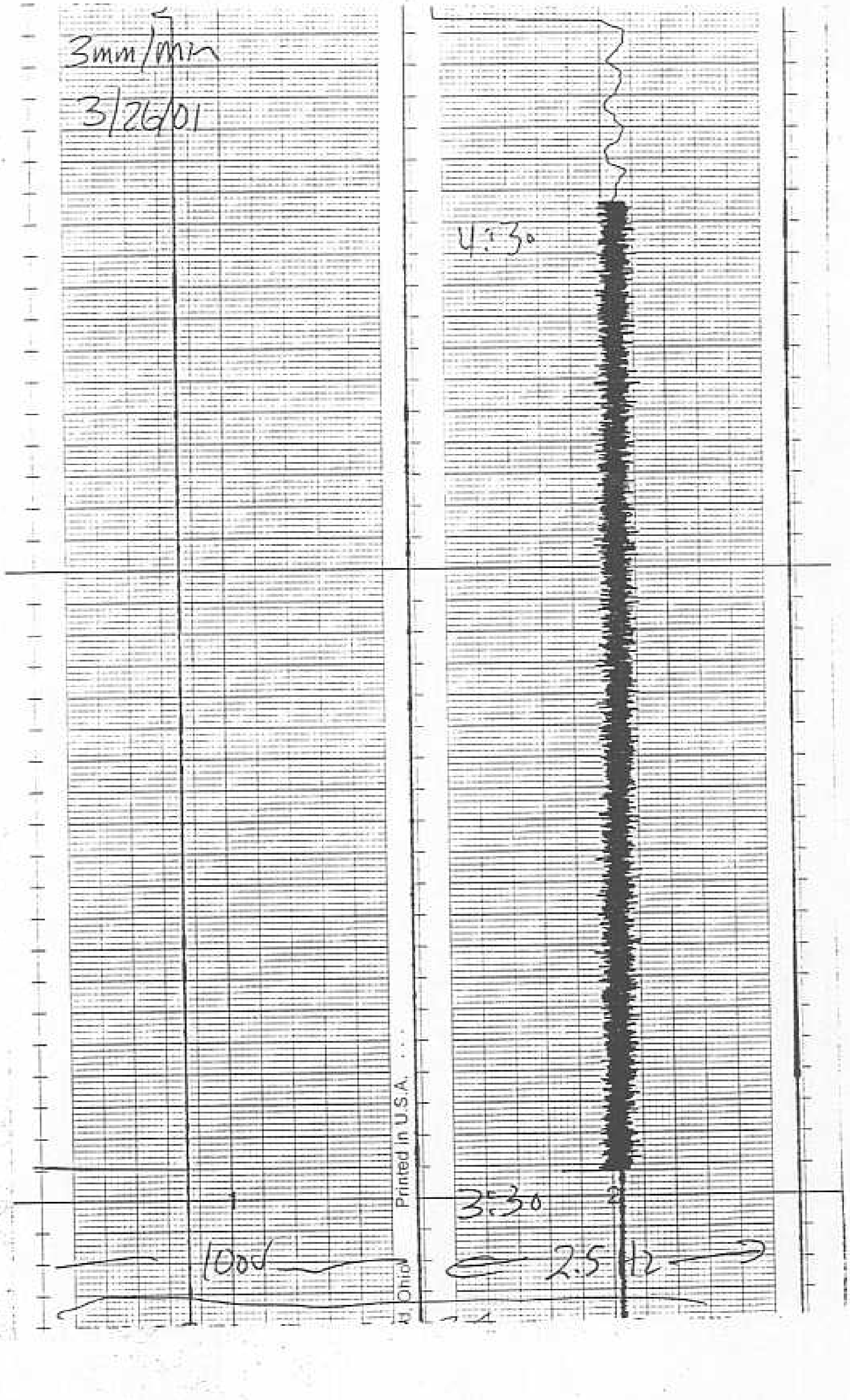
ATTACHMENT I JOB NUMBER 2462 DATE 3-23-01

FACTORY TEST LOG
RECIPROCATING DIESEL

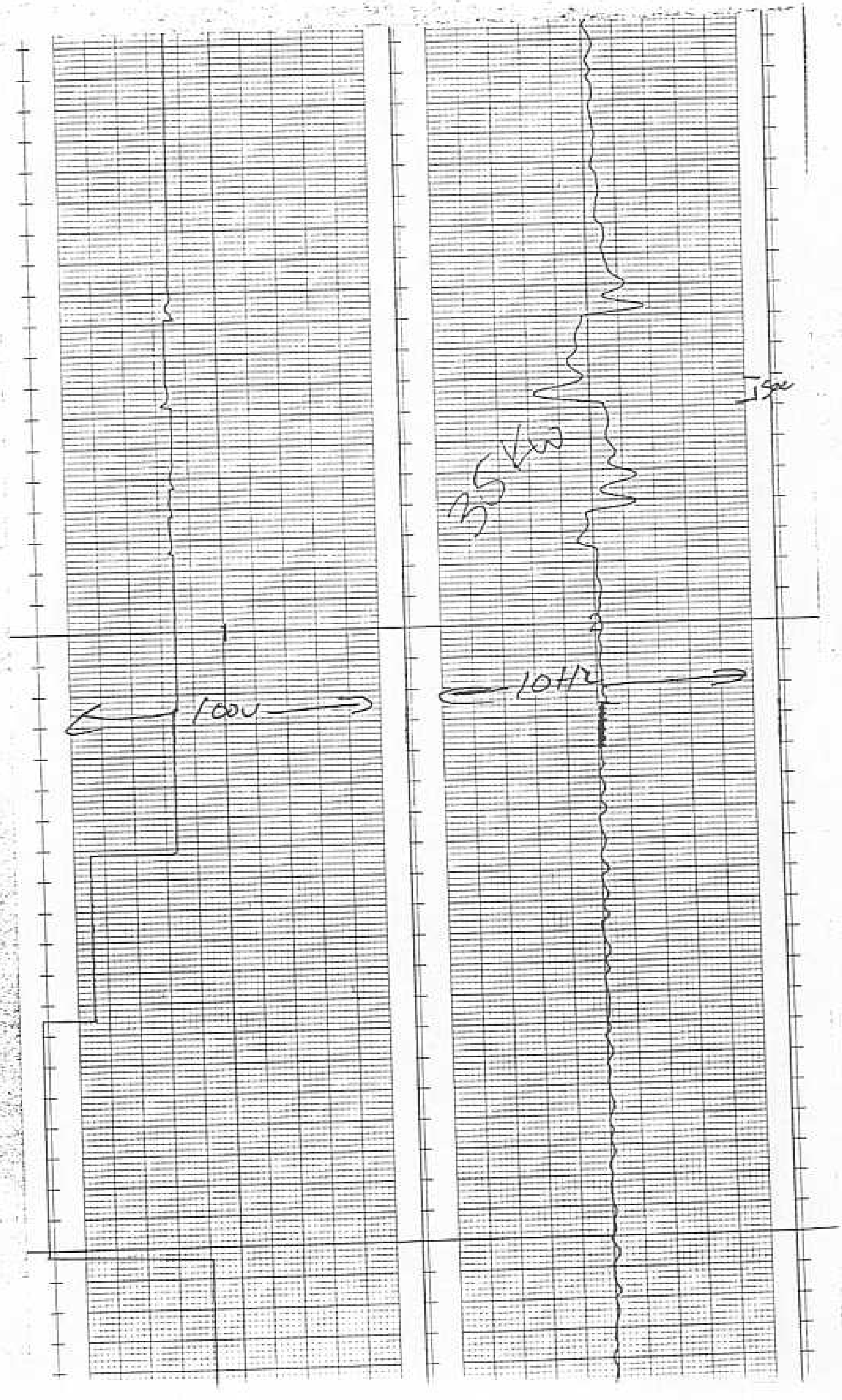
TIME	3:20	3:45	4:00	4:15	4:30					
AMBIENT TEMP	74	74	71	75	71					
OIL TEMP	200	220	220	219	221					
WATER TEMP	203	203	203	203	203					
OIL PRESSURE	50	44	44	44	44					
ALTERNATOR INLET	72	74	74	73	79					
ALTERNATOR OUTLET	79	79	79	83	83					
L1-L2 VOLTS	204.6	204.6	204.6	204.6	204.6					
L2-L3 VOLTS (1Ø L1-N)	206.1	206.1	206.1	206.3	206.2					
L3-L1 VOLTS (1Ø L2-N)	205.5	205.5	205.5	205.5	205.5					
AMPS L-1 (TAKEN Before Fan Motor)	194.3	205	206	206	209					
AMPS L-2	213	224	224	224	223					
AMPS L-3	194	202	203	202	202					
KVA										
KW	71.2	75	75	75	75					
PF										
HZ										
CONTROL PANEL										
WATER TEMP	~~49~~									
OIL PRESSURE	49	44	43	43	43					
L1-L2 VOLTS	206	206	206	206	206					
L2-L3 VOLTS	209	209	208	208	208					
L3-L1 VOLTS	209	209	208	208	208					
AMPS L-1	199	199	199	199	199					
AMPS L-2	217	217	217	217	217					
AMPS L-3	198	198	198	198	198					
KVA	73	74	74	74	74					
PF	74	74	74	74	74					
HZ	59.9	59.7	59.7	59.7	59.7					

Wtr cond in	91	91	92	90	92
cond out	93	93	94	94	95
Exh Manifold Left in		102	107	102	100
out		110	110	110	114
Exh Manifold in		93	96	91	94
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

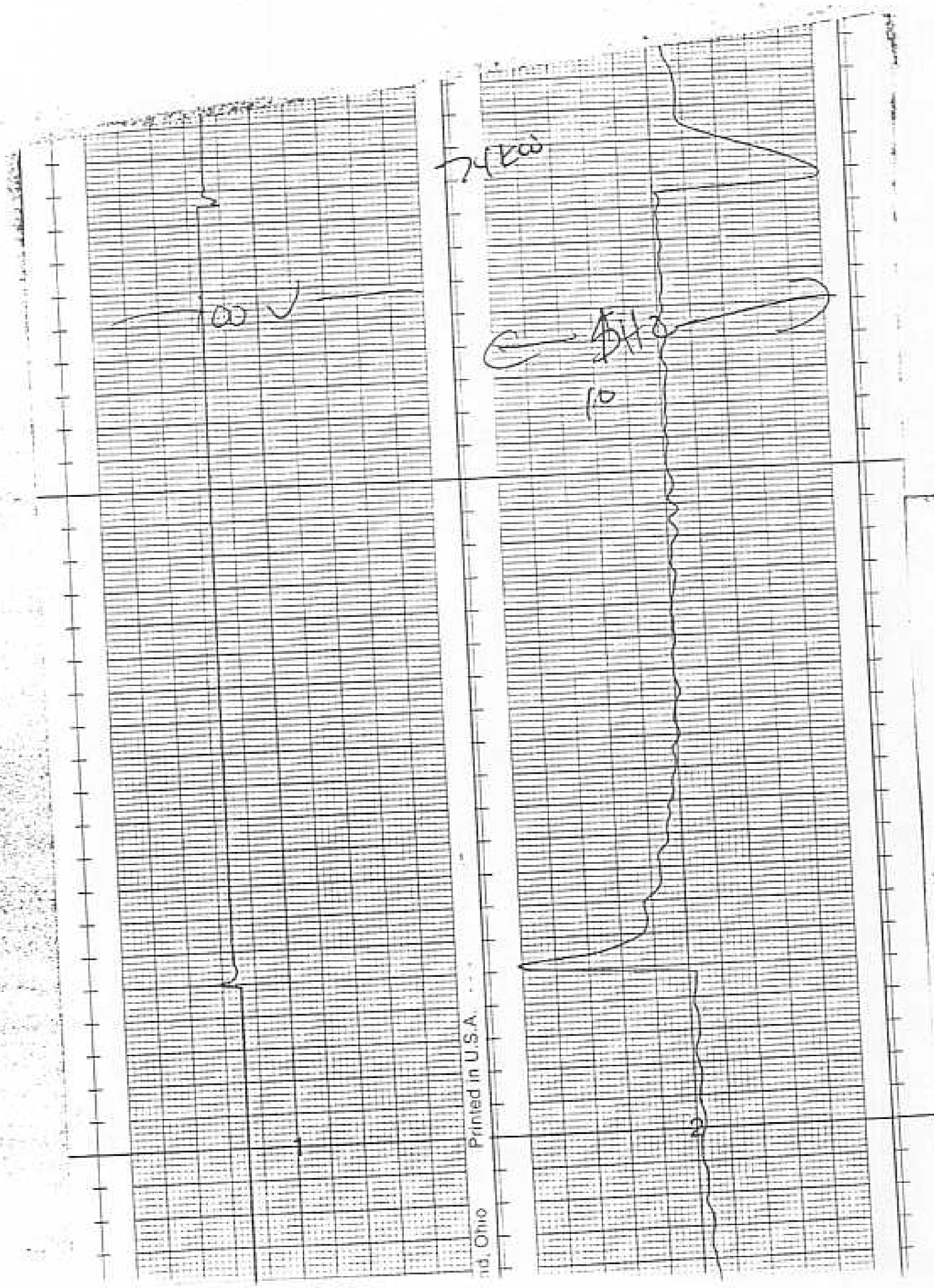
1 hour Heat Run



35KW Transient



74kw Trainsient



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TRAVELER

WORK ORDER 2462
PAGE 2 OF 3

PLANNER	PART NAME Chiller	QTY 1	SERIAL NUMBER 2462-1		PART NUMBER		REV
QA	CUSTOMER GTI		REL DATE	REV DATE	NEED DATE	JOB NUMBER	

OPER NO.	DEPT NO.	OPERATION	TECH	DATE	INSP
130	50	PERFORM COLD START TEST PURSUANT TO SECTION ~~XI~~ X OF FACTORY DATA TEST SHEET.	DAC	3-23-01	
		No Vibration Data			
140	50	PERFORM HEAT RUN TEST PURSUANT TO SECTION ~~XII~~ XI OF FACTORY DATA TEST SHEET.	DAC	3-23-01	
150	50	CONTACT PROJECT ENGINEER/PRODUCTION MANAGER/QA FOR HEAT RUN SIGN OFF ON FACTORY DATA TEST SHEET.	DAC	3-23-01	
160	50	PERFORM TRANSIENT RESPONSE TEST PURSUANT TO SECTION XIV OF FACTORY DATA TEST SHEET.	DAC	3-23-01	
170	50	PERFORM HOT START TEST PURSUANT TO SECTION ~~XIII~~ XII OF FACTORY DATA TEST SHEET.	DAC	3-23-01	
180	50	PERFORM MAX. LOAD/COOL DOWN TEST PURSUANT TO SECTION XV OF FACTORY DATA TEST SHEET.	DAC	3-23-01	
190	50	PERFORM SOUND READING, ENTER DATA SECTION XVI.	DAC	3-23-01	
200	50	INSPECT UNIT FOR LEAKS, STRUCTURAL DAMAGE, EXCESSIVE VIBRATION OR ANY OTHER MATTER WHICH MAY APPEAR INCONSISTENT WITH TYPE OF	DAC	3-26-01	
		EQUIPMENT.			
210	50	INSURE ALL TEST DATA IS COMPLETE, THAT ALL COMPONENT FAILURES ARE CORRECTED, LOGGED, AND RETESTED.	DAC	3-26-01	
220	50	FILL OUT DISCREPANCY SHEET AS NEEDED/TEST CELL LOG.	DAC	3-26-01	
225	60	CONTACT QA FOR INSPECTION	DAC	3-26-01	
230	60	RELEASE UNIT TO PRODUCTION WITH DISCREPANCY LIST IF REQUIRED FOR FINAL SHIPPING PREPARATION.	DAC	3-26-01	

ALTURDYNE

TRAVELER

WORK ORDER 2462
PAGE 1 OF 3

PLANNER	PART NAME Chiller	QTY 1	SERIAL NUMBER	PART NUMBER	REV
QA	CUSTOMER GTI	REL DATE	REV DATE	NEED DATE	JOB NUMBER

OPER NO.	DEPT NO.	OPERATION	TECH	DATE	INSP
10	50	RECEIVE UNIT IN TEST CELL. PERFORM VISUAL INSPECTION TO INSURE ALL REQUIRED COMPONENTS, ARTWORK, DRAWINGS AND ACCESSORIES ARE AVAILABLE. NOTIFY PRODUCTION, PROJECT ENGINEER OF ANY DEFICIENCIES (INITIAL SETUP).	DAL	3-12-01	
20	50	RECORD PRODUCT DATA IN SECTION I OF FACTORY TEST DATA SHEET (PRODUCT DATA).	DAL	3-12-01	
30	50	STATIC CHECK OR VERIFY THAT ALL MAJOR ELECTRICAL SUB-ASSEMBLIES HAVE BEEN STATIC TESTED BY DEPARTMENT 50 - ELECTRICAL. RECORD DATA IN SECTION II OF FACTORY TEST DATA SHEET (STATIC TEST).	DAL	3-14-01	
40	50	PREPARE UNIT AND CONNECT TEST APPARATUS PURSUANT TO SECTION III OF FACTORY TEST DATA SHEET (TEST PREPARATION).	DAL	3-14-01	
50	50	PERFORM TESTS AND RECORD APPROPRIATE DATA PURSUANT TO SECTION IV OF FACTORY TEST DATA SHEET (PRELIM. TESTS).	DAL	3-15-01	
60	50	PERFORM INITIAL STARTUP PURSUANT TO SECTION V OF FACTORY TEST DATA SHEET (INITIAL STARTUP).	DAL	3-16-01	
70	50	PERFORM AC SETUP PURSUANT TO SECTION VI OF FACTORY TEST DATA SHEET (AC SETUP).	DAL	3-17-01	
80	50	SETUP GOVERNOR PURSUANT TO SECTION VII OF FACTORY TEST DATA SHEET ~~(GOVERNOR SETUP)~~. MOTOR START TEST	DAL	3-23-01	
90	50	RECORD ALL APPLICABLE COMPONENT SETTINGS PURSUANT TO SECTION VIII OF FACTORY TEST DATA SHEET (COMPONENT SETTINGS).	DAL	3-20-01	
100	50	VERIFY AND RECORD ALL APPLICABLE SAFETIES AND RELATED FUNCTIONS PURSUANT TO SECTION ~~IX~~ VII OF FACTORY TEST DATA SHEET. (MAJOR MALF)	DAL	3-20-01	
110	50	VERIFY AND RECORD ALL APPLICABLE MINOR MALFUNCTIONS AND RELATED FUNCTIONS PURSUANT TO SECTION X OF FACTORY TEST DATA SHEET (MINOR ALARM VERIFICATION).	DAL	3-21-01	
120	50	PERFORM VIBRATION TEST, ENTER RESULTS SECTION XV.	~~DAL~~		

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TRAVELER

WORK ORDER 2462
PAGE 3 OF 3

PLANNER	PART NAME	QTY	SERIAL NUMBER	PART NUMBER	REV
	Chiller	1	2462-1		

QA	CUSTOMER	REL DATE	REV DATE	NEED DATE	JOB NUMBER
	GTI				

OPER NO.	DEPT NO.	OPERATION	TECH	DATE	INSP
240	50	ALL ORIGINAL TEST DATA TO PROJECT ENGINEER FOR JOB FOLDER	DAC	3264	
		A) TRAVELER B) TEST DATA SHEET			
		C) HEAT RUN LOG D) STRIP CHART (HEAT & TRANSIENT)			
		E) DISCREPANCY LIST			
		COPIES TO TEST CELL FILES FOR FUTURE REFERENCE.			

Appendix G

Economic Analysis Report

gti

Final Report

Energy Analysis of Hybrid Gas/Electric Chiller/Cogenerator

Prepared for:

Gas Technology Institute
Chicago, Illinois

GRI Contract No. 8175

Prepared by:

GARD Analytics, Inc.
Park Ridge, Illinois

November 2000

Table of Contents

1 Introduction

The work described in this report was performed for GRI in support of their contract with the USDOE National Energy Technology Laboratory (NETL) to develop an innovative hybrid gas/electric chiller/cogenerator. The chiller/cogenerator concept combines a gas engine, motor/generator and cooling compressor mounted on a single platform to provide either gas powered cooling and simultaneous electric power generation or electric powered cooling to a commercial building. Hybrid chiller operation refers to air conditioning using both natural gas and electricity as primary fuels. A hybrid chiller plant would provide the building owner with the flexibility to minimize cooling operating costs irrespective of energy rates by using he lowest cost fuel (either natural gas or electricity). The hybrid chiller/cogenerator can also operate as an emergency generator to provide electrical power in time of a local power outage. Or, electricity could be generated simultaneously along with chilled water when running in the gas cooling mode.

2 Objective and Scope

The objective of this hybrid chiller/cogenerator energy analysis was to perform a comparative energy cost savings analysis of the hybrid chiller/cogenerator versus conventional electric cooling equipment when applied to a prototype commercial building located in several cities.

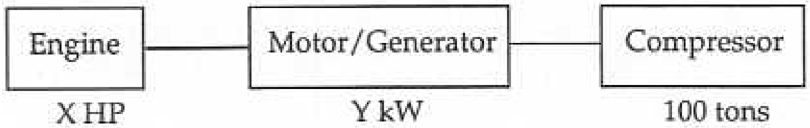
3 Approach

Energy cost savings analyses were performed using the DOE-2 building energy analysis program to simulate the application of various cooling plant equipment configurations to a prototype commercial building. Analyses were performed for several cities where a commercial building would be on a time-of-day electric rate with an on-peak and off-peak electric cost schedule.

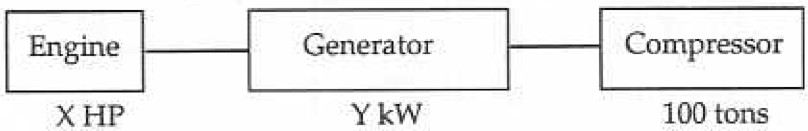
4 Application

A retail store application was selected because of its long operating hours and sustained demand for cooling during a significant portion of the year. Since the initial design of the chiller/cogenerator is sized for a 100 ton peak cooling load, the size of the retail store in terms of floor area was adjusted in each city to achieve a 100 ton cooling design load. The baseline conventional cooling plant was assumed to be a single 100 ton water cooled electric chiller which was available all year to meet cooling demand. Alternative cooling plant designs included a variable speed gas engine-driven chiller and several hybrid chiller/cogenerator plant configurations with and without an electric motor which operated at constant speed (see schematic below) and also sized to provide 100 tons of cooling.

Hybrid Chiller/Cogenerator (gas powered or electric powered cooling)



Gas Chiller/Cogenerator (gas powered cooling only)



The size of the gas engine, motor/generator and generator were varied to investigate operating cost sensitivity. When the hybrid plant is running in the gas cooling mode, unused engine capacity is available to operate the generator which is interconnected with the electric utility grid to satisfy a portion of the building's electric load. One additional case simulated an engine generator set dedicated to an electric chiller with the generator operating only when there was a demand for cooling.

Typically the hybrid cooling plant would be operated in the electric cooling mode during off-peak electric rate schedule hours when electricity rates are low and in the gas cooling mode during on-peak hours when electric costs are higher.

5 Locations

In recognition of the fact that operating costs and savings will vary depending upon location due to variation in climate and cost of electricity and gas, the following three cities were chosen for investigation:

New York City
Detroit
Los Angeles suburb

The specifics for these cities are as follows:

New York City

Summer 1% Design Dry-Bulb/Mean Coincident Wet-Bulb 89/73°F

Electric Utility:	Consolidated Edison		
Electric Rate:	Rate 9-III-Low Tension		
	Demand, $/kW	Summer	Winter
	All hours, All days	9.79	3.17
	On-peak	12.17	0
	Mid-peak	11.05	17.69

	Energy, $/kWh		
	On-peak	0.1041	0.0685
	All other hours	0.0523	0.0478
	On-peak period - 8AM to 6PM weekdays, all year		
	Mid-peak period - 8AM to 10PM, weekdays, all year		
	Off-peak period - all other hours		
	Demand charge for the month is the sum three demand charges		
Gas Utility:	Brooklyn Union		
Gas Rate:	Rate 2		
	Energy, $/therm	Summer	Winter
	First 6 therms, total	22.50	22.50
	Next 94, each	0.94864	1.01114
	All other	0.66664	0.72914
Gas Rate:	Rate 4-B Gas Cooling		
	Energy, $/therm	Summer	Winter
	First therm, total	20.65	N/A
	Next 199 therms	0.84964	N/A
	All other	0.67264	N/A

Detroit

Summer 1% Design Dry-Bulb/Mean Coincident Wet-Bulb 87/72°F

Electric Utility:	Detroit Edison		
Electric Rate:	Rate D6-TOU Primary Service		
	Demand, $/kW	Summer	Winter
	For primary service	3.75	3.75
	On-peak	14.25	14.25
	Off-peak	0	0
	Energy, $/kWh		
	On-peak	0.0296	0.0296
	Off-peak	0.0296	0.0296
	On-peak period - Noon to 7PM weekdays, all year		
	Off-peak period - All other hours		
Gas Utility:	Michigan Consolidated		
Gas Rate:	Rate 1		
	Energy, $/therm	Summer	Winter
	All therms	0.47679	0.47679

Los Angeles Suburb

Summer 1% Design Dry-Bulb/Mean Coincident Wet-Bulb 81/64°F

Electric Utility:	Southern California Edison		
Electric Rate:	Rate TOU-GS-2B		
	Demand, $/kW	Summer	Winter
	Facility charge	5.40	5.40

	On-peak	16.40	0
	Mid-peak	2.45	0
	Off-peak	0	0
	Energy, $/kWh		
	On-peak	0.14896	0
	Mid-peak	0.06613	0.07811
	Off-peak	0.04271	0.04271
	On-peak period - Noon to 6PM weekdays, June thru Sept.		
	Mid-peak period - 8AM to Noon, 6PM to 11PM, weekdays, June thru Sept.		
	Off-peak period - All other hours		
Gas Utility:	Southern California Gas		
Gas Rate:	Rate GN-10		
	Energy, $/therm	Summer	Winter
	First 100 therms	0.79587	0.79587
	Next 4067 therms	0.64262	0.64262
	All other	0.51314	0.51314
	Rate G-AC Gas Cooling		
	Energy, $/therm	Summer	Winter
	All cooling gas	0.49858	N/A

6 Assumptions

The results of the analyses are based on the following assumptions:

1) Electric cooling efficiency, 0.79 kW/ton (4.45 COP) based on ASHRAE Standard 90.1, positive displacement water cooled chiller

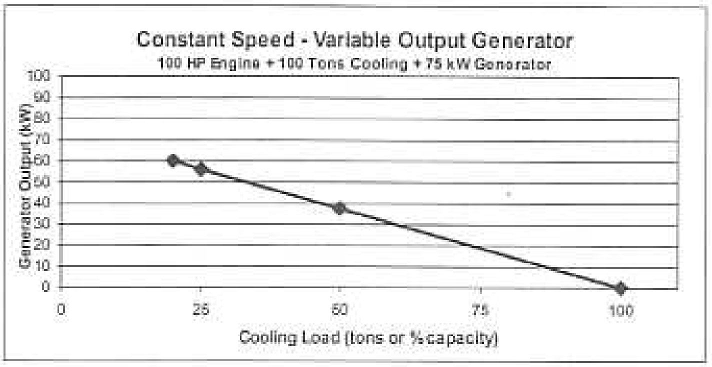
2) Gas cooling efficiency, 1.46 COP with 0.02 kW/ton electric parasitics based on water cooled engine driven chiller

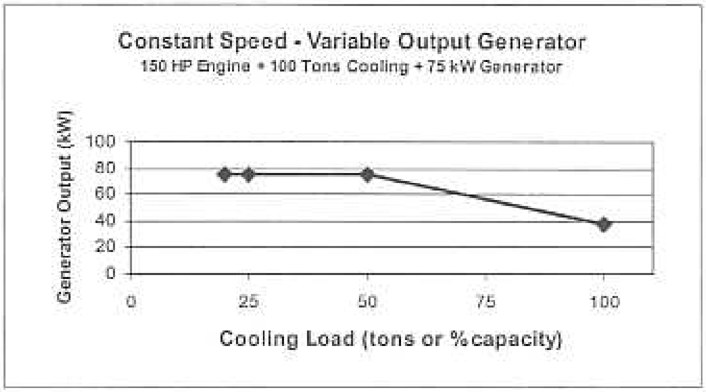
3) For hybrid chiller/cogenerator, gas engine runs at constant speed and fuel consumption anytime cooling is needed during the on-peak electric period which is different for each city

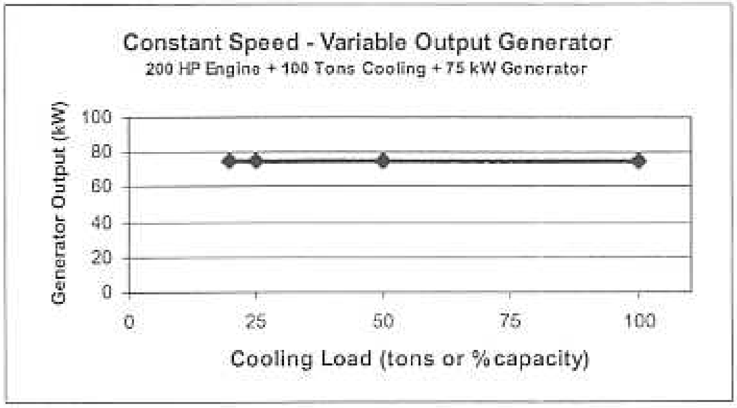
4) Generator runs at constant speed with variable output when gas engine runs

5) Generator set was assumed to be interconnected to the utility electric grid and allowed to operate during the on-peak period hours to reduce the building's dependency on the grid.

6) After satisfying cooling load for any hour, unused engine HP is used to operate generator; generator output varies as shown below with for three different engine sizes







7) Two different operating scenarios were investigated:

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

b) Generator allowed to operate during all on-peak hours even below 20% cooling capacity by falsely loading compressor. This allowed generator to peak shave and produce kWh during on-peak hours when it normally not be operating.

8) Annual electric and gas costs for each case were calculated using rate schedules for each city that applied to this retail application. Savings during on-peak hours were determined using marginal rates as follows:

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

9) Maintenance costs for operation of the engine were determined as follows:

For gas engine cooling, $0.015/ton-hr
For engine generator, $0.015/HP-hr of generator output

10) For the cases utilizing a conventional engine generator set, the fuel input efficiency was assumed to be 25% at full load output varying down to 15% efficiency at 25% of full load output.

7 Results

Annual energy cost savings for each alternative compared to an electric cooling plant are summarized on a set of bar charts presented at the end of this report for each of the 3 cities. Additional charts and monthly energy consumption and cost details for each case analyzed can be found in Appendics A, B and C.

Simulations and analyses were performed for 15 separate cooling plant designs including:

Conventional Cooling Plants

1) All electric cooling plant

2) All gas cooling plant

Dedicated Engine-Generator Set

3) 75 kW engine generator set operating at full capacity during on-peak hours

4) 112 kW engine generator set operating at full capacity during on-peak hours

5) 75 kW engine generator dedicated to running electric chiller; generator operates only when cooling required

Hybrid Chiller/Cogenerator

6) Hybrid cooling plant operating in gas cooling mode during on-peak hours and electric cooing mode during off-peak hours

7) Hybrid chiller/cogenerator with 100 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

8) Hybrid chiller/cogenerator with 100 HP engine, 100 ton compressor, 75 kW generator operating during all on-peak hours

9) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

10) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 75 kW generator operating during all on-peak hours

11) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 93 kW generator operating during on-peak hours when cooling required

12) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 93 kW generator operating during all on-peak hours

13) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 75 kW generator operating during on-peak hours when cooling required

14) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 112 kW generator operating during on-peak hours when cooling required

15) Hybrid chiller/cogenerator with 200 HP engine, 100 ton compressor, 112 kW generator operating during all on-peak hours

Gas Chiller or Hybrid Chiller with 35 kW Cogenerator

16) Hybrid chiller/cogenerator with 150 HP engine, 100 ton compressor, 35 kW generator operating during all on-peak hours

17) Gas chiller/ cogenerator with 150 HP engine, 100 ton compressor, 35 kW generator operating during all cooling hours

18) Gas chiller/ cogenerator with 150 HP engine, 100 ton compressor, 35 kW generator operating during on-peak cooling hours

8 Conclusions

An all gas cooling plant saves $6,000 - $10,000 annually (engine maintenance costs included) versus an all electric cooling plant for the three cities analyzed.

For the Hybrid/Cogenerator cases analyzed:

a) Annual savings can be maximized if the chiller/cogenerator is allowed to operate during all on-peak hours even when no cooling is needed.

b) The chiller/cogenerator configuration with a 100 HP engine, 100 ton compressor and 75 kW generator operating during all on-peak hours gives annual savings including maintenance of $7,000 - $12,000 versus the all electric cooling plant.

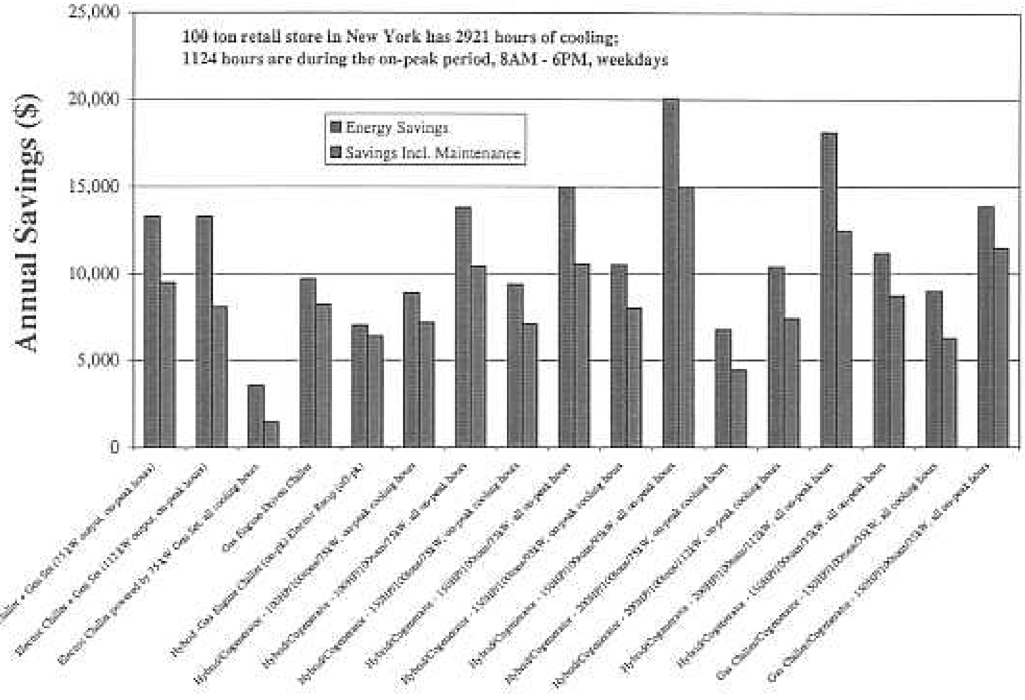
c) The optimum chiller/cogenerator configuration based on the alternatives analyzed appears to be the system with a 150 HP gas engine, 100 ton compressor and 93 kW generator operating all on-peak hours. This configuration produces annual savings including maintenance versus the all electric cooling plant of $9,000 - $15,000.

c) Greater annual savings are possible in Los Angeles (>$19,000) but only at the expense of installing a larger 200 HP engine.

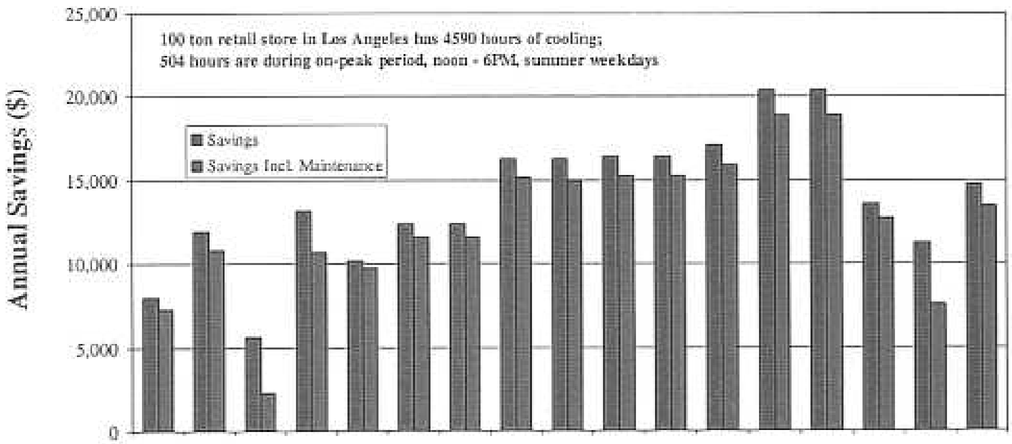
d) The hybrid chiller/cogenerator makes most sense in cities and applications that have time-of-use electric rates with on-peak and off-peak schedules where electric demand and energy charges are higher during on-peak periods. For cities in which time-of-use rates don't apply, but electric rates are high, an engine-driven chiller would generally provide the best economics.

e) Where interconnect with the electric grid is a problem, a 150 HP engine powering a 100 ton gas chiller and a 35 kW synchronous generator which serves a fixed load during on-peak hours which can be switched to the grid can give annual savings of $8,000 - $13,000 (including maintenance). Also provides emergency power backup.

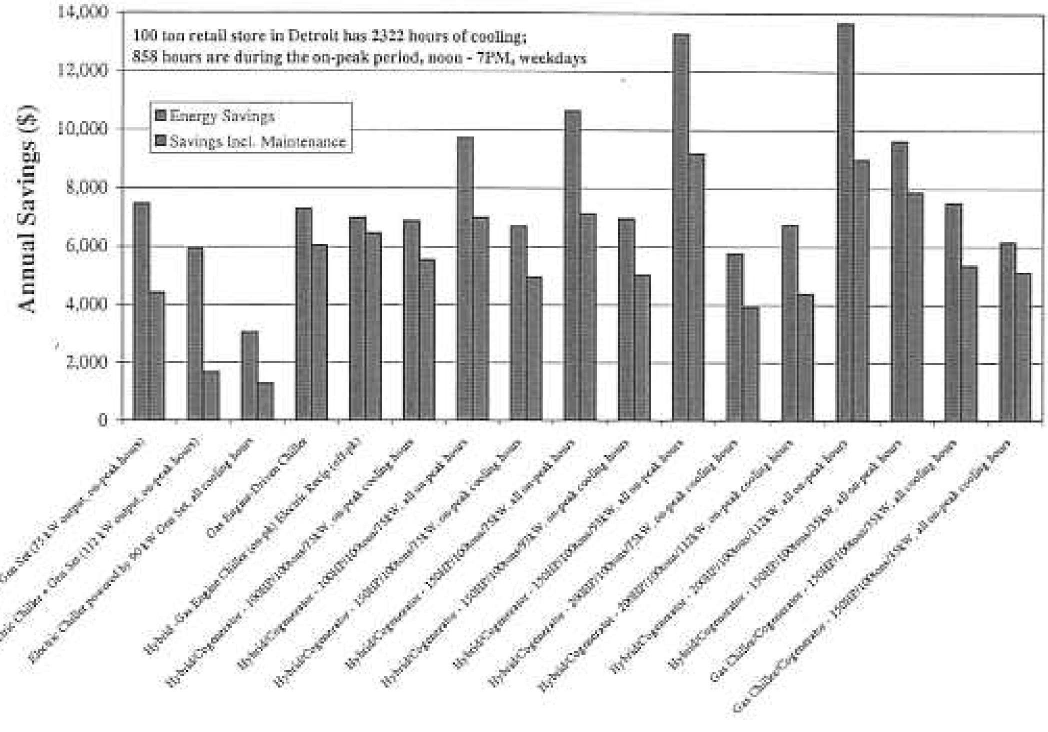
New York Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store



Los Angeles Savings Versus All Electric for various Cooling Plant Scenarios 100 Ton Retail Store

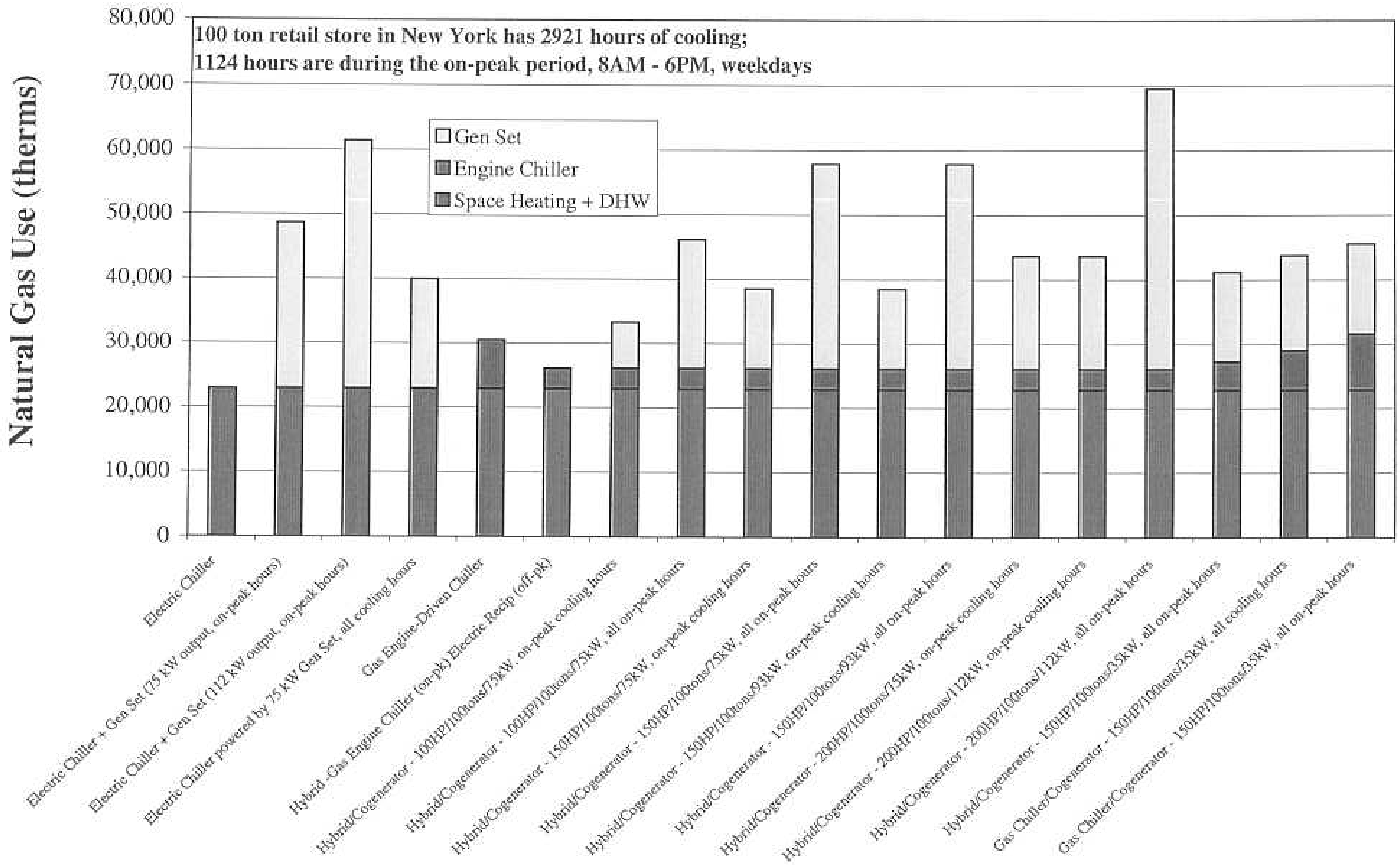


Detroit Annual Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store

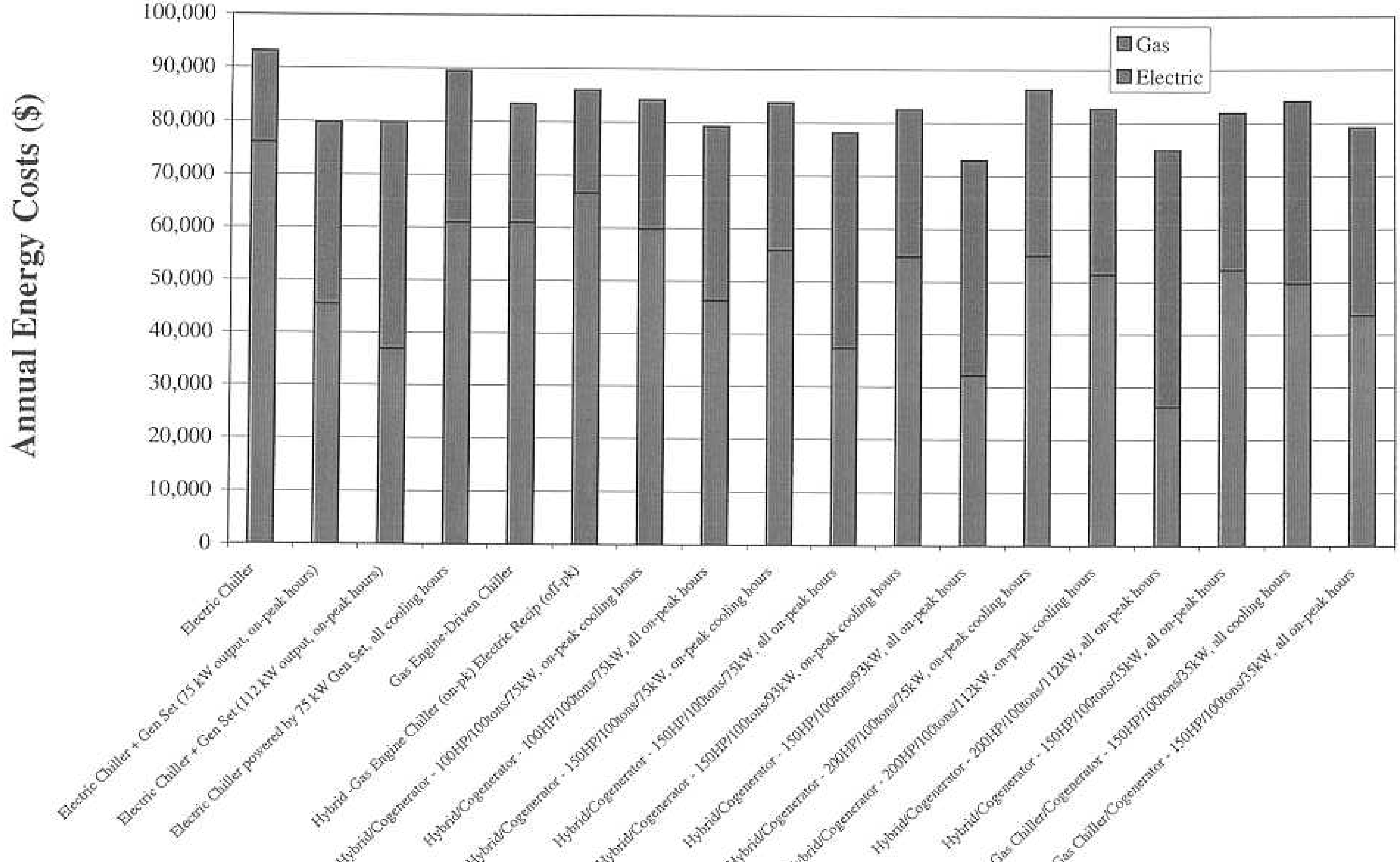


Appendix A
New York City
Annual Energy Usage, Costs and Savings
for Various Cooling Plant Scenarios
for Retail Store with 100 Tons Cooling

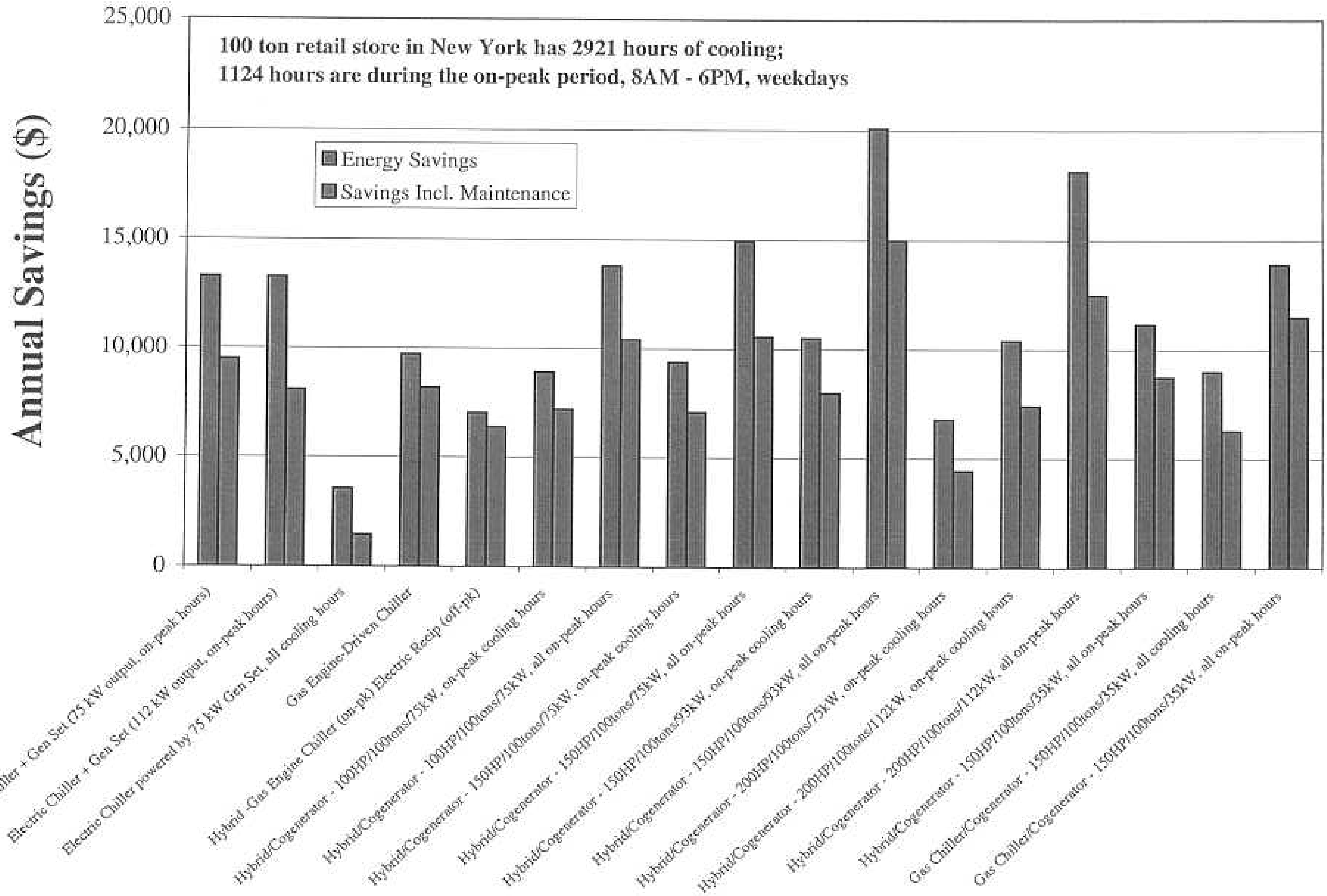
New York Annual Natural Gas Use for Various Cooling Plant Scenarios 100 Ton Retail Store



New York Energy Costs for Various Cooling Plant Scenarios 100 Ton Retail Store



New York Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store



Retail Store, 32000 SF
New York
200 HP constant speed engine, 100 tons cooling, 112.5 kW generator

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 112.5 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   Between 20-50 tons cooling, 112.5 kW
   Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   At full cooling capacity,100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension

	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $/kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2

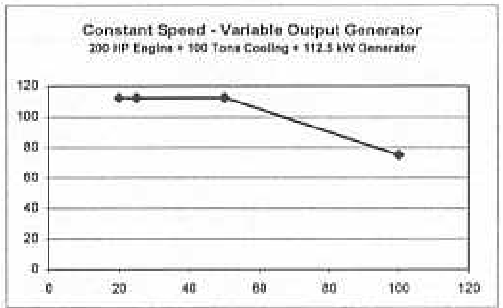
	Summer	Winter
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94664	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling

First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis

On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Feb	45,093	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Mar	50,525	121.0	106.5	95.6	11.0	946	157	134	98	(106)	126	9	20.5%	105.1
Apr	48,811	119.1	107.1	95.6	11.5	2,315	379	140	241	(255)	126	22	20.8%	105.2
May	54,201	137.6	106.2	95.6	10.7	14,014	2,251	130	1,459	(1,514)	75	135	21.3%	103.8
June	59,697	165.0	107.3	91.7	15.6	21,746	3,297	190	2,284	(2,218)	236	209	22.5%	104.0
July	64,673	171.0	106.2	21.9	84.3	21,476	3,070	1,026	2,236	(2,065)	1,197	210	23.9%	102.3
Aug	64,357	168.4	107.2	17.0	90.2	23,798	3,439	1,098	2,477	(2,313)	1,262	230	23.6%	103.5
Sept	59,159	165.7	106.9	95.1	11.9	18,608	2,813	145	1,937	(1,892)	190	181	22.6%	102.8
Oct	52,053	128.5	106.9	95.6	11.3	12,380	2,009	138	1,289	(1,351)	76	119	21.0%	104.0
Nov	48,146	113.6	102.4	95.6	6.8	918	163	83	98	(110)	69	9	19.2%	102.0
Dec	49,829	110.7	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Totals	646,921					116,202	17,577	3,082	12,097	(11,823)	3,356	1,124	22.6%	103.4

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	3,356
Total Savings	10,392
Savings/ton Installed Cooling	103.92

Retail Store, 32000 SF
New York
200 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate generator at full load continuous output of 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

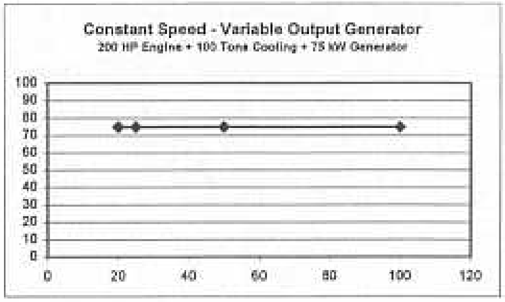
On-Peak period - 8AM to 6PM weekdays. All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94884	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis		
On-Peak Demand Charge	12.17	$/kW
On-Peak Energy Cost	0.1041	$/kWh
Gas Cooling Rate	0.67264	$/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms
Jan	50,177	96.3	96.3	96.3	0.0	-	-
Feb	45,093	96.3	96.3	96.3	0.0	-	-
Mar	50,525	121.0	106.5	95.6	11.0	675	157
Apr	48,811	119.1	107.1	95.6	11.5	1,650	379
May	54,201	137.6	106.2	95.6	10.7	10,125	2,251
June	59,697	165.0	107.3	91.7	15.6	15,675	3,297
July	64,873	171.0	106.2	31.2	75.0	15,750	3,070
Aug	64,357	166.4	107.2	32.2	75.0	17,250	3,439
Sept	59,159	165.7	106.9	95.1	11.9	13,575	2,813
Oct	52,053	126.5	106.9	95.6	11.3	8,925	2,009
Nov	48,146	113.6	102.4	95.6	6.8	675	163
Dec	49,829	110.7	96.3	96.3	0.0	-	-
Totals	646,921					84,300	17,577

	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	-	-	-	-	-		0.0
Feb	-	-	-	-	-		0.0
Mar	134	70	(106)	98	9	14.7%	75.0
Apr	140	172	(255)	57	22	14.9%	75.0
May	130	1,054	(1,514)	(330)	135	15.4%	75.0
June	190	1,632	(2,218)	(396)	209	16.2%	75.0
July	913	1,640	(2,065)	487	210	17.5%	75.0
Aug	913	1,796	(2,313)	395	230	17.1%	75.0
Sept	145	1,413	(1,892)	(334)	181	16.5%	75.0
Oct	138	929	(1,351)	(284)	119	15.2%	75.0
Nov	83	70	(110)	43	9	14.1%	75.0
Dec	-	-	-	-	-		0.0
Totals	2,784	6,776	(11,823)	(263)	1,124	16.4%	75.0

Note: There are on-peak hours during March, April, May, June, Sept, Oct, Nov when there is no cooling required, therefore generator cannot operate to produce 75kW avoided demand

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	(263)
Total Savings	6,773
Savings/ton Installed Cooling	67.73

Retail Store, 32000 SF
New York
75 kW natural gas generator

Assumptions
1. Building cooled with one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. One engine-generator set operating during on-peak hours at full output
3. Engine-generator fuel input efficiency at full load, 25%
4. Generator capacity, 75 kW

	Summer	Winter
Consolidated Edison Rate 9-III-Low Tension		
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $/kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Marginal energy costs used in analysis

On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm

Results below are for an electric cooling plant with engine-generator operating during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	21.3	75.0	16,500	2,253	913	1718	(1515)	1115	220	220	25.0%	75.0
Feb	45,093	96.3	96.3	21.3	75.0	14,250	1,945	913	1483	(1309)	1088	190	190	25.0%	75.0
Mar	50,765	135.0	130.8	55.8	75.0	16,500	2,253	913	1718	(1515)	1115	220	220	25.0%	75.0
Apr	49,463	136.9	136.9	61.9	75.0	15,750	2,150	913	1640	(1446)	1106	210	210	25.0%	75.0
May	59,430	149.9	149.9	74.9	75.0	16,500	2,253	913	1718	(1515)	1115	220	220	25.0%	75.0
June	70,888	170.1	161.4	86.4	75.0	15,750	2,150	913	1640	(1446)	1106	210	210	25.0%	75.0
July	78,797	177.4	177.4	102.4	75.0	15,750	2,150	913	1640	(1446)	1106	210	210	25.0%	75.0
Aug	78,190	171.4	171.4	96.4	75.0	17,250	2,355	913	1796	(1584)	1124	230	230	25.0%	75.0
Sept	69,628	172.3	172.3	97.3	75.0	14,250	1,945	913	1483	(1309)	1088	190	190	25.0%	75.0
Oct	55,720	142.0	142.0	67.0	75.0	16,500	2,253	913	1718	(1515)	1115	220	220	25.0%	75.0
Nov	48,348	126.1	112.1	37.1	75.0	15,000	2,048	913	1562	(1377)	1097	200	200	25.0%	75.0
Dec	49,901	120.1	96.3	21.3	75.0	15,000	2,048	913	1562	(1377)	1097	200	200	25.0%	75.0
Totals	706,420					189,000	25,802	10,953	19,675	(17,356)	13,272	2,520	2,520	25.0%	75.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	91,981
Savings from E-G Operation	13,272
Revised Annual Energy Cost	78,709

Retail Store, 32000 SF
New York
112 kW natural gas generator

Assumptions
1. Building cooled with one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. One engine-generator set operating during on-peak hours at full output
3. Engine-generator fuel input efficiency at full load, 25%
4. Generator capacity, 112 kW

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $/kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Marginal energy costs used in analysis
- On-Peak Demand Charge: 12.17 $/kW
- On-Peak Energy Cost: 0.1041 $/kWh
- Gas Cooling Rate: 0.67264 $/therm

Results below are for an electric cooling plant with engine-generator operating during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	0.0	0.0	21,098	3,364	0	2196	(2263)	(66)	220	220	21.4%	95.9
Feb	45,093	96.3	96.3	0.0	0.0	18,177	2,905	0	1892	(1954)	(62)	190	190	21.4%	95.7
Mar	50,785	136.0	130.8	18.8	112.0	21,108	3,364	1363	2197	(2263)	1297	220	220	21.4%	95.9
Apr	49,463	136.9	136.9	24.9	112.0	20,345	3,211	1363	2118	(2160)	1321	210	210	21.6%	96.9
May	59,430	149.9	149.9	37.9	112.0	22,970	3,364	1363	2391	(2263)	1492	220	220	23.3%	104.4
June	70,888	170.1	161.4	49.4	112.0	23,497	3,211	1363	2446	(2160)	1649	210	210	25.0%	111.9
July	78,797	177.4	177.4	65.4	112.0	23,520	3,211	1363	2448	(2160)	1652	210	210	25.0%	112.0
Aug	78,190	171.4	171.4	59.4	112.0	25,760	3,517	1363	2682	(2366)	1679	230	230	25.0%	112.0
Sept	69,628	172.3	172.3	60.3	112.0	21,111	2,905	1363	2198	(1954)	1607	190	190	24.8%	111.1
Oct	55,720	142.0	142.0	30.0	112.0	22,824	3,364	1363	2376	(2263)	1476	220	220	23.2%	103.7
Nov	48,348	126.1	112.1	0.1	112.0	19,120	3,058	1363	1990	(2057)	1296	200	200	21.3%	95.6
Dec	49,901	120.1	96.3	0.0	0.0	19,094	3,058	0	1988	(2057)	(69)	200	200	21.3%	95.5
Totals	706,420					258,620	38,531	12,267	26,922	(25,918)	13,272	2,520	2,520	22.9%	102.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	91,981
Savings from E-G Operation	13,272
Revised Annual Energy Cost	78,709

Retail Store, 32000 SF
New York
75 kW natural gas generator powering electric chiller
On-Peak Cooling Hours Only

Assumptions

1. One engine-generator set operating during on-peak hours when cooling required
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 75 kW
4. E-G must operate to provide power to chiller any time chiller operates during on-peak period
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2	Summer	Winter
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis		
On-Peak Demand Charge	12.17	$/kW
On-Peak Energy Cost	0.1041	$/kWh
Gas Cooling Rate	0.67264	$/therm

Results below are for an electric cooling plant powered from engine-generator during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	96.3	0.0	-	-	0	0	0	0	0	220		
Feb	45,093	96.3	96.3	96.3	0.0	-	-	0	0	0	0	0	190		
Mar	50,785	136.0	130.8	104.3	26.4	186	40	321	19	(27)	314	9	220	16.0%	20.6
Apr	49,463	136.9	136.9	104.8	32.1	501	101	390	52	(68)	374	22	210	16.9%	22.8
May	59,430	149.9	149.9	104.4	45.5	3,853	696	554	401	(468)	487	135	220	18.9%	28.5
June	70,888	170.1	161.4	104.6	56.9	7,766	1,251	692	808	(841)	659	209	210	21.2%	37.2
July	78,797	177.4	177.4	103.4	74.1	9,876	1,460	901	1028	(982)	947	210	210	23.1%	47.0
Aug	78,190	171.4	171.4	104.5	66.9	10,134	1,529	814	1055	(1028)	841	230	230	22.6%	44.1
Sept	69,628	172.3	172.3	104.2	68.0	7,041	1,117	828	733	(751)	810	181	190	21.5%	38.9
Oct	55,720	142.0	142.0	104.6	37.4	3,084	584	455	321	(393)	383	119	220	18.0%	25.9
Nov	48,348	126.1	112.1	101.1	11.0	169	38	134	18	(25)	126	9	200	15.3%	18.8
Dec	49,901	120.1	96.3	96.3	0.0	-	-	0	0	0	0	0	200		
Totals	706,420					42,609	6,815	5,091	4,436	(4,584)	4,943	1,124	2,520	21.3%	37.9

Summary	Annual Energy $
Baseline Electric Cooling Plant	91,981
Savings from E-G Operation	4,943
Revised Annual Energy Cost	87,038

Retail Store, 32000 SF

New York

75 kW natural gas generator powering electric chiller

All Cooling Hours

Assumptions

1. One engine-generator set operating hours when cooling required
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 75 kW
4. E-G must operate to provide power to chiller any time chiller operates
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2	Summer	Winter
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis

On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm

Results below are for an electric cooling plant powered from engine-generator during cooling hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	45,093	96.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	50,785	138.0	138.0	104.7	31.3	487	100	381	51	(67)	365	22	22	16.6%	22.1
Apr	49,463	136.9	136.9	104.8	32.1	1,158	239	390	121	(161)	350	53	53	16.5%	21.9
May	59,430	149.9	149.9	104.4	45.5	8,878	1,622	554	924	(1091)	387	319	319	18.7%	27.8
June	70,888	170.1	170.1	104.6	65.5	19,362	3,196	797	2016	(2150)	663	553	553	20.7%	35.0
July	78,797	177.4	177.4	103.4	74.1	25,349	3,894	901	2639	(2619)	921	602	602	22.2%	42.1
Aug	78,190	171.4	171.4	104.5	66.9	24,293	3,781	814	2529	(2543)	800	600	600	21.9%	40.5
Sept	69,628	172.3	172.3	104.3	68.0	18,870	3,080	827	1964	(2071)	720	523	523	20.9%	36.1
Oct	55,720	142.0	142.0	104.6	37.4	5,208	969	455	542	(672)	325	206	206	17.8%	25.3
Nov	48,348	126.1	126.1	104.1	22.0	563	128	267	61	(86)	242	30	30	15.5%	19.4
Dec	49,901	120.1	120.1	101.1	19.0	244	55	232	25	(37)	220	13	13		
Totals	706,420					104,432	17,094	5,819	10,871	(11,498)	4,993	2,921	2,921	20.9%	35.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	91,981
Savings from E-G Operation	4,993
Revised Annual Energy Cost	86,988

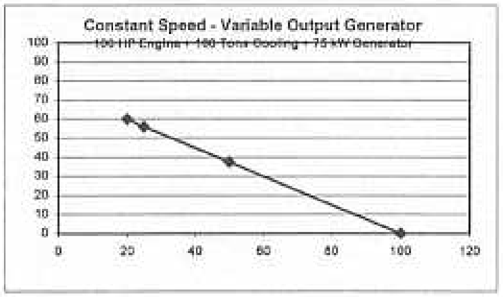
Retail Store, 32000 SF
New York
100 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

	Summer	Winter
Consolidated Edison Rate 9-III-Low Tension		
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	
Marginal energy costs used in analysis		
On-Peak Demand Charge	12.17 $/kW	
On-Peak Energy Cost	0.1041 $/kWh	
Gas Cooling Rate	0.67264 $/therm	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	96.3	0.0	-	-	0	0	0	0	0	220		-
Feb	45,093	96.3	96.3	96.3	0.0	-	-	0	0	0	0	0	190		-
Mar	50,525	121.0	106.5	95.6	11.0	540	74	134	56	(50)	140	9	220	24.9%	60.0
Apr	48,811	119.1	107.1	95.6	11.5	1,303	176	140	136	(118)	158	22	210	25.3%	59.2
May	54,201	137.6	106.2	95.6	10.7	7,423	1,002	130	773	(674)	228	135	220	25.3%	55.0
June	59,697	165.0	107.3	91.7	15.6	10,154	1,364	190	1057	(917)	330	209	210	25.4%	48.6
July	64,673	171.0	106.2	96.9	9.3	7,715	1,127	113	803	(758)	158	210	210	23.4%	36.7
Aug	64,357	166.4	107.2	92.0	15.2	9,226	1,312	185	960	(882)	263	230	230	24.0%	40.1
Sept	59,159	165.7	106.9	95.1	11.9	8,366	1,139	145	871	(766)	250	181	190	25.1%	46.2
Oct	52,053	126.5	106.9	95.6	11.3	6,901	908	138	718	(611)	246	119	220	25.9%	58.0
Nov	48,146	113.6	102.4	95.6	6.8	540	80	83	56	(54)	85	9	200	23.1%	60.0
Dec	49,829	110.7	96.3	96.3	0.0	-	-	0	0	0	0	0	200		-
Totals	646,921					52,167	7,180	1,257	5,431	(4,830)	1,858	1,124	2,520	24.8%	46.4

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	1,858
Total Savings	8,894
Savings/ton Installed Cooling	88.94

Retail Store, 32000 SF
New York
100 HP constant speed engine, 100 tons cooling, 75 kW generator runs during all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Generator operates every hour during on-peak period even if cooling load is below 20%. Below 20% cooling capacity, assume cooling system operates operates at 20% capacity to account for fuel consumption

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $/kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

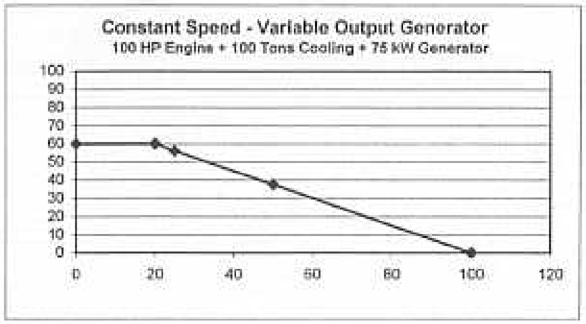
On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis	
On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	36.3	60.0	13,200	2,036	730	1374	(1369)	735	220	220	22.1%	60.0
Feb	45,093	96.3	96.3	36.3	60.0	11,400	1,758	730	1187	(1182)	735	190	190	22.1%	60.0
Mar	50,525	121.0	106.5	46.5	60.0	13,200	2,026	730	1374	(1363)	742	220	220	22.2%	60.0
Apr	48,811	119.1	107.1	50.1	57.0	12,583	1,915	693	1310	(1288)	715	210	210	22.4%	59.9
May	54,201	137.6	106.2	70.0	36.2	12,523	1,788	441	1304	(1203)	541	220	220	23.9%	56.9
June	59,697	165.0	107.3	83.2	24.1	10,214	1,373	294	1063	(924)	434	210	210	25.4%	48.6
July	64,873	171.0	106.2	96.9	9.3	7,715	1,127	113	803	(758)	158	210	210	23.4%	36.7
Aug	64,357	166.4	107.2	92.0	15.2	9,226	1,312	185	960	(882)	263	230	230	24.0%	40.1
Sept	59,159	165.7	106.9	92.6	14.3	8,906	1,222	174	927	(822)	280	190	190	24.9%	46.9
Oct	52,053	126.5	106.9	59.9	47.0	12,961	1,842	572	1349	(1239)	682	220	220	24.0%	58.9
Nov	46,146	113.6	102.4	42.4	60.0	12,000	1,846	730	1249	(1242)	737	200	200	22.2%	60.0
Dec	49,829	110.7	96.3	36.3	60.0	12,000	1,850	730	1249	(1244)	735	200	200	22.1%	60.0
Totals	646,921					135,927	20,093	6,124	14,150	(13,516)	6,758	2,520	2,520	23.1%	53.9

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	6,758
Total Savings	13,794
Savings/ton Installed Cooling	138

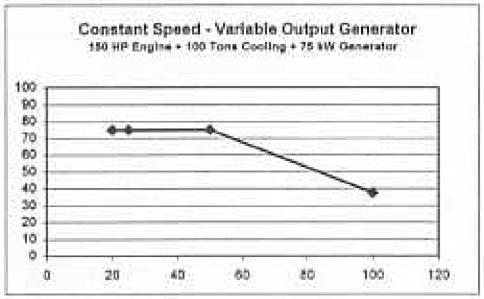
Retail Store, 32000 SF
New York
150 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,367,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   Between 20-50 tons cooling, 75 kW
   Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   At full cooling capacity,100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges



Marginal energy costs used in analysis
- On-Peak Demand Charge 12.17 $/kW
- On-Peak Energy Cost 0.1041 $/kWh
- Gas Cooling Rate 0.67264 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building* Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Feb	45,093	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Mar	50,525	121.0	106.5	95.6	11.0	675	116	134	70	(78)	126	9	19.9%	75.0
Apr	48,811	119.1	107.1	95.6	11.5	1,650	277	140	172	(187)	125	22	20.3%	75.0
May	54,201	137.6	106.2	95.6	10.7	10,121	1,626	130	1,054	(1,094)	89	135	21.2%	75.0
June	59,697	165.0	107.3	91.7	15.6	15,431	2,330	190	1,606	(1,568)	229	209	22.6%	73.8
July	64,873	171.0	106.2	59.4	46.8	14,663	2,099	570	1,526	(1,412)	684	210	23.8%	69.8
Aug	64,357	166.4	107.2	54.5	52.7	16,428	2,375	642	1,710	(1,598)	754	230	23.6%	71.4
Sept	59,159	165.7	106.9	95.1	11.9	13,023	1,976	145	1,356	(1,329)	171	181	22.5%	72.0
Oct	52,053	128.5	106.9	95.6	11.3	8,925	1,458	138	929	(981)	86	119	20.9%	75.0
Nov	48,146	113.6	102.4	95.6	6.8	675	121	83	70	(82)	71	9	19.0%	75.0
Dec	49,829	110.7	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Totals	646,921					81,591	12,379	2,170	8,494	(8,327)	2,337	1,124	22.5%	72.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	2,337
Total Savings	9,373
Savings/ton Installed Cooling	93.73

Retail Store, 32000 SF
New York

150 HP constant speed engine, 100 tons cooling, 75 kW generator
Generator operates all on-peak hours

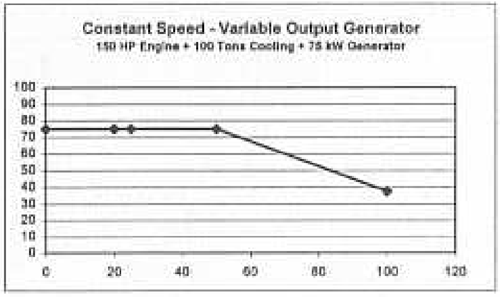
Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   Between 0-50 tons cooling, 75 kW
   Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   At full cooling capacity,100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges



Marginal energy costs used in analysis
On-Peak Demand Charge 12.17 $/kW
On-Peak Energy Cost 0.1041 $/kWh
Gas Cooling Rate 0.67264 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	21.3	75.0	16,500	3,053	913	1,718	(2,053)	577	220		0.0
Feb	45,093	96.3	96.3	21.3	75.0	14,250	2,636	913	1,483	(1,773)	623	190		0.0
Mar	50,525	121.0	106.5	31.5	75.0	16,500	3,043	913	1,718	(2,047)	583	220	18.5%	75.0
Apr	48,811	119.1	107.1	32.1	75.0	15,750	2,886	913	1,640	(1,941)	611	210	18.6%	75.0
May	54,201	137.6	106.2	32.5	73.7	16,496	2,806	897	1,717	(1,887)	727	220	20.1%	75.0
June	59,697	165.0	107.3	45.7	61.6	15,506	2,344	750	1,614	(1,577)	787	210	22.6%	73.8
July	64,873	171.0	106.2	59.4	46.8	14,663	2,099	570	1,526	(1,412)	684	210	23.8%	69.8
Aug	64,357	166.4	107.2	54.5	52.7	16,428	2,375	642	1,710	(1,598)	754	230	23.6%	71.4
Sept	59,159	165.7	106.9	55.1	51.8	13,698	2,101	631	1,426	(1,413)	644	190	22.3%	72.1
Oct	52,053	126.5	106.9	31.9	75.0	16,500	2,860	913	1,718	(1,924)	707	220	19.7%	75.0
Nov	48,145	113.6	102.4	27.4	75.0	15,000	2,771	913	1,562	(1,864)	610	200	18.5%	75.0
Dec	49,829	110.7	96.3	21.3	75.0	15,000	2,775	913	1,562	(1,867)	608	200		0.0
Totals	646,921					186,291	31,748	9,876	19,393	(21,355)	7,916	2,520	20.0%	73.9

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	7,916
Total Savings	14,952
Savings/ton Installed Cooling	149.52

Retail Store, 32000 SF
New York
150 HP constant speed engine, 100 tons cooling, 93 kW generator

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   Between 20-25 tons cooling, generator output constant at 93 kW
   Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   At full cooling capacity,100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

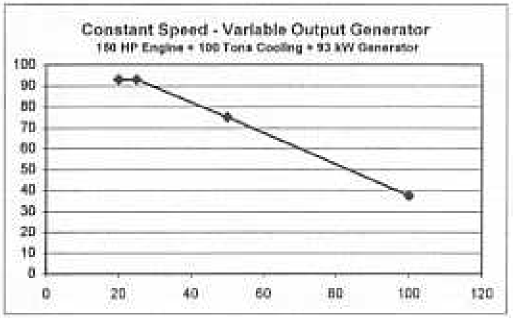
On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

On-Peak Demand Charge	12.17	$/kW
On-Peak Energy Cost	0.1041	$/kWh
Gas Cooling Rate	0.67264	$/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Feb	45,093	96.3	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Mar	50,525	121.0	106.5	95.6	11.0	837	116	134	87	(78)	143	9	24.7%	93.0
Apr	48,811	119.1	107.1	95.6	11.5	2,044	277	140	213	(187)	166	22	25.2%	92.9
May	54,201	137.6	106.2	95.6	10.7	12,089	1,626	130	1,258	(1,094)	294	135	25.4%	89.5
June	59,697	165.0	107.3	91.7	15.6	17,690	2,330	190	1,841	(1,568)	463	209	25.9%	84.6
July	64,873	171.0	106.2	59.5	46.7	15,479	2,099	568	1,611	(1,412)	768	210	25.2%	73.7
Aug	64,357	166.4	107.2	54.7	52.5	17,664	2,375	639	1,839	(1,598)	880	230	25.4%	76.8
Sept	59,159	165.7	106.9	95.1	11.9	14,866	1,976	145	1,546	(1,329)	363	181	25.7%	82.1
Oct	52,053	126.5	106.9	95.6	11.3	10,941	1,458	138	1,139	(981)	296	119	25.6%	91.9
Nov	48,146	113.6	102.4	95.6	6.8	837	121	83	87	(82)	88	9	23.5%	93.0
Dec	49,829	110.7	96.3	96.3	0.0	-	-	-	-	-	-	-		0.0
Totals	646,921					92,437	12,379	2,166	9,623	(8,327)	3,462	1,124	25.5%	82.2

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	3,462
Total Savings	10,498
Savings/ton Installed Cooling	104.98

Retail Store, 32000 SF
New York
150 HP constant speed engine, 100 tons cooling, 93 kW generator
Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   - Between 0-25 tons cooling, generator output constant at 93 kW
   - Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   - At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0665
All other hours	0.0523	0.0478

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

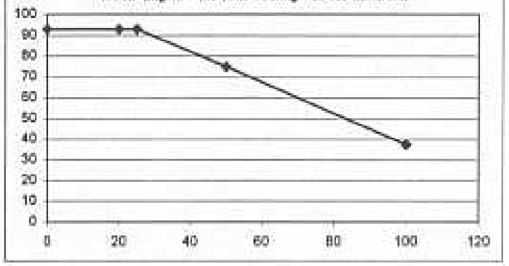
Brooklyn Union Rate 2	Summer	Winter
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94884	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67284

On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67284 $/therm

Constant Speed - Variable Output Generator

150 HP Engine + 100 Tons Cooling + 93 kW Generator



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	3.3	93.0	20,460	3,053	1,132	2,130	(2,053)	1,208	220		0.0
Feb	45,093	96.3	96.3	3.3	93.0	17,670	2,636	1,132	1,639	(1,773)	1,198	190		0.0
Mar	50,525	121.0	106.5	13.5	93.0	20,460	3,043	1,132	2,130	(2,047)	1,215	220	22.9%	93.0
Apr	48,811	119.1	107.1	14.1	93.0	19,528	2,688	1,132	2,033	(1,941)	1,224	210	23.1%	93.0
May	54,201	137.8	106.2	33.0	73.2	19,994	2,806	891	2,081	(1,887)	1,085	220	24.3%	90.9
June	59,697	165.0	107.3	46.0	61.4	17,773	2,344	747	1,850	(1,577)	1,020	210	25.9%	84.6
July	64,873	171.0	106.2	59.5	46.7	15,479	2,099	568	1,611	(1,412)	768	210	25.2%	73.7
Aug	64,357	166.4	107.2	54.7	52.5	17,664	2,375	639	1,839	(1,598)	880	230	25.4%	76.8
Sept	59,159	165.7	106.9	55.3	51.6	15,703	2,101	629	1,635	(1,413)	850	190	25.5%	82.6
Oct	52,053	126.5	106.9	23.0	83.9	20,334	2,860	1,022	2,117	(1,924)	1,215	220	24.3%	92.4
Nov	48,146	113.6	102.4	9.4	93.0	18,600	2,771	1,132	1,936	(1,864)	1,204	200	22.9%	93.0
Dec	49,829	110.7	96.3	3.3	93.0	18,600	2,775	1,132	1,936	(1,867)	1,201	200		0.0
Totals	646,921					222,265	31,748	11,286	23,136	(21,355)	13,069	2,520	23.9%	88.2

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	13,069
Total Savings	20,105
Savings/ton Installed Cooling	201.05

Retail Store, 32000 SF
New York
200 HP constant speed engine, 100 tons cooling, 112.5 kW generator
Generator operates all on-peak hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.48 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 112.5 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   Between 0-50 tons cooling, 112.5 kW
   Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   At full cooling capacity, 100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Consolidated Edison Rate 9-III-Low Tension

	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

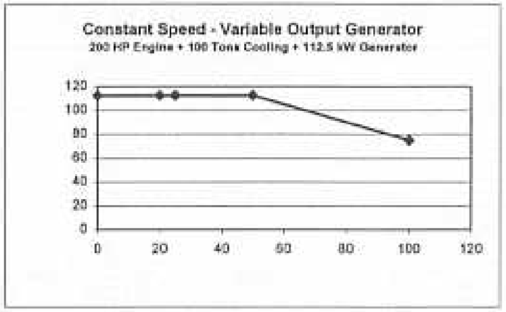
Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2

	Summer	Winter
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling

First one, total	20.65
Next 199	0.84964
All other	0.67264



Marginal energy costs used in analysis

On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	0.0	96.3	21,098	4,070	1,172	2,196	(2,738)	631	220	17.7%	95.9
Feb	45,093	96.3	96.3	0.0	96.3	18,177	3,515	1,172	1,892	(2,364)	700	190	17.6%	95.7
Mar	50,525	121.0	106.5	0.0	106.5	21,049	4,061	1,296	2,191	(2,731)	756	220	17.7%	95.7
Apr	48,611	119.1	107.1	0.0	107.1	20,196	3,857	1,303	2,102	(2,594)	811	210	17.9%	96.2
May	54,201	137.6	106.2	0.0	106.2	21,902	3,823	1,293	2,280	(2,572)	1,001	220	19.6%	99.6
June	59,897	165.0	107.3	8.2	99.1	21,839	3,316	1,207	2,273	(2,230)	1,250	210	22.5%	104.0
July	64,673	171.0	106.2	21.9	84.3	21,478	3,070	1,026	2,236	(2,065)	1,197	210	23.9%	102.3
Aug	64,357	166.4	107.2	17.0	90.2	23,798	3,439	1,098	2,477	(2,313)	1,262	230	23.8%	103.5
Sept	59,159	165.7	106.9	17.6	89.3	19,449	2,979	1,087	2,025	(2,004)	1,108	190	22.3%	102.4
Oct	52,053	126.5	106.9	0.0	106.9	21,879	3,877	1,301	2,278	(2,606)	971	220	19.3%	99.5
Nov	48,146	113.6	102.4	0.0	102.4	19,072	3,696	1,246	1,985	(2,486)	745	200	17.6%	95.4
Dec	49,629	110.7	96.3	0.0	96.3	19,094	3,700	1,172	1,988	(2,489)	671	200	17.6%	95.5
Totals	646,921					249,028	43,403	14,373	25,924	(29,195)	11,102	2,520	19.6%	98.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Generator	11,102
Total Savings	18,138
Savings/ton Installed Cooling	181.38

Retail Store, 32000 SF

New York

150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator

Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and variable output during on-peak period
4. 1,397,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours
8. Chillers sized at 103 tons

Consolidated Edison Rate 9-III-Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	9.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $.kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0476

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Brooklyn Union Rate 2		
Energy, $/therm		
First 6 therms, total	22.5	22.5
Next 94	0.94864	1.01114
All other	0.66664	0.72914

Brooklyn Union Rate 4-B Gas Cooling	
First one, total	20.65
Next 199	0.84964
All other	0.67264

Marginal energy costs used in analysis	
On-Peak Demand Charge	12.17 $/kW
On-Peak Energy Cost	0.1041 $/kWh
Gas Cooling Rate	0.67264 $/therm

On-peak and mid-peak overlap, so use on-peak demand cost

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Chil+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	50,177	96.3	96.3	61.3	35.0	7,700	1,314	426	802	(884)	344	220	35.0
Feb	45,093	96.3	96.3	61.3	35.0	6,650	1,135	426	692	(763)	355	190	35.0
Mar	50,525	121.0	106.5	71.5	35.0	7,700	1,318	426	802	(887)	341	220	35.0
Apr	48,811	119.1	107.1	72.1	35.0	7,350	1,261	426	765	(848)	343	210	35.0
May	54,201	137.6	106.2	71.2	35.0	7,700	1,340	426	802	(901)	326	220	35.0
June	59,697	165.0	107.3	72.3	35.0	7,350	1,249	426	765	(840)	351	210	35.0
July	64,873	171.0	106.2	71.2	35.0	7,350	1,273	426	765	(856)	335	210	35.0
Aug	64,357	166.4	107.2	72.2	35.0	8,050	1,387	426	838	(933)	331	230	35.0
Sept	59,159	165.7	106.9	71.9	35.0	6,650	1,135	426	692	(763)	355	190	35.0
Oct	52,053	126.5	106.9	71.9	35.0	7,700	1,324	426	802	(891)	337	220	35.0
Nov	48,146	113.6	102.4	67.4	35.0	7,000	1,204	426	729	(810)	345	200	35.0
Dec	49,829	110.7	96.3	61.3	35.0	7,000	1,194	426	729	(803)	351	200	35.0
Totals	646,921					88,200	15,134	5,111	9,182	(10,180)	4,113	2,520	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
Hybrid Cooling Plant	86,045
Savings	7,036
Additional Savings with Chill+Gen	4,113
Total Savings	11,149
Savings/ton Installed Cooling	111.49

Additional Gas vs. Variable Speed Cooling: 1142 therms, 35.51% more

Additional Gas to Run Generator: 13991 therms

Retail Store, 32000 SF
New York
150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator

Generator operates all cooling hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogen system is gas engine cooling (1.46 COP, 0.02 electric parasitics)
3. 150 HP gas engine runs at constant speed and variable output during cooling period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data of GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all cooling hours
8. Chillers sized at 100 tons

Consolidated Edison Rate 9-III Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	8.78	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.68
Energy, $/kWh		
On Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 3 therms, total	22.5	22.5
Next 94	0.94664	1.01114
All other	0.86664	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.85	
Next 199	0.84664	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Marginal energy costs used in analysis

On-Peak Demand Charge	12.17	$/kW
On-Peak Energy Cost	0.1041	$/kWh
Gas Cooling Rate	0.67264	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-Peak Period kW	Building Demand During On-Peak Period With Generator Operating kW	Avoided Demand During On-Peak Period kW	Building Demand During Mid-Peak Period kW	Building Demand During Mid-Peak Hours With Generator Operating kW	Avoided Demand During Mid-Peak Period kW	Building Demand During Off-Peak Period kW	Building Demand During Off-Peak Hours With Generator Operating kW	Avoided Demand During Off-Peak Period kW	Electricity Generated During On-Peak Period kWh	Electricity Generated During On-peak & Mid-Peak Period kWh	Electricity Generated During Off-Peak Period kWh	Additional Engine Gas therms	On-Peak Electric Demand Cost Savings $	Mid-Peak Electric Demand Cost Savings $	Off-Peak Electric Demand Cost Savings $	On-Peak Electric Energy Cost Savings $	Mid-Peak Electric Energy Cost Savings $	Off-Peak Electric Energy Cost Savings $	Additional Gas Cost to Run Chll+Gen $	Net Add'l Savings $	Number Hours Generator Operating
Jan	50,117	96.3	96.3	96.3	0.0	96.3	96.3	0.0	96.3	96.3	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb	45,093	96.3	96.3	96.3	0.0	96.3	96.3	0.0	96.3	96.3	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Mar	50,420	107.4	106.8	95.8	11.0	106.8	95.8	11.0	107.4	96.3	11.0	-	316	455	139	134	134	-	-	22	22	(93)	218	22
Apr	48,595	107.1	107.1	95.8	11.5	107.1	95.8	11.5	106.7	95.5	11.2	-	1,085	770	337	140	140	-	-	74	37	(227)	165	53
May	51,945	107.1	106.2	95.6	10.7	106.2	95.6	10.7	107.1	95.6	11.6	-	6,510	4,655	1,969	130	130	-	-	440	223	(1,324)	(398)	319
June	53,251	107.3	107.3	91.7	15.6	107.3	91.7	15.6	105.8	91.7	14.1	-	10,295	9,100	3,315	190	190	-	-	1,068	478	(2,230)	(306)	553
July	56,130	106.2	106.2	71.2	35.0	106.2	71.2	35.0	106.1	71.1	35.0	-	10,290	10,790	3,625	426	426	-	-	1,071	564	(2,436)	49	602
Aug	56,567	107.3	107.3	72.3	35.0	107.3	72.3	35.0	106.0	71.2	35.0	-	11,270	9,730	3,615	426	426	-	-	1,173	509	(2,432)	102	600
Sept	52,388	107.0	107.0	95.1	11.9	107.0	95.1	11.9	105.8	95.3	10.8	-	8,860	8,415	3,140	145	145	-	-	923	440	(2,112)	(480)	523
Oct	51,158	106.8	106.8	95.6	11.4	106.8	95.6	11.4	106.8	95.5	11.2	-	5,110	3,130	1,251	138	138	-	-	350	100	(842)	(714)	708
Nov	48,017	105.4	102.4	95.6	6.8	102.8	95.8	7.0	105.4	95.5	8.8	-	365	665	201	83	88	-	-	26	33	(135)	82	50
Dec	48,768	103.0	96.3	96.3	0.0	96.3	96.3	0.0	103.0	96.3	6.8	-	-	400	88	-	-	-	-	-	22	(58)	(37)	13
Totals	611,825											-	54,110	48,120 102,230	17,060	1,813	1,816	-	-	5,158	2,476	(11,897)	(633)	3,921

Summary	Annual Energy $
Baseline Electric Cooling Plant	93,081
All gas cooling	83,376
Savings	9,705
Additional Savings with Chll+Gen	(633)
Total Savings	9,072
Savings/ton Installed Cooling	90.72

Additional Gas vs. Variable Speed Cooling	2879	therms
	27.72%	more
Additional Gas to Run Generator	14601	therms

Retail Store, 32000 SF
New York

150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator
Generator operates all on-peak hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogen system is gas engine cooling (1.46 COP, 0.02 electric parasitics)
3. 150 HP gas engine runs at constant speed and variable output during cooling period
4. 1,267,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data of GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours
8. Chillers sized at 100 tons

Consolidated Edison Rate 9-II Low Tension	Summer	Winter
Demand, $/kW		
All Hours - All Days	5.79	3.17
On-Peak	12.17	0
Mid-Peak	11.05	17.69
Energy, $/kWh		
On-Peak	0.1041	0.0685
All other hours	0.0523	0.0478
Brooklyn Union Rate 2		
Energy, $/therm		
First 8 therms, total	22.5	22.5
Next 84	0.84864	1.01114
All other	0.66964	0.72914
Brooklyn Union Rate 4-B Gas Cooling		
First one, total	20.65	
Next 199	0.84964	
All other	0.67264	

On-Peak period - 8AM to 6PM weekdays, All year
Mid-Peak period - 8AM to 10PM weekdays, all year
Off-Peak period - all other hours
Charges are additive

Had to create the mid-peak period
to handle additive demand charges

Marginal energy costs used in analysis		
On-Peak Demand Charge	12.17	$/kW
On-Peak Energy Cost	0.1041	$/kWh
Gas Cooling Rate	0.67264	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-Peak Period kW	Building Demand During On-Peak Period With Generator Operating kW	Avoided Demand During On-Peak Period kW	Building Demand During Mid-Peak Period kW	Building Demand During Mid-Peak Hours With Generator Operating kW	Avoided Demand During Mid-Peak Period kW	Building Demand During Off-Peak Period kW	Building Demand During Off-Peak Hours With Generator Operating kW	Avoided Demand During Off-Peak Period kW
Jan	50,177	96.3	96.3	61.3	35.0	96.3	61.3	35.0	96.3	96.3	0.0
Feb	45,093	96.3	96.3	61.3	35.0	96.3	61.3	35.0	96.3	96.3	0.0
Mar	50,423	107.4	106.8	71.8	35.0	106.8	71.8	35.0	107.4	107.4	0.0
Apr	48,595	107.1	107.1	72.1	35.0	107.1	72.1	35.0	106.7	106.7	0.0
May	51,845	107.1	106.2	71.2	35.0	106.2	71.2	35.0	107.1	107.1	0.0
June	53,251	107.3	107.3	72.3	35.0	107.3	72.3	35.0	105.8	105.8	0.0
July	55,100	106.2	106.2	71.2	35.0	106.2	71.2	35.0	106.1	106.1	0.0
Aug	55,587	107.3	107.3	72.3	35.0	107.3	72.3	35.0	106.0	106.0	0.0
Sept	52,385	107.0	107.0	72.0	35.0	107.0	72.0	35.0	105.8	105.8	0.0
Oct	51,188	106.8	106.8	71.8	35.0	106.8	71.8	35.0	106.8	106.8	0.0
Nov	48,017	105.4	102.4	67.4	35.0	102.8	67.8	35.0	105.4	105.4	0.0
Dec	48,168	103.0	96.3	61.3	35.0	96.3	61.3	35.0	103.0	103.0	0.0
Totals	611,523										

	Electricity Generated During On-Peak Period kWh	Electricity Generated During Mid-Peak Period kWh	Electricity Generated During Off-Peak Period kWh	Additional Engine Gas therms	On-Peak Electric Demand Cost Savings $	Mid-Peak Electric Demand Cost Savings $	Off-Peak Electric Demand Cost Savings $	On-Peak Electric Energy Cost Savings $	Mid-Peak Electric Energy Cost Savings $	Off-Peak Electric Energy Cost Savings $	Additional Gas Cost to Run Chill+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	7,700	-	-	1,214	428	428	-	527	-	-	(584)	498	220	35.0
Feb	6,650	-	-	1,135	428	428	-	458	-	-	(182)	544	190	35.0
Mar	7,700	-	-	1,353	428	428	-	527	-	-	(913)	468	220	35.0
Apr	7,350	-	-	1,390	428	428	-	503	-	-	(956)	447	210	35.0
May	7,700	-	-	1,622	428	428	-	527	-	-	(1,228)	154	220	35.0
June	7,350	-	-	2,077	428	428	-	765	-	-	(1,387)	220	210	35.0
July	7,350	-	-	2,184	428	428	-	765	-	-	(1,469)	148	210	35.0
Aug	8,050	-	-	2,259	428	428	-	838	-	-	(1,520)	170	230	35.0
Sept	6,650	-	-	1,854	428	428	-	692	-	-	(1,314)	230	190	35.0
Oct	7,700	-	-	1,547	428	428	-	527.45	-	-	(1,041)	339	220	35.0
Nov	7,000	-	-	1,287	428	428	-	479.50	-	-	(853)	479	200	35.0
Dec	7,000	-	-	1,236	428	428	-	479.50	-	-	(833)	500	200	35.0
Totals	85,200	-	-	19,490	5,111	5,111	-	7,364	-	-	(13,118)	4,196	2,520	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	83,081
All gas cooling	73,376
Savings	9,705
Additional Savings with Chill+Gen	4,196
Total Savings	13,901
Savings/ton Installed Cooling	139.01

Additional Gas vs. Variable Speed Cooling	5507	therms
	72.17%	more
Additional Gas to Run Generator	13991	therms

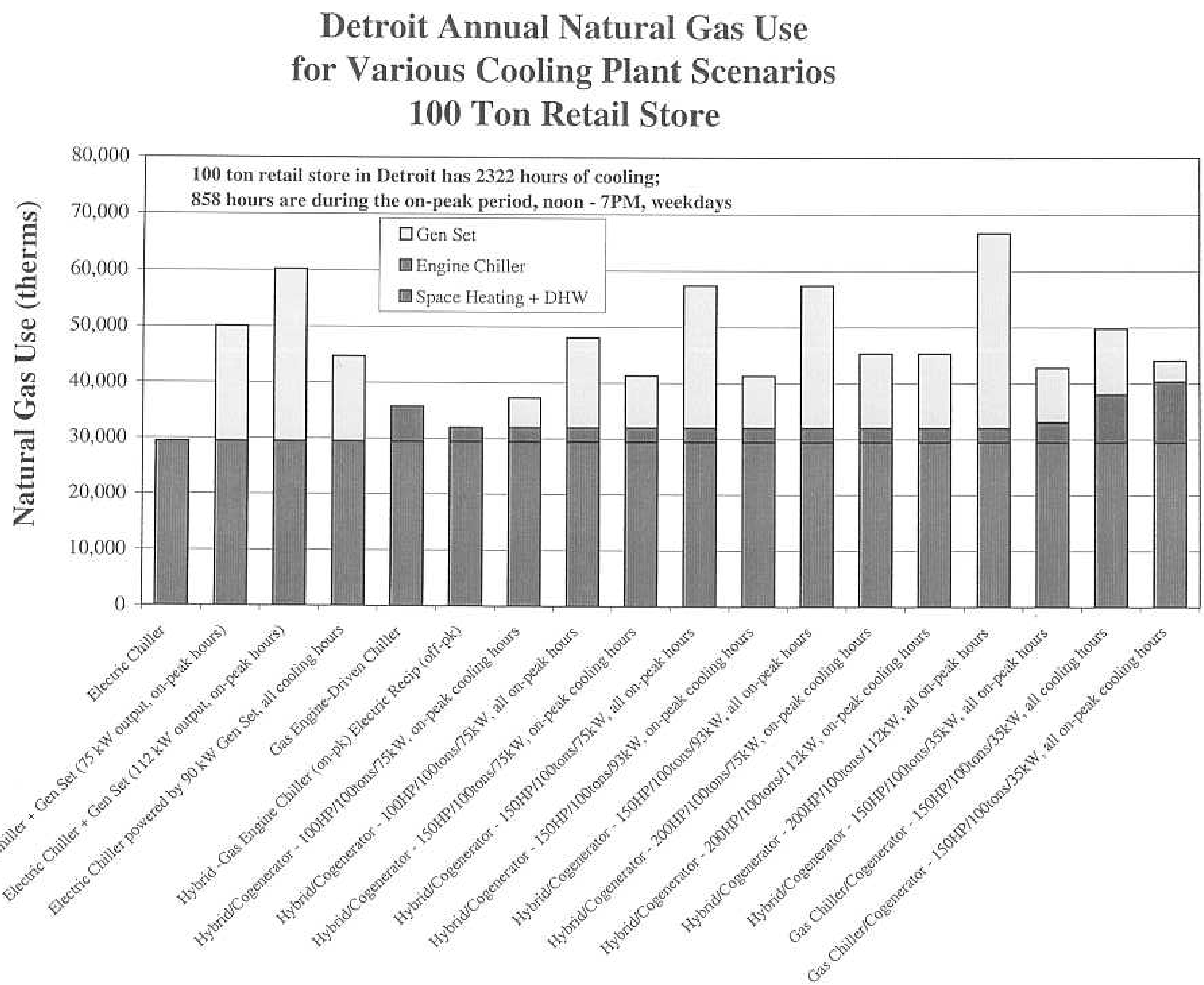
Appendix B

Detroit

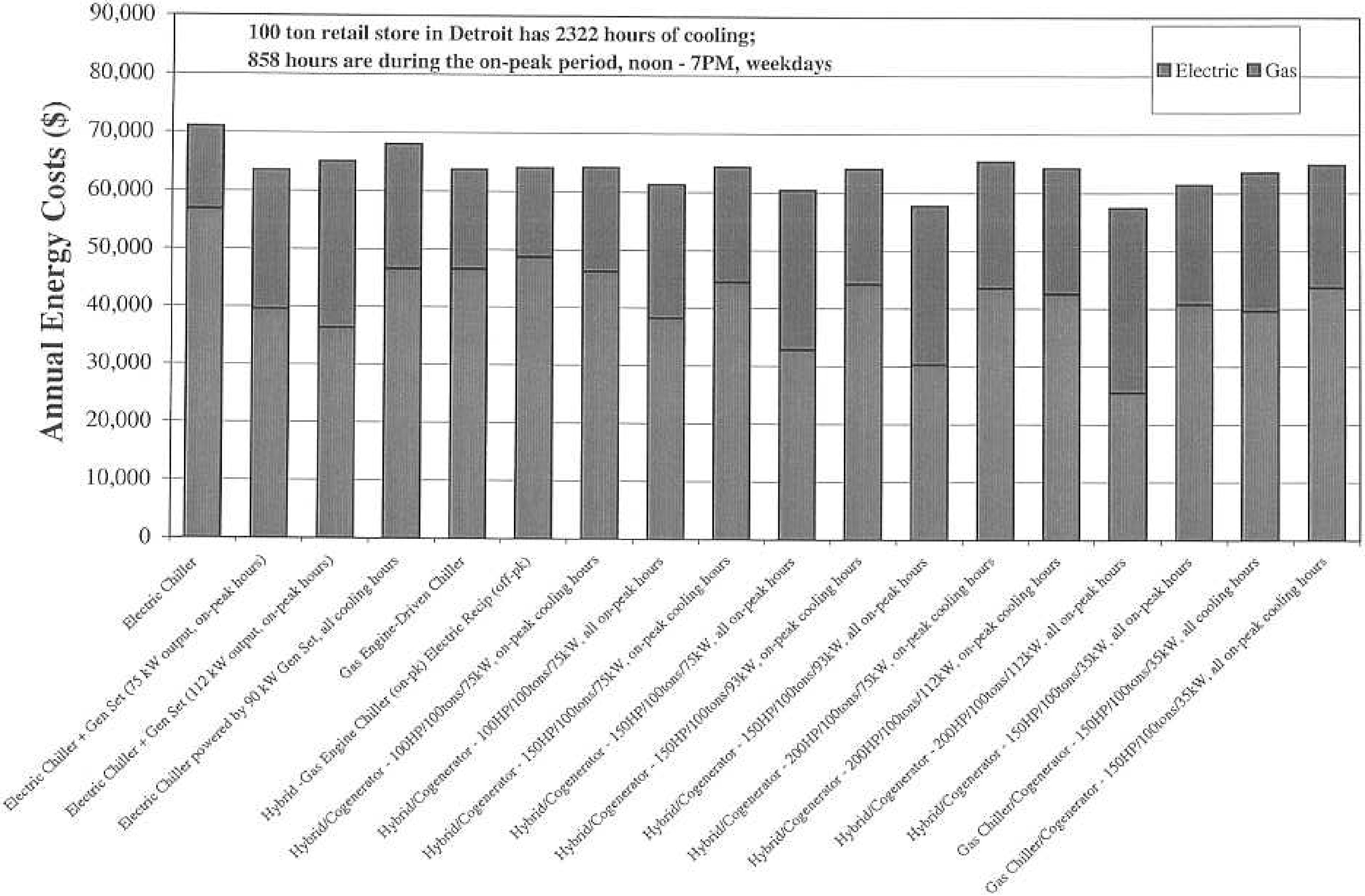
Annual Energy Usage, Costs and Savings

for Various Cooling Plant Scenarios

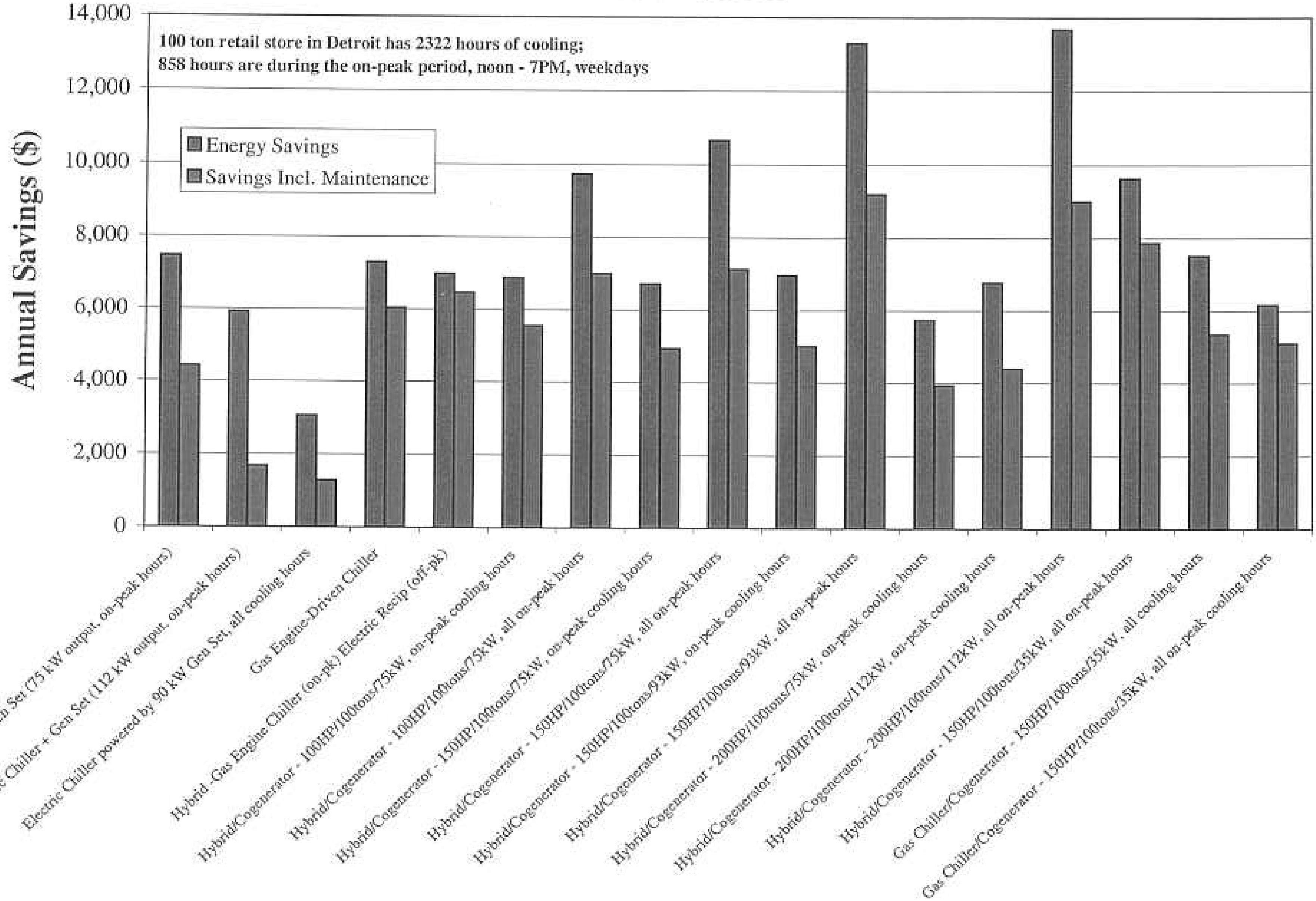
for Retail Store with 100 Tons Cooling


Detroit Annual Natural Gas Use
for Various Cooling Plant Scenarios
100 Ton Retail Store
100 ton retail store in Detroit has 2322 hours of cooling;
858 hours are during the on-peak period, noon - 7PM, weekdays
Gen Set
Engine Chiller
Space Heating + DHW
Natural Gas Use (therms)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Electric Chiller
Electric Chiller + Gen Set (75 kW output, on-peak hours)
Electric Chiller + Gen Set (112 kW output, on-peak hours)
Electric Chiller powered by 90 kW Gen Set, all cooling hours
Gas Engine-Driven Chiller
Hybrid -Gas Engine Chiller (on-pk) Electric Recip (off-pk)
Hybrid/Cogenerator - 100HP/100tons/75kW, on-peak cooling hours
Hybrid/Cogenerator - 100HP/100tons/75kW, all on-peak hours
Hybrid/Cogenerator - 150HP/100tons/75kW, on-peak cooling hours
Hybrid/Cogenerator - 150HP/100tons/75kW, all on-peak hours
Hybrid/Cogenerator - 150HP/100tons/93kW, on-peak cooling hours
Hybrid/Cogenerator - 150HP/100tons/93kW, all on-peak hours
Hybrid/Cogenerator - 200HP/100tons/75kW, on-peak cooling hours
Hybrid/Cogenerator - 200HP/100tons/112kW, on-peak cooling hours
Hybrid/Cogenerator - 200HP/100tons/112kW, all on-peak hours
Hybrid/Cogenerator - 150HP/100tons/35kW, all on-peak hours
Gas Chiller/Cogenerator - 150HP/100tons/35kW, all cooling hours
Gas Chiller/Cogenerator - 150HP/100tons/35kW, all on-peak cooling hours

Detroit Annual Energy Costs for Various Cooling Plant Scenarios 100 Ton Retail Store



Detroit Annual Savings Versus All Electric for Various Cooling Plant Scenarios 100 Ton Retail Store



Retail Store, 33000 SF
Detroit
75 kW natural gas generator

Assumptions
1. Building cooled with one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. One engine-generator set operating during on-peak hours at full output
3. Engine-generator fuel input efficiency at full load, 25%
4. Generator capacity, 75 kW

	Summer	Winter
Detroit Edison Rate D6-TOU Primary Service		
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for an electric cooling plant with engine-generator operating during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	25.7	75.0	11,550	1,577	1069	342	(752)	659	154	154	25.0%	75.0
Feb	47,251	100.7	100.7	25.7	75.0	9,975	1,362	1069	295	(649)	715	133	133	25.0%	75.0
Mar	52,713	125.9	119.2	44.2	75.0	11,550	1,577	1069	342	(752)	659	154	154	25.0%	75.0
Apr	51,128	131.3	131.3	56.3	75.0	11,025	1,505	1069	326	(718)	677	147	147	25.0%	75.0
May	59,375	165.6	165.6	90.6	75.0	11,550	1,577	1069	342	(752)	659	154	154	25.0%	75.0
June	72,160	191.5	191.5	116.5	75.0	11,025	1,505	1069	326	(718)	677	147	147	25.0%	75.0
July	79,190	191.6	191.6	116.6	75.0	11,025	1,505	1069	326	(718)	677	147	147	25.0%	75.0
Aug	76,208	175.1	175.1	100.1	75.0	12,075	1,648	1069	357	(786)	640	161	161	25.0%	75.0
Sept	65,721	196.3	170.3	95.3	75.0	9,975	1,362	1069	295	(649)	715	133	133	25.0%	75.0
Oct	54,197	140.1	138.9	63.9	75.0	11,550	1,577	1069	342	(752)	659	154	154	25.0%	75.0
Nov	50,726	141.2	141.2	66.2	75.0	10,500	1,433	1069	311	(683)	696	140	140	25.0%	75.0
Dec	52,126	100.7	100.7	25.7	75.0	10,500	1,433	1069	311	(683)	696	140	140	25.0%	75.0
Totals	713,316					132,300	18,062	12,825	3,916	(8,612)	8,129	1,764	1,764	25.0%	75.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Savings from E-G Operation	8,129
Revised Annual Energy Cost	62,921

Retail Store, 33000 SF
Detroit
112 kW natural gas generator

Assumptions

1. Building cooled with one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. One engine-generator set operating during on-peak hours at full output
3. Engine-generator fuel input efficiency at full load, 25%
4. Generator capacity, 112 kW

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for an electric cooling plant with engine-generator operating during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	0.0	0.0	15,397	2,355	0	456	(1123)	(667)	154	154	22.3%	100.0
Feb	47,251	100.7	100.7	0.0	0.0	13,302	2,034	0	394	(970)	(576)	133	133	22.3%	100.0
Mar	52,713	125.9	119.2	7.2	112.0	15,363	2,355	1596	455	(1123)	928	154	154	22.3%	99.8
Apr	51,128	131.3	131.3	19.3	112.0	14,980	2,248	1596	443	(1072)	968	147	147	22.7%	101.9
May	59,375	165.6	165.6	53.6	112.0	16,497	2,355	1596	488	(1123)	962	154	154	23.9%	107.1
June	72,160	191.5	191.5	79.5	112.0	16,464	2,248	1596	487	(1072)	1012	147	147	25.0%	112.0
July	79,190	191.6	191.6	79.6	112.0	16,464	2,248	1596	487	(1072)	1012	147	147	25.0%	112.0
Aug	78,208	175.1	175.1	63.1	112.0	17,990	2,462	1596	533	(1174)	955	161	161	24.9%	111.7
Sept	65,721	196.3	170.3	58.3	112.0	14,357	2,034	1596	425	(970)	1051	133	133	24.1%	107.9
Oct	54,197	140.1	138.9	26.9	112.0	16,010	2,355	1596	474	(1123)	947	154	154	23.2%	104.0
Nov	50,726	141.2	141.2	29.2	112.0	14,068	2,141	1596	416	(1021)	992	140	140	22.4%	100.5
Dec	52,126	100.7	100.7	0.0	0.0	13,990	2,141	0	414	(1021)	(607)	140	140	22.3%	99.9
Totals	713,316					184,881	26,972	14,364	5,472	(12,860)	6,977	1,764	1,764	23.4%	104.8

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Savings from E-G Operation	6,977
Revised Annual Energy Cost	64,073

Retail Store, 33000 SF
Detroit
90 kW natural gas generator powering electric chiller
On-Peak Cooling Hours Only

1. One engine-generator set operating hours when cooling required during on-peak hours
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 90 kW
4. E-G must operate to provide power to chiller any time chiller operates during on-peak period
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter	
Demand, $/kW			
For Primary Service	3.75	3.75	
On-Peak	14.25	14.25	On-Peak period - Noon to 7PM weekdays, all year
Off-Peak	0	0	Off-Peak period - all other hours
Energy, $.kWh			
On-Peak	0.0296	0.0296	
Off-Peak	0.0266	0.0266	
Michigan Consolidated Gas Rate 1			
Energy, $/therm			
All therms	0.47679	0.47679	

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for an electric cooling plant powered from engine-generator during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	154		
Feb	47,251	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	133		
Mar	52,713	125.9	119.2	105.4	13.7	45	10	196	1	(5)	192	2	154	15.3%	22.5
Apr	51,128	131.3	131.3	109.5	21.8	752	167	311	22	(80)	254	33	147	15.4%	22.8
May	59,375	165.6	165.6	109.3	56.3	3,250	606	802	96	(289)	610	101	154	18.3%	32.2
June	72,160	191.5	191.5	109.2	82.3	6,425	1,049	1172	190	(500)	862	147	147	20.9%	43.7
July	79,190	191.6	191.6	108.3	83.3	7,295	1,127	1187	216	(537)	865	147	147	22.1%	49.6
Aug	76,208	175.1	175.1	109.4	65.7	7,096	1,138	936	210	(543)	604	158	161	21.3%	44.9
Sept	65,721	196.3	170.3	107.6	62.7	4,057	671	894	120	(320)	694	97	133	20.6%	41.8
Oct	54,197	140.1	138.9	109.3	29.6	1,641	346	421	49	(165)	305	65	154	16.2%	25.2
Nov	50,726	141.2	141.2	109.0	32.3	358	69	460	11	(33)	437	12	140	17.6%	29.8
Dec	52,126	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	140		
Totals	713,316					30,919	5,183	6,379	915	(2,471)	4,823	762	1,764	20.4%	40.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Savings from E-G Operation	4,823
Revised Annual Energy Cost	66,227

Retail Store, 33000 SF
Detroit
90 kW natural gas generator powering electric chiller
All Cooling Hours

1. One engine-generator set operating hours when cooling required
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 90 kW
4. E-G must operate to provide power to chiller any time chiller operates
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for an electric cooling plant powered from engine-generator during cooling hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	47,251	100.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	52,713	125.9	125.9	103.4	22.5	135	30	321	4	(14)	310	6	6	15.3%	22.5
Apr	51,128	131.3	131.3	105.5	25.8	842	187	368	25	(89)	303	37	37	15.4%	22.8
May	59,375	165.6	165.6	109.2	56.4	6,868	1,321	804	203	(630)	378	228	228	17.7%	30.1
June	72,160	191.5	191.5	109.2	82.3	18,845	3,284	1172	558	(1566)	164	505	505	19.6%	37.3
July	79,190	191.6	191.6	108.3	83.3	23,970	3,955	1187	710	(1886)	11	569	569	20.7%	42.1
Aug	76,208	175.1	175.1	109.4	65.7	20,788	3,514	936	615	(1675)	(124)	523	523	20.2%	39.7
Sept	65,721	196.3	196.3	108.8	87.5	13,991	2,349	1246	414	(1120)	540	344	344	20.3%	40.7
Oct	54,197	140.1	140.1	109.3	30.8	2,283	483	440	68	(230)	277	91	91	16.1%	25.1
Nov	50,726	141.2	141.2	105.9	35.3	545	108	504	16	(51)	468	19	19	17.3%	28.7
Dec	52,126	100.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Totals	713,316					88,267	15,232	6,977	2,613	(7,262)	2,328	2,322	2,322	19.8%	38.0

Must use demand savings from on-peak case and energy savings from this case

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Savings from E-G Operation	2,328
Revised Annual Energy Cost	68,722

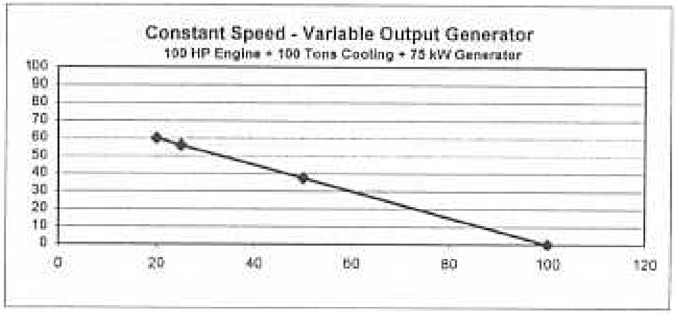
Retail Store, 33000 SF
Detroit
100 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service		
Demand, $/kW	Summer	Winter
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours



Marginal energy costs used in analysis		
On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	154		
Feb	47,251	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	133		
Mar	52,655	117.5	106.9	100.7	6.2	120	17	88	4	(8)	84	2	154	24.4%	60.0
Apr	50,691	114.6	110.9	99.8	11.1	1,980	276	158	59	(132)	85	33	147	24.5%	60.0
May	54,978	138.6	111.6	99.8	11.8	6,286	823	168	186	(392)	(38)	114	154	26.1%	55.1
June	61,058	164.8	112.0	104.3	7.7	7,734	1,006	110	229	(480)	(141)	168	147	26.2%	46.0
July	66,347	179.6	111.5	104.9	6.5	6,372	879	93	189	(419)	(137)	168	147	24.7%	37.9
Aug	64,247	159.9	112.1	99.4	12.8	7,643	1,037	182	226	(495)	(87)	180	161	25.1%	42.5
Sept	58,517	198.8	110.1	99.2	11.0	5,028	671	156	149	(320)	(15)	109	133	25.6%	46.1
Oct	52,579	124.2	111.5	99.8	11.7	4,200	550	167	124	(262)	28	70	154	26.0%	60.0
Nov	50,305	121.6	110.2	100.7	9.5	828	104	136	25	(50)	111	14	140	27.2%	59.1
Dec	52,126	100.7	100.7	100.7	0.0	-	-	0	0	0	0	0	140		
Totals	663,277					40,191	5,363	1,258	1,190	(2,557)	(109)	858	1,764	25.6%	46.8

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	(109)
Total Savings	6,878
Savings/ton Installed Cooling	68.78

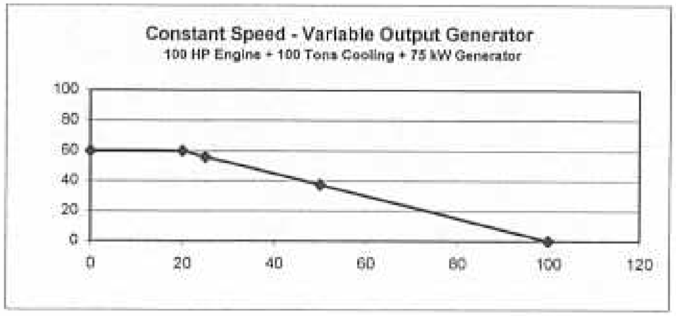
Retail Store, 33000 SF
Detroit
100 HP constant speed engine, 100 tons cooling, 75 kW generator runs during all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Generator operates every hour during on-peak period even if cooling load is below 20%. Below 20% cooling capacity, assume cooling system operates operates at 20% capacity to account for fuel consumption

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours



Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Bldg. Demand During On-Peak Period kW	Building Demand During Peak Period When Generator Operates kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	40.7	60.0	9,240	1,425	855	274	(679)	449	154	154	22.1%	60.0
Feb	47,251	100.7	100.7	40.7	60.0	7,980	1,230	855	236	(587)	505	133	133	22.1%	60.0
Mar	52,655	117.5	108.9	46.9	60.0	9,240	1,423	855	274	(678)	450	154	154	22.2%	60.0
Apr	50,691	114.8	110.9	50.9	60.0	8,820	1,330	855	261	(634)	482	147	147	22.6%	60.0
May	54,978	138.6	111.6	83.6	28.0	8,724	1,215	399	258	(579)	78	154	154	24.5%	56.6
June	61,058	184.8	112.0	104.3	7.7	6,664	869	110	197	(414)	(107)	147	147	26.2%	45.3
July	66,347	179.6	111.5	104.9	6.5	5,497	761	93	163	(363)	(107)	147	147	24.7%	37.4
Aug	64,247	159.9	112.1	92.0	20.1	6,808	930	286	202	(443)	44	161	161	25.0%	42.3
Sept	58,517	198.8	110.1	87.7	22.4	6,599	927	320	195	(442)	73	133	133	24.3%	49.6
Oct	52,579	124.2	111.5	51.5	60.0	9,240	1,332	855	274	(635)	494	154	154	23.7%	60.0
Nov	50,305	121.6	110.2	52.7	57.5	8,389	1,273	819	248	(607)	461	140	140	22.5%	59.9
Dec	52,126	100.7	100.7	40.7	60.0	8,400	1,295	855	249	(617)	486	140	140	22.1%	60.0
Totals	663,277					95,601	14,008	7,157	2,830	(6,679)	3,308	1,764	1,764	23.3%	54.2

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	3,308
Total Savings	10,295
Savings/ton Installed Cooling	102.95

Retail Store, 33000 SF
Detroit
150 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   - Between 20-50 tons cooling, 75 kW
   - Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   - At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service

	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266

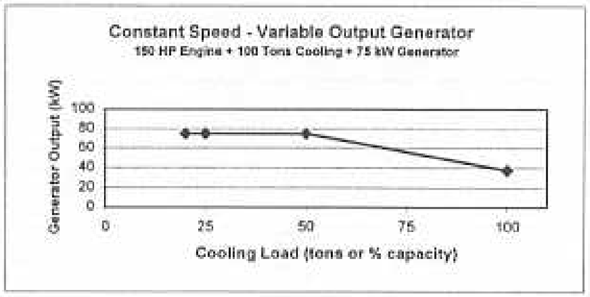
On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Michigan Consolidated Gas Rate 1

Energy, $/therm		
All therms	0.47679	0.47679

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Feb	47,251	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Mar	52,655	117.5	106.9	100.7	6.2	150	26	88	4	(12)	80	2		
Apr	50,691	114.6	110.9	99.8	11.1	2,475	428	158	73	(204)	27	33		
May	54,978	138.6	111.6	99.8	11.8	8,499	1,350	168	252	(644)	(224)	114	21.5%	74.6
June	61,058	164.8	112.0	66.8	45.2	12,069	1,783	644	357	(850)	152	168	23.1%	71.8
July	66,347	179.6	111.5	67.4	44.0	11,897	1,656	627	352	(789)	190	168	24.5%	70.8
Aug	64,247	159.9	112.1	99.4	12.8	13,051	1,870	182	386	(892)	(324)	180	23.8%	72.5
Sept	58,517	198.8	110.1	99.2	11.0	7,956	1,175	156	235	(560)	(168)	109	23.1%	73.0
Oct	52,679	124.2	111.5	99.8	11.7	5,250	874	167	155	(417)	(95)	70		
Nov	50,305	121.6	110.2	100.7	9.5	1,050	169	136	31	(80)	87	14	21.2%	75.0
Dec	52,126	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Totals	663,277					62,396	9,331	2,327	1,847	(4,449)	(275)	858	22.8%	72.7

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	(275)
Total Savings	6,712
Savings/ton Installed Cooling	67.12

Retail Store, 33000 SF
Detroit
150 HP constant speed engine, 100 tons cooling, 75 kW generator
Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   Between 0-50 tons cooling, 75 kW
   Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   At full cooling capacity,100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours

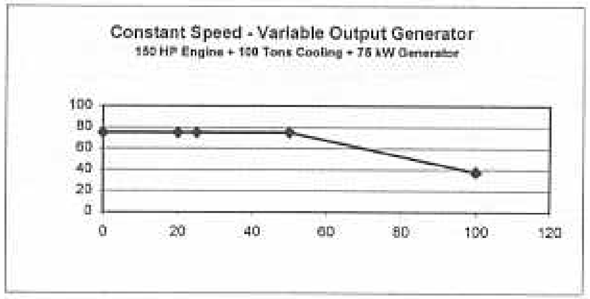
Detroit Edison Rate D6-TOU Primary Service

	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Michigan Consolidated Gas Rate 1

Energy, $/therm		
All therms	0.47679	0.47679



Marginal energy costs used in analysis

On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	25.7	75.0	11,550	2,137	1,069	342	(1,019)	392	154	18.4%	75.0
Feb	47,251	100.7	100.7	25.7	75.0	9,975	1,845	1,069	295	(880)	484	133	18.4%	75.0
Mar	52,655	117.5	106.9	31.9	75.0	11,550	2,135	1,069	342	(1,018)	393	154	18.5%	75.0
Apr	50,691	114.6	110.9	35.9	75.0	11,025	2,010	1,069	326	(958)	437	147	18.7%	75.0
May	54,978	138.6	111.6	46.1	65.5	11,499	1,927	933	340	(919)	355	154	20.4%	74.7
June	61,058	164.8	112.0	66.8	45.2	10,530	1,549	644	312	(738)	218	147	23.2%	71.6
July	66,347	179.6	111.5	67.4	44.0	10,374	1,441	627	307	(687)	247	147	24.6%	70.6
Aug	64,247	159.9	112.1	54.5	57.6	11,655	1,674	820	345	(798)	367	161	23.8%	72.4
Sept	58,517	198.8	110.1	50.2	59.9	9,766	1,542	854	289	(735)	408	133	21.6%	73.4
Oct	52,579	124.2	111.5	36.5	75.0	11,550	2,044	1,069	342	(975)	436	154	19.3%	75.0
Nov	50,305	121.6	110.2	35.2	75.0	10,500	1,921	1,069	311	(916)	464	140	18.7%	75.0
Dec	52,126	100.7	100.7	25.7	75.0	10,500	1,943	1,069	311	(926)	453	140	18.4%	75.0
Totals	663,277					130,475	22,167	11,361	3,862	(10,569)	4,654	1,764	20.1%	74.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	4,654
Total Savings	11,641
Savings/ton Installed Cooling	116.41

Retail Store, 33000 SF
Detroit
150 HP constant speed engine, 100 tons cooling, 93 kW generator

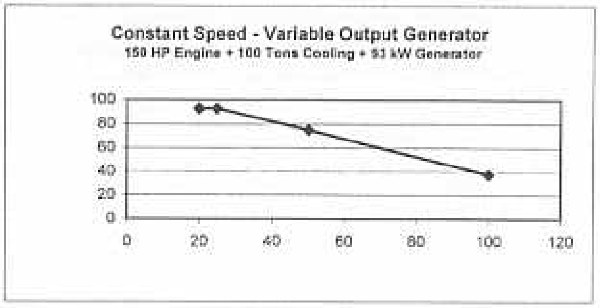
Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   Between 20-25 tons cooling, generator output constant at 93 kW
   Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service

	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours



Marginal energy costs used in analysis

On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms
Jan	52,522	100.7	100.7	100.7	0.0	-	-
Feb	47,251	100.7	100.7	100.7	0.0	-	-
Mar	52,655	117.5	106.9	100.7	6.2	186	26
Apr	50,691	114.6	110.9	99.8	11.1	3,069	428
May	54,978	138.6	111.6	99.8	11.8	10,189	1,350
June	61,058	164.8	112.0	66.9	45.1	13,832	1,783
July	66,347	179.6	111.5	67.5	43.9	12,572	1,656
Aug	64,247	159.9	112.1	99.4	12.8	14,192	1,870
Sept	58,517	198.8	110.1	99.2	11.0	8,985	1,175
Oct	52,579	124.2	111.5	99.8	11.7	6,510	874
Nov	50,305	121.6	110.2	100.7	9.5	1,302	169
Dec	52,126	100.7	100.7	100.7	0.0	-	-
Totals	663,277					70,836	9,331

	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	-	-	-	-	-		
Feb	-	-	-	-	-		
Mar	88	6	(12)	81	2	24.4%	93.0
Apr	158	91	(204)	45	33	24.4%	93.0
May	168	302	(644)	(174)	114	25.8%	89.4
June	643	409	(850)	202	168	26.5%	82.3
July	626	372	(789)	209	168	25.9%	74.8
Aug	182	420	(892)	(290)	180	25.9%	78.8
Sept	156	266	(560)	(138)	109	26.1%	82.4
Oct	167	193	(417)	(57)	70	25.4%	93.0
Nov	136	39	(80)	94	14	26.3%	93.0
Dec	-	-	-	-	-		
Totals	2,324	2,097	(4,449)	(28)	858	25.9%	82.6

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	(28)
Total Savings	6,959
Savings/ton Installed Cooling	69.59

Retail Store, 33000 SF

Detroit

150 HP constant speed engine, 100 tons cooling, 93 kW generator

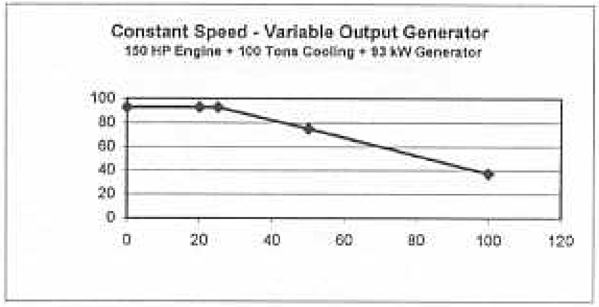
Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   Between 0-25 tons cooling, generator output constant at 93 kW
   Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours



Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	7.7	93.0	14,322	2,137	1,325	424	(1,019)	730	154	22.9%	93.0
Feb	47,251	100.7	100.7	7.7	93.0	12,369	1,845	1,325	366	(880)	812	133	22.9%	93.0
Mar	52,655	117.5	106.9	13.9	93.0	14,322	2,135	1,325	424	(1,018)	731	154	22.9%	93.0
Apr	50,691	114.6	110.9	17.9	93.0	13,671	2,010	1,325	405	(958)	771	147	23.2%	93.0
May	54,978	138.6	111.6	46.5	65.2	13,936	1,927	929	413	(919)	422	154	24.7%	90.5
June	61,058	164.8	112.0	66.9	45.1	12,013	1,549	643	356	(738)	260	147	26.5%	81.7
July	66,347	179.6	111.5	67.5	43.9	10,929	1,441	626	323	(687)	263	147	25.9%	74.3
Aug	64,247	159.9	112.1	54.8	57.3	12,663	1,674	817	375	(798)	394	161	25.8%	78.7
Sept	58,517	198.8	110.1	50.5	59.6	11,307	1,542	850	335	(735)	449	133	25.0%	85.0
Oct	52,579	124.2	111.5	18.5	93.0	14,322	2,044	1,325	424	(975)	775	154	23.9%	93.0
Nov	50,305	121.6	110.2	17.2	93.0	13,020	1,921	1,325	385	(916)	795	140	23.1%	93.0
Dec	52,126	100.7	100.7	7.7	93.0	13,020	1,943	1,325	385	(926)	784	140	22.9%	93.0
Totals	663,277					155,894	22,167	13,141	4,614	(10,569)	7,187	1,764	24.0%	88.4

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	7,187
Total Savings	14,174
Savings/ton Installed Cooling	141.74

Retail Store, 33000 SF
Detroit
200 HP constant speed engine, 100 tons cooling, 75 kW generator

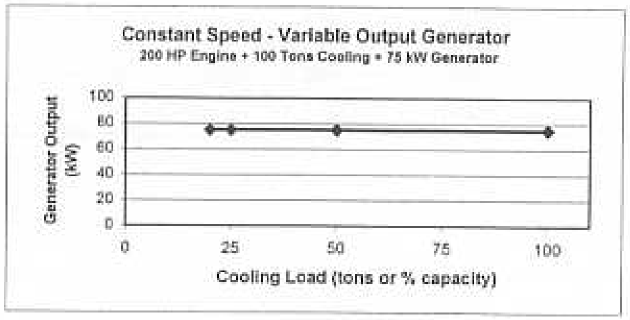
Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate generator at full load continuous output of 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Feb	47,251	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Mar	52,655	117.5	106.9	100.7	6.2	150	35	88	4	(17)	76	2		
Apr	50,691	114.6	110.9	99.8	11.1	2,475	581	158	73	(277)	(45)	33		
May	54,978	138.6	111.6	99.8	11.8	8,550	1,878	168	253	(895)	(474)	114	15.5%	75.0
June	61,058	164.8	112.0	37.0	75.0	12,600	2,560	1,069	373	(1,221)	221	168	16.8%	75.0
July	66,347	179.6	111.5	36.5	75.0	12,600	2,433	1,069	373	(1,160)	282	168	17.7%	75.0
Aug	64,247	159.9	112.1	99.4	12.8	13,500	2,702	182	400	(1,289)	(707)	180	17.0%	75.0
Sept	58,517	198.8	110.1	99.2	11.0	8,175	1,679	156	242	(800)	(402)	109	16.6%	75.0
Oct	52,579	124.2	111.5	99.8	11.7	5,250	1,198	167	155	(571)	(249)	70		
Nov	50,305	121.6	110.2	100.7	9.5	1,050	233	136	31	(111)	56	14	15.4%	75.0
Dec	52,126	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Totals	663,277					64,350	13,299	3,193	1,905	(6,341)	(1,243)	858	16.5%	75.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	(1,243)
Total Savings	5,744
Savings/ton Installed Cooling	57.44

Retail Store, 33000 SF
Detroit
200 HP constant speed engine, 100 tons cooling, 112.5 kW generator

Assumptions

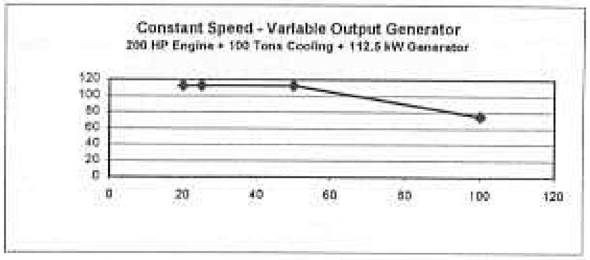
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 112.5 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   Between 20-50 tons cooling, 112.5 kW
   Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   At full cooling capacity,100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Feb	47,251	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Mar	52,655	117.5	106.9	100.7	6.2	214	35	88	6	(17)	78	2	20.7%	106.9
Apr	50,691	114.6	110.9	99.8	11.1	3,577	581	158	106	(277)	(13)	33	21.0%	108.4
May	54,978	138.6	111.6	99.8	11.8	10,937	1,676	168	324	(895)	(403)	101	19.9%	108.3
June	61,058	164.8	112.0	29.3	82.7	15,613	2,560	1,179	462	(1,221)	420	147	20.8%	106.2
July	66,347	179.6	111.5	29.9	81.5	15,598	2,433	1,162	462	(1,160)	464	147	21.9%	106.1
Aug	64,247	159.9	112.1	99.4	12.8	16,994	2,702	182	503	(1,289)	(604)	158	21.5%	107.6
Sept	58,517	198.8	110.1	99.2	11.0	10,406	1,679	156	308	(800)	(336)	97	21.2%	107.3
Oct	52,579	124.2	111.5	99.8	11.7	7,018	1,198	167	208	(571)	(197)	65	20.0%	108.0
Nov	50,305	121.6	110.2	100.7	9.5	1,300	233	136	38	(111)	63	12	19.0%	108.3
Dec	52,126	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-		
Totals	653,277					81,658	13,299	3,396	2,417	(6,341)	(528)	762	21.0%	107.2

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	(528)
Total Savings	6,459
Savings/ton Installed Cooling	64.59

Retail Store, 33000 SF

Detroit

200 HP constant speed engine, 100 tons cooling, 112.5 kW generator

Generator operates all on-peak hours

Assumptions

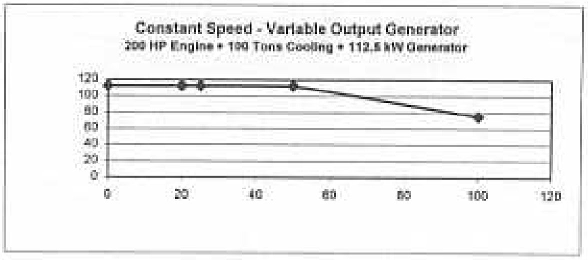
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 112.5 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   - Between 0-50 tons cooling, 112.5 kW
   - Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   - At full cooling capacity,100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis

On-Peak Demand Charge	14.25	$/kW
On-Peak Energy Cost	0.0296	$/kWh
Gas Cooling Rate	0.47679	$/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	0.0	100.7	15,397	2,849	1,435	456	(1,358)	532	154	18.4%	100.0
Feb	47,251	100.7	100.7	0.0	100.7	13,302	2,461	1,435	394	(1,173)	655	133	18.5%	100.0
Mar	52,655	117.5	106.9	0.0	106.9	15,353	2,847	1,523	454	(1,358)	620	154	18.4%	99.7
Apr	50,691	114.6	110.9	0.0	110.9	14,865	2,690	1,581	440	(1,283)	738	147	18.9%	101.1
May	54,978	138.6	111.6	8.6	103.0	16,128	2,639	1,468	477	(1,258)	687	154	20.9%	104.7
June	61,058	164.8	112.0	29.3	82.7	15,613	2,229	1,179	462	(1,063)	578	147	23.9%	106.2
July	66,347	179.6	111.5	29.9	81.5	15,598	2,121	1,162	462	(1,011)	612	147	25.1%	106.1
Aug	64,247	159.9	112.1	17.0	95.1	17,288	2,419	1,355	512	(1,153)	713	161	24.4%	107.4
Sept	58,517	198.8	110.1	12.7	97.4	13,899	2,157	1,388	411	(1,028)	771	133	22.0%	104.5
Oct	52,579	124.2	111.5	0.0	111.5	15,748	2,756	1,589	466	(1,314)	741	154	19.5%	102.3
Nov	50,305	121.6	110.2	0.0	110.2	14,024	2,568	1,571	415	(1,224)	761	140	18.6%	100.2
Dec	52,126	100.7	100.7	0.0	100.7	13,990	2,590	1,435	414	(1,235)	614	140	18.4%	99.9
Totals	663,277					181,206	30,325	17,120	5,364	(14,459)	8,025	1,764	20.4%	102.7

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Generator	8,025
Total Savings	15,012
Savings/ton Installed Cooling	150.12

Retail Store, 33000 SF
Detroit
150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator
Generator operates all on-peak hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and variable output during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Taco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours
8. Chillers sized at 104 tons

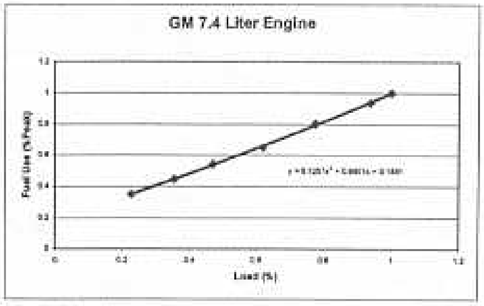
Detroit Edison Rate D6-TOU Primary Service

	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Michigan Consolidated Gas Rate 1

Energy, $/therm		
All therms	0.47679	0.47679



Marginal energy costs used in analysis

On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Chil+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	65.7	35.0	5,390	920	499	160	(439)	220	154	35.0
Feb	47,251	100.7	100.7	65.7	35.0	4,655	794	499	138	(379)	258	133	35.0
Mar	52,655	117.5	106.9	71.9	35.0	5,390	921	499	160	(439)	219	154	35.0
Apr	50,691	114.6	110.9	75.9	35.0	5,145	901	499	152	(430)	221	147	35.0
May	54,978	138.6	111.6	76.6	35.0	5,390	965	499	160	(460)	198	154	35.0
June	61,058	164.8	112.0	77.0	35.0	5,145	915	499	152	(436)	215	147	35.0
July	66,347	179.6	111.5	76.5	35.0	5,145	941	499	152	(449)	202	147	35.0
Aug	64,247	159.9	112.1	77.1	35.0	5,635	1,031	499	167	(491)	174	161	35.0
Sept	58,517	198.8	110.1	75.1	35.0	4,655	830	499	138	(396)	241	133	35.0
Oct	52,579	124.2	111.5	76.5	35.0	5,390	947	499	160	(451)	207	154	35.0
Nov	50,305	121.6	110.2	75.2	35.0	4,900	839	499	145	(400)	244	140	35.0
Dec	52,126	100.7	100.7	65.7	35.0	4,900	836	499	145	(399)	245	140	35.0
Totals	663,277					61,740	10,841	5,985	1,828	(5,169)	2,644	1,764	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
Hybrid Cooling Plant	64,063
Savings	6,987
Additional Savings with Chil+Gen	2,644
Total Savings	9,631
Savings/ton Installed Cooling	96.31

Additional Gas vs. Variable Speed Cooling	1043 therms
	40.53% more
Additional Gas to Run Generator	9798 therms

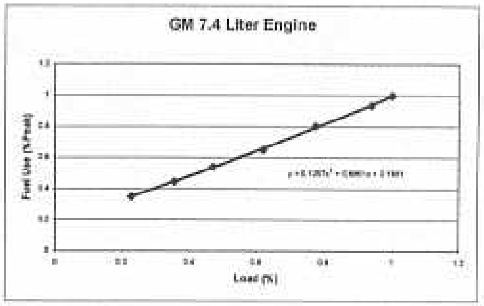
Retail Store, 33000 SF
Detroit
150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator
Generator operates all cooling hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogenerator is gas engine cooling (1.46 COP, 0.02 electric parasitics) and generator
3. 150 HP gas engine runs at constant speed and variable output during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all cooling hours
8. Chillers sized at 104 tons

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis
- On-Peak Demand Charge: 14.25 $/kW
- On-Peak Energy Cost: 0.0296 $/kWh
- Gas Cooling Rate: 0.47679 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Cooling Hours kW	Building Demand During Cooling Hours With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Chil+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	52,522	100.7	0.0	0.0	0.0	-	-	-	-	-	-	-	#DIV/0!
Feb	47,251	100.7	0.0	0.0	0.0	-	-	-	-	-	-	-	#DIV/0!
Mar	52,628	110.6	110.6	75.6	35.0	210	40	499	6	(19)	486	6	35.0
Apr	50,678	111.0	111.0	76.0	35.0	1,295	249	499	38	(119)	419	37	35.0
May	53,653	111.9	111.9	76.9	35.0	7,980	1,399	499	236	(667)	68	228	35.0
June	55,087	112.0	112.0	77.0	35.0	17,675	3,011	499	523	(1,436)	(414)	505	35.0
July	57,078	111.4	111.4	76.4	35.0	19,915	3,436	499	589	(1,638)	(550)	569	35.0
Aug	57,085	112.1	112.1	77.1	35.0	18,305	3,153	499	542	(1,503)	(463)	523	35.0
Sept	52,814	112.0	112.0	77.0	35.0	12,040	2,053	499	356	(979)	(124)	344	35.0
Oct	52,399	111.5	111.5	76.5	35.0	3,185	565	499	94	(269)	324	91	35.0
Nov	50,259	110.3	110.3	75.3	35.0	665	112	499	20	(54)	465	19	35.0
Dec	52,126	100.7	0.0	0.0	0.0	-	-	-	-	-	-	-	#DIV/0!
Totals	633,580					81,270	14,018	4,489	2,406	(6,684)	211	2,322	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
All Gas Cooling	63,750
Savings	7,300
Additional Savings with Chil+Gen	211
Total Savings	7,511
Savings/ton Installed Cooling	75.11

Additional Gas vs. Variable Speed Cooling	2290 therms
	36.16% more
Additional Gas to Run Generator	11728 therms

Retail Store, 33000 SF

Detroit

150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator

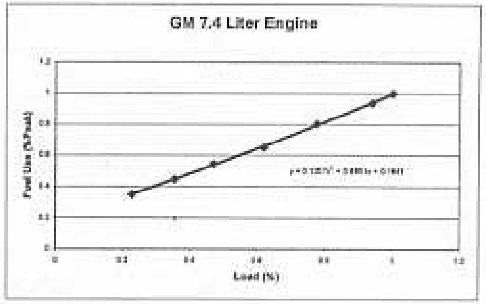
Generator operates all on-peak cooling hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogenerator is gas engine cooling (1.46 COP, 0.02 electric parasitics) and generator
3. 150 HP gas engine runs at constant speed and variable output during cooling hours
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak cooling hours
8. Chillers sized at 104 tons

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours



Marginal energy costs used in analysis	
On-Peak Demand Charge	14.25 $/kW
On-Peak Energy Cost	0.0296 $/kWh
Gas Cooling Rate	0.47679 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Cooling Hours kW	Building Demand During Cooling Hours With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Chil+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-	#DIV/0!
Feb	47,251	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-	#DIV/0!
Mar	52,628	110.6	106.9	100.7	6.2	70	25	89	2	(12)	79	2	35.0
Apr	50,678	111.0	111.0	99.8	11.1	1,155	235	159	34	(112)	81	33	35.0
May	53,653	111.9	111.7	99.8	11.8	3,535	947	169	105	(452)	(178)	101	35.0
June	55,087	112.0	112.0	77.0	35.0	5,145	1,719	499	152	(820)	(169)	147	35.0
July	57,078	111.4	111.4	76.4	35.0	5,145	1,888	499	152	(900)	(249)	147	35.0
Aug	57,085	112.1	112.1	99.4	12.8	5,530	1,824	182	164	(869)	(524)	158	35.0
Sept	52,814	112.0	110.1	99.2	11.0	3,395	1,147	157	100	(547)	(290)	97	35.0
Oct	52,399	111.5	111.5	99.8	11.7	2,275	473	167	67	(226)	9	65	35.0
Nov	50,259	110.3	110.3	100.7	9.6	420	88	136	12	(42)	107	12	35.0
Dec	52,126	100.7	100.7	100.7	0.0	-	-	-	-	-	-	-	#DIV/0!
Totals	633,580					26,670	8,346	2,056	789	(3,979)	(1,134)	762	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
All Gas Cooling	63,750
Savings	7,300
Additional Savings with Chil+Gen	(1,134)
Total Savings	6,166
Savings/ton Installed Cooling	61.66

Additional Gas vs. Variable Speed Cooling	4532 therms
	71.56% more
Additional Gas to Run Generator	3814 therms

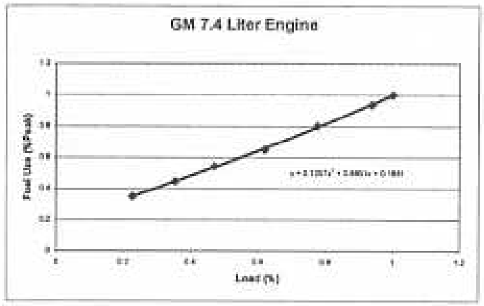
Retail Store, 33000 SF
Detroit
150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator
Generator operates all on-peak hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogenerator is gas engine cooling (1.46 COP, 0.02 electric parasitics) and generator
3. 150 HP gas engine runs at constant speed and variable output during cooling hours
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours
8. Chillers sized at 104 tons

Detroit Edison Rate D6-TOU Primary Service	Summer	Winter
Demand, $/kW		
For Primary Service	3.75	3.75
On-Peak	14.25	14.25
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.0296	0.0296
Off-Peak	0.0266	0.0266
Michigan Consolidated Gas Rate 1		
Energy, $/therm		
All therms	0.47679	0.47679

On-Peak period - Noon to 7PM weekdays, all year
Off-Peak period - all other hours

Marginal energy costs used in analysis
On-Peak Demand Charge 14.25 $/kW
On-Peak Energy Cost 0.0296 $/kWh
Gas Cooling Rate 0.47679 $/therm



Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

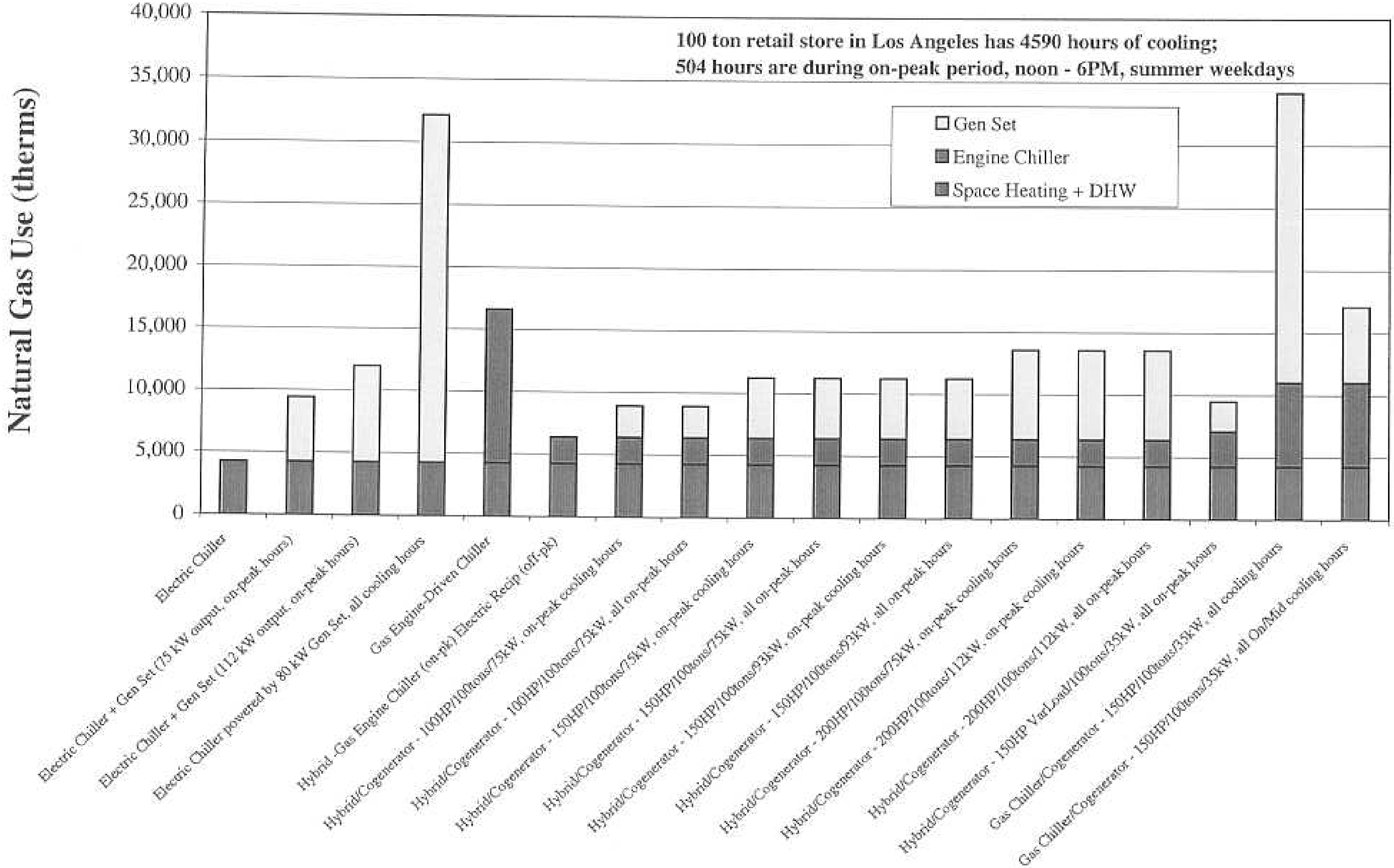
	Building Energy Usage kWh	Building Demand kW	Building Demand During Cooling Hours kW	Building Demand During Cooling Hours With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Chil+Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	52,522	100.7	100.7	65.7	35.0	5,390	920	499	160	(439)	220	154	35.0
Feb	47,251	100.7	100.7	65.7	35.0	4,655	794	499	138	(379)	258	133	35.0
Mar	52,628	110.6	106.9	71.9	35.0	5,390	933	499	160	(445)	213	154	35.0
Apr	50,678	111.0	111.0	76.0	35.0	5,145	915	499	152	(436)	215	147	35.0
May	53,653	111.9	111.7	76.7	35.0	5,390	1,264	499	160	(602)	56	154	35.0
June	55,087	112.0	112.0	77.0	35.0	5,145	1,719	499	152	(820)	(169)	147	35.0
July	57,078	111.4	111.4	76.4	35.0	5,145	1,888	499	152	(900)	(249)	147	35.0
Aug	57,085	112.1	112.1	77.1	35.0	5,635	1,841	499	167	(878)	(212)	161	35.0
Sept	52,814	112.0	110.1	75.1	35.0	4,655	1,362	499	138	(650)	(13)	133	35.0
Oct	52,399	111.5	111.5	76.5	35.0	5,390	1,005	499	160	(479)	179	154	35.0
Nov	50,259	110.3	110.3	75.3	35.0	4,900	852	499	145	(406)	237	140	35.0
Dec	52,126	100.7	100.7	65.7	35.0	4,900	836	499	145	(399)	245	140	35.0
Totals	633,580					61,740	14,330	5,985	1,828	(6,832)	980	1,764	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	71,050
All Gas Cooling	63,750
Savings	7,300
Additional Savings with Chil+Gen	980
Total Savings	8,280
Savings/ton Installed Cooling	82.80

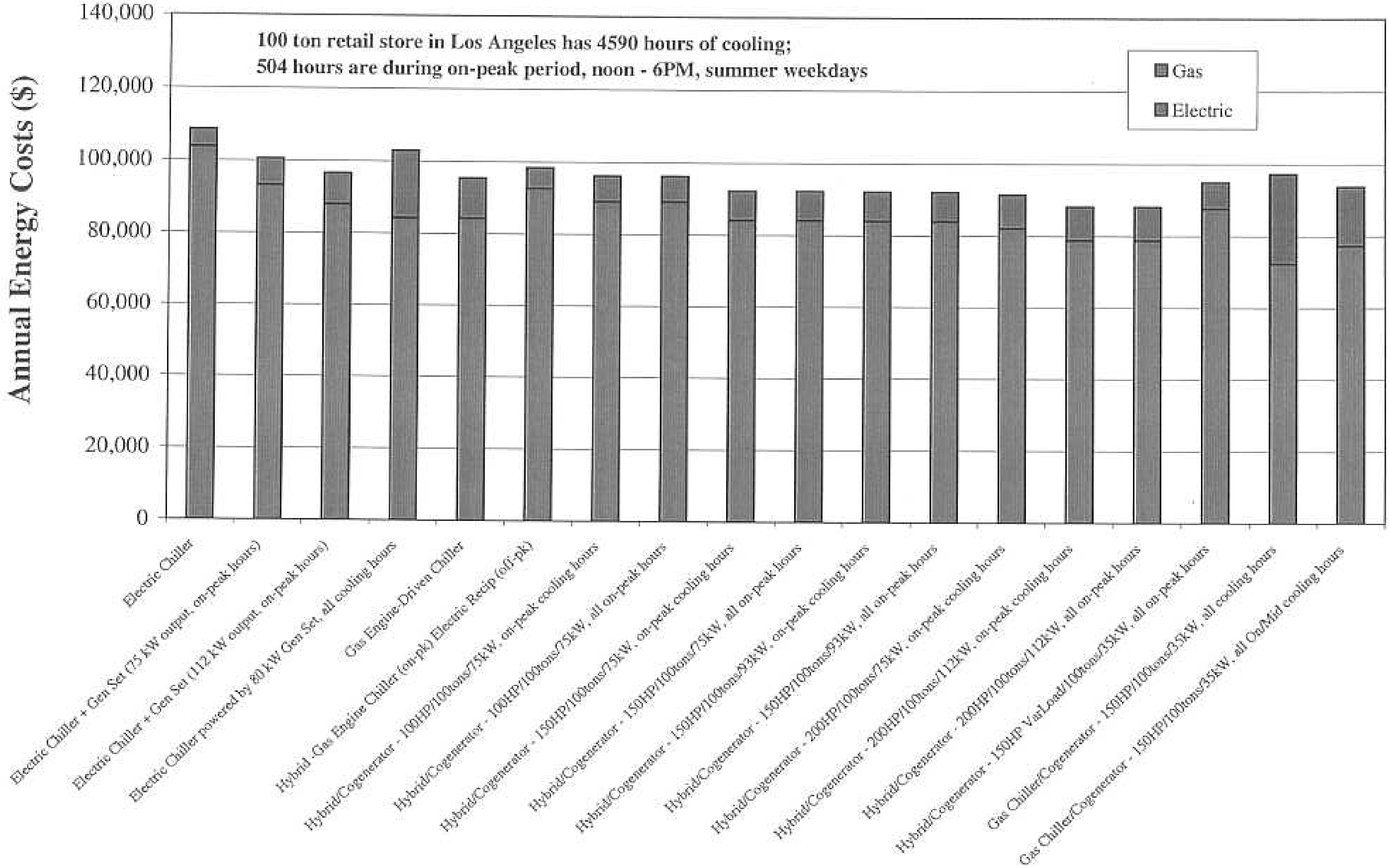
Additional Gas vs. Variable Speed Cooling 4532 therms
71.56% more
Additional Gas to Run Generator 9798 therms

Appendix C
Los Angeles Suburb
Annual Energy Usage, Costs and Savings
for Various Cooling Plant Scenarios
for Retail Store with 100 Tons Cooling

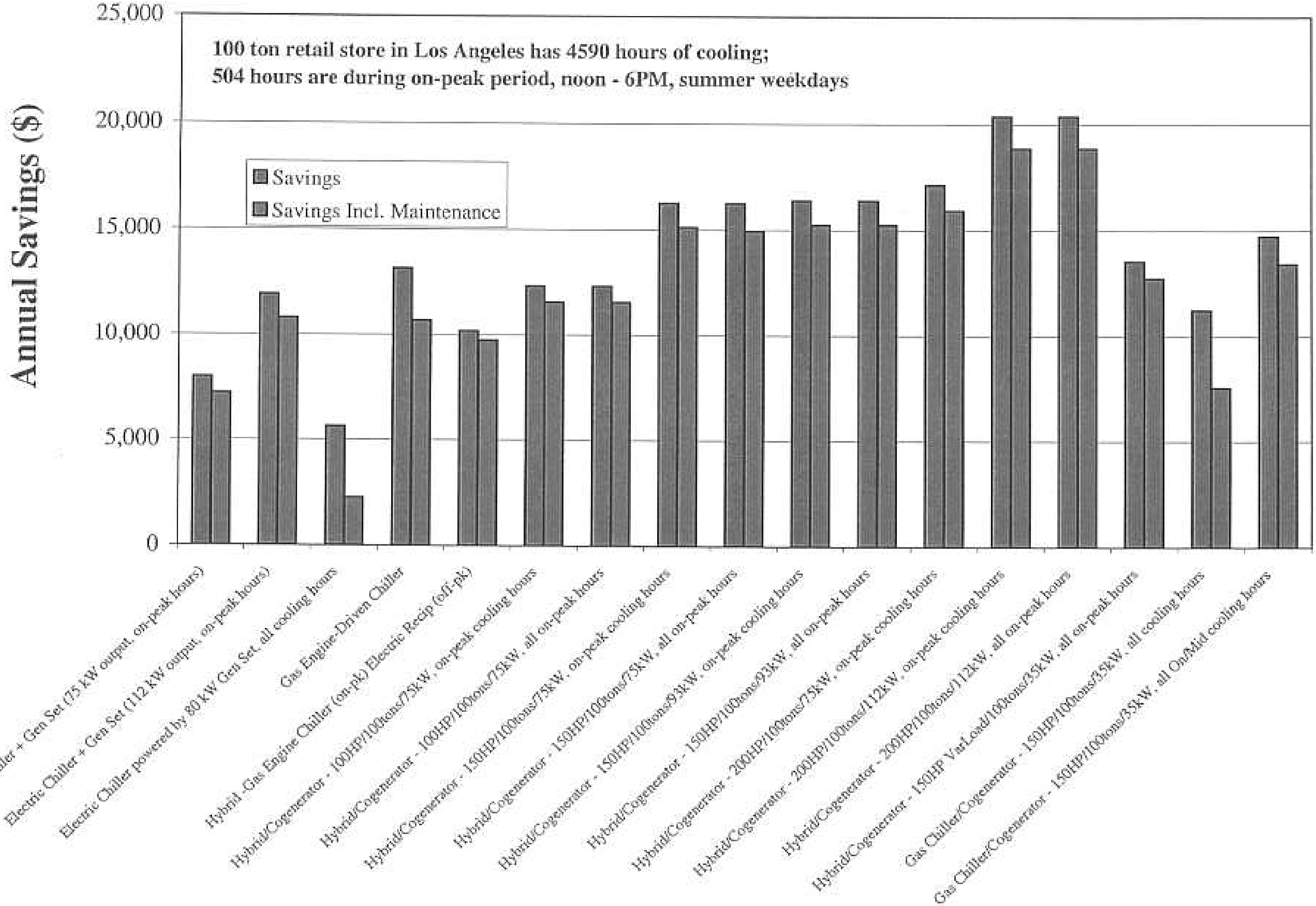
Los Angeles Annual Natural Gas Use for Various Cooling Plant Scenarios 100 Ton Retail Store



Los Angeles Annual Energy Costs for Various Cooling Plant Scenarios 100 Ton Retail Store



Los Angeles Savings Versus All Electric for various Cooling Plant Scenarios 100 Ton Retail Store



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Los Angeles

75 kW natural gas generator

Assumptions
1. Building cooled with one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. One engine-generator set operating during on-peak hours at full output
3. Engine-generator fuel input efficiency at full load, 25%
4. Generator capacity, 75 kW

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07611
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Marginal energy costs used in analysis

On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for an electric cooling plant with engine-generator operating during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	79,198	201.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	70,387	198.9	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	81,472	196.0	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Apr	81,266	206.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
May	89,523	213.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
June	91,887	205.7	205.7	130.7	75.0	9,450	1,290	1230	1408	(643)	1994	126	126	25.0%	75.0
July	101,156	211.8	211.8	136.8	75.0	9,450	1,290	1230	1408	(643)	1994	126	126	25.0%	75.0
Aug	105,040	228.6	228.6	153.6	75.0	10,350	1,413	1230	1542	(704)	2067	138	138	25.0%	75.0
Sept	97,899	219.3	219.3	144.3	75.0	8,550	1,167	1230	1274	(582)	1922	114	114	25.0%	75.0
Oct	96,868	207.8	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Nov	83,634	199.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Dec	82,527	202.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Totals	1,060,857					37,800	5,160	4,920	5,631	(2,573)	7,978	504	504	25.0%	75.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Savings from E-G Operation	7,978
Revised Annual Energy Cost	100,449

Retail Store, 50000 SF

Los Angeles

80 kW natural gas generator powering electric chiller during on-peak hours

Assumptions

1. One engine-generator set operating hours when cooling required during on-peak period
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 80 kW
4. E-G must operate to provide power to chiller any time chiller operates during on-peak period
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

	Summer	Winter
Southern California Edison Rate TOU-GS-2B		
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Marginal energy costs used in analysis

On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for an electric cooling plant powered from engine-generator during on-peak hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	79,198	201.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	70,387	198.9	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	81,472	196.0	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Apr	81,266	206.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
May	89,523	213.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
June	91,887	205.7	205.7	149.7	55.9	5,073	811	918	756	(404)	1269	126	126	21.3%	40.3
July	101,156	211.8	211.8	150.0	61.8	6,217	918	1014	926	(458)	1482	126	126	23.1%	49.3
Aug	105,040	228.6	228.6	150.6	78.0	7,828	1,116	1279	1166	(557)	1888	138	138	23.9%	56.7
Sept	97,899	219.3	219.3	153.2	66.1	5,582	828	1084	831	(413)	1503	114	114	23.0%	49.0
Oct	96,868	207.8	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Nov	83,634	199.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Dec	82,527	202.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Totals	1,060,857					24,700	3,673	4,294	3,679	(1,831)	6,142	504	504	23.0%	49.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Savings from E-G Operation	6,142
Revised Annual Energy Cost	102,285

Retail Store, 50000 SF

Los Angeles

80 kW natural gas generator powering electric chiller

All Cooling Hours

Assumptions

1. One engine-generator set operating hours when cooling required
2. Engine-generator fuel input efficiency at full load, 25%
3. Generator capacity, 80 kW
4. E-G must operate to provide power to chiller any time chiller operates
5. Building cooled with electric screw chiller, 0.79 kW/ton
6. E-G provides power for electric chiller
7. Efficiency of E-G varies from 25% at 100% output to 15% at 25% output

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Marginal energy costs used in analysis

On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for an electric cooling plant powered from engine-generator during cooling hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours in On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	79,198	201.3	201.3	152.7	48.6	4,615	847	796	686	(422)	1061	156	156	18.6%	29.6
Feb	70,387	198.9	198.9	152.5	46.5	3,808	702	762	567	(350)	980	130	130	18.5%	29.3
Mar	81,472	196.0	196.0	152.5	43.5	6,529	1,233	713	972	(615)	1070	234	234	18.1%	27.9
Apr	81,266	206.3	206.3	153.1	53.2	8,822	1,603	873	1314	(799)	1388	292	292	18.8%	30.2
May	89,523	213.7	213.7	150.2	63.5	13,714	2,384	1042	2043	(1188)	1896	412	412	19.6%	33.3
June	91,887	205.7	205.7	149.7	55.9	17,350	2,942	918	2584	(1467)	2035	494	496	20.1%	35.1
July	101,156	211.8	211.8	150.1	61.7	23,933	3,807	1011	3565	(1898)	2678	587	588	21.5%	40.8
Aug	105,040	228.6	228.6	150.6	78.0	26,734	4,127	1279	3982	(2058)	3203	601	601	22.1%	44.5
Sept	97,899	219.3	219.3	153.3	65.9	23,165	3,689	1081	3451	(1839)	2693	569	566	21.4%	40.7
Oct	96,868	207.8	207.8	152.8	55.0	19,648	3,272	902	2927	(1631)	2197	537	537	20.5%	36.6
Nov	83,634	199.5	199.5	152.7	46.8	10,939	1,912	768	1629	(953)	1444	332	332	19.5%	32.9
Dec	82,527	202.5	202.5	152.7	49.8	7,643	1,372	817	1139	(684)	1271	246	246	19.0%	31.1
Totals	1,060,857					166,899	27,890	10,961	24,861	(13,906)	21,917	4,590	4,590	20.4%	36.4

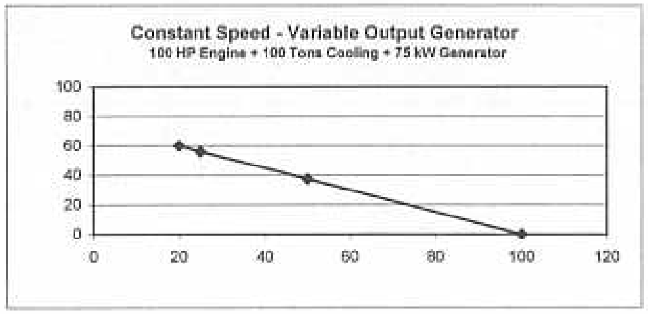
Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Savings from E-G Operation	21,917
Revised Annual Energy Cost	86,510

Retail Store, 50000 SF
Los Angeles
100 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

	Summer	Winter
Southern California Edison Rate TOU-GS-2B		
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.08613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal energy costs used in analysis

On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	68,638	190.2	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
May	84,458	207.8	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
June	82,682	193.5	152.2	128.0	24.2	5,499	775	396	819	(386)	829	126	126	24.2%	43.6
July	89,896	205.2	152.4	134.0	18.4	4,002	632	301	596	(315)	583	126	126	21.6%	31.8
Aug	92,456	223.7	152.7	151.9	0.8	3,349	566	14	499	(282)	230	138	138	20.2%	24.3
Sept	87,372	212.6	155.7	141.0	14.8	3,694	577	242	550	(287)	505	114	114	21.9%	32.4
Oct	90,514	200.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Totals	988,612					16,544	2,548	953	2,464	(1,271)	2,147	504	504	22.2%	32.8

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	2,147
Total Savings	12,196
Savings/ton Installed Cooling	121.96

Retail Store, 50000 SF
Los Angeles
100 HP constant speed engine, 100 tons cooling, 75 kW generator runs during all on-peak hours

Assumptions

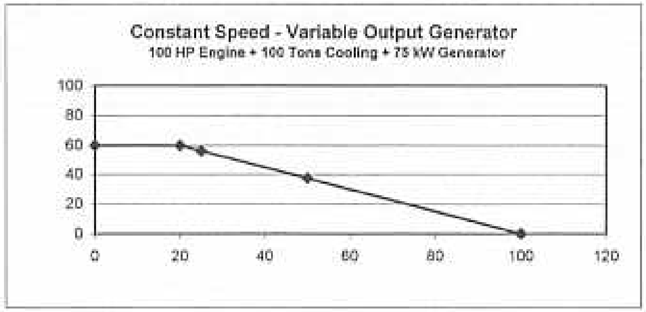
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 100 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 925,000 Btu/hr fuel consumption for 100 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. After satisfying cooling load, unused engine HP any hour can be used to operate generator; generator output varies with unused engine capacity
7. Generator operates every hour during on-peak period even if cooling load is below 20%. Below 20% cooling capacity, assume cooling system operates operates at 20% capacity to account for fuel consumption

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314

Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A



Marginal energy costs used in analysis		
On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Number of Hours In On-Peak	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
May	84,458	207.8	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
June	82,682	193.5	152.2	128.0	24.2	5,459	775	396	819	(386)	829	126	126	24.2%	43.6
July	89,896	205.2	152.4	134.0	18.4	4,002	632	301	596	(315)	583	126	126	21.6%	31.8
Aug	92,456	223.7	152.7	151.9	0.8	3,349	568	14	499	(282)	230	138	138	20.2%	24.3
Sept	87,372	212.6	155.7	141.0	14.8	3,694	577	242	550	(287)	505	114	114	21.9%	32.4
Oct	90,514	200.7	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	0	0	0	0	0	0		
Totals	988,812					16,544	2,548	953	2,464	(1,271)	2,147	504	504	22.2%	32.6

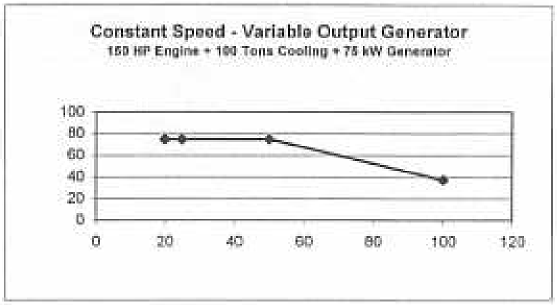
Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	2,147
Total Savings	12,196
Savings/ton Installed Cooling	121.96

Retail Store, 50000 SF
Los Angeles
150 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   Between 20-50 tons cooling, 75 kW
   Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal costs used in analysis
- On-Peak Demand Charge 16.4 $/kW
- On-Peak Energy Cost 0.14896 $/kWh
- Gas Cooling Rate 0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	76,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	90.5	61.7	9,341	1,357	1,011	1,391	(677)	1,726	126	23.5%	74.1
July	89,896	205.2	152.4	96.5	55.9	8,619	1,214	916	1,284	(605)	1,595	126	24.2%	68.4
Aug	92,456	223.7	152.7	114.4	38.3	8,494	1,204	629	1,265	(600)	1,294	138	24.1%	61.6
Sept	87,372	212.6	155.7	103.5	52.3	7,812	1,104	657	1,164	(550)	1,470	114	24.2%	68.5
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					34,266	4,879	3,413	5,104	(2,433)	6,085	504	24.0%	68.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	6,085
Total Savings	16,134
Savings/ton Installed Cooling	161.34

Retail Store, 50000 SF
Los Angeles
150 HP constant speed engine, 100 tons cooling, 75 kW generator
Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate a 75 kW generator as follows
   Between 0-50 tons cooling, 75 kW
   Between 50-100 tons cooling, generator output varies proportionally from 75 kW down to 37.5 kW
   At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours

Southern California Edison Rate TOU-GS-2B

	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271

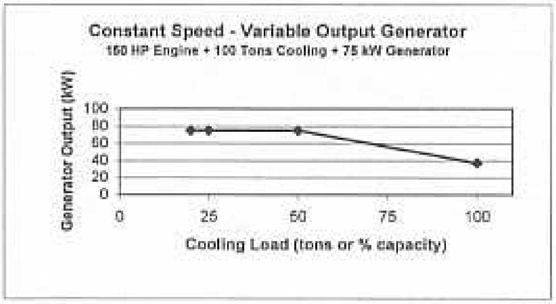
On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Southern California Gas Rate GN-10

	Summer	Winter
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314

Southern California Gas Rate G-AC Gas Cooling

	Summer	Winter
All cooling gas	0.49858	N/A



Marginal costs used in analysis

On-Peak Demand Charge	16.4 $/kW
On-Peak Energy Cost	0.14896 $/kWh
Gas Cooling Rate	0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	186.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	90.5	61.7	9,341	1,357	1,011	1,291	(577)	1,726	126	23.5%	74.1
July	89,896	205.2	152.4	96.5	55.9	8,619	1,214	916	1,284	(605)	1,595	126	24.2%	68.4
Aug	92,456	223.7	152.7	114.4	38.3	8,494	1,204	629	1,265	(600)	1,294	138	24.1%	61.6
Sept	87,372	212.6	155.7	103.5	52.3	7,812	1,104	857	1,164	(550)	1,470	114	24.2%	68.5
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					34,266	4,879	3,413	5,104	(2,433)	6,085	504	24.0%	68.0

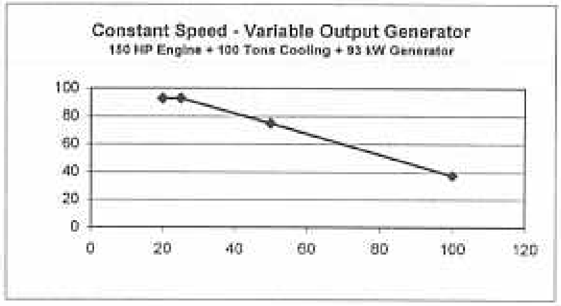
Summary	Annual Energy $
Baseline Electric Cooling Plant	106,427
Hybrid Cooling Plant	96,378
Savings	10,049
Additional Savings with Generator	6,085
Total Savings	16,134
Savings/ton Installed Cooling	161.34

Retail Store, 50000 SF
Los Angeles
150 HP constant speed engine, 100 tons cooling, 93 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,367,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   Between 20-25 tons cooling, generator output constant at 93 kW
   Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   At full cooling capacity,100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49859	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal costs used in analysis
On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	90.8	61.3	10,133	1,357	1,006	1,509	(677)	1,838	126	25.5%	80.4
July	89,696	205.2	152.4	96.8	55.6	8,674	1,214	912	1,292	(605)	1,599	126	24.4%	68.8
Aug	92,456	223.7	152.7	114.4	38.3	8,479	1,204	628	1,263	(600)	1,291	138	24.0%	61.4
Sept	87,372	212.6	155.7	103.6	52.1	7,920	1,104	855	1,160	(550)	1,484	114	24.5%	69.5
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					35,206	4,879	3,401	5,244	(2,433)	6,213	504	24.6%	69.9

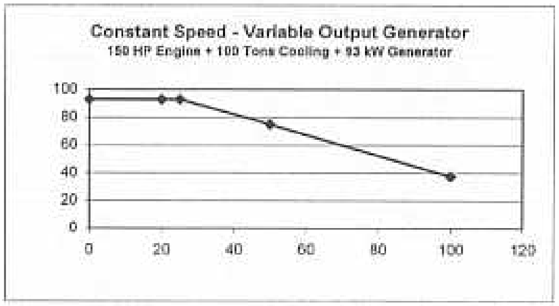
Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	6,213
Total Savings	16,262
Savings/ton Installed Cooling	162.62

Retail Store, 50000 SF
Los Angeles
150 HP constant speed engine, 100 tons cooling, 93 kW generator
Generator operates all on-peak hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,367,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 93 kW capacity
6. Oversized engine has HP available to operate a 93 kW generator as follows
   Between 0-25 tons cooling, generator output constant at 93 kW
   Between 25-100 tons cooling, generator output varies proportionally from 93 kW down to 37.5 kW
   At full cooling capacity, 100 tons, generator can output 37.5 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06813	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal costs used in analysis
- On-Peak Demand Charge: 16.4 $/kW
- On-Peak Energy Cost: 0.14896 $/kWh
- Gas Cooling Rate: 0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	90.8	61.3	10,133	1,357	1,006	1,509	(677)	1,838	126	25.5%	80.4
July	89,896	205.2	152.4	96.8	55.6	8,674	1,214	912	1,292	(605)	1,599	126	24.4%	68.8
Aug	92,456	223.7	152.7	114.4	38.3	8,479	1,204	628	1,263	(600)	1,291	138	24.0%	61.4
Sept	87,372	212.6	155.7	103.6	52.1	7,920	1,104	855	1,180	(550)	1,484	114	24.5%	69.5
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	968,812					35,206	4,879	3,401	5,244	(2,433)	6,213	504	24.6%	69.9

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	6,213
Total Savings	16,262
Savings/ton Installed Cooling	162.62

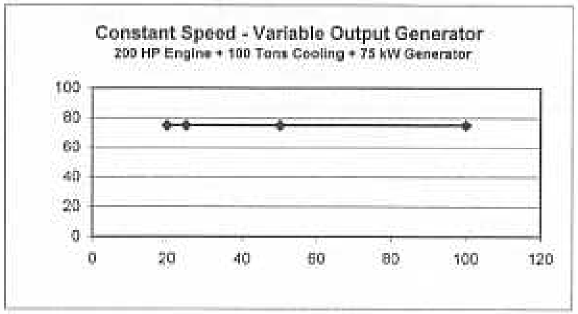
Retail Store, 50000 SF
Los Angeles
200 HP constant speed engine, 100 tons cooling, 75 kW generator

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate generator at full load continuous output of 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal costs used in analysis

On-Peak Demand Charge	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,662	193.5	152.2	77.2	75.0	9,450	1,940	1,230	1,408	(967)	1,670	126	16.6%	75.0
July	89,896	205.2	152.4	77.4	75.0	9,450	1,797	1,230	1,408	(896)	1,742	126	17.9%	75.0
Aug	92,456	223.7	152.7	77.7	75.0	10,350	1,842	1,230	1,542	(918)	1,853	138	19.2%	75.0
Sept	87,372	212.6	155.7	80.7	75.0	8,550	1,631	1,230	1,274	(813)	1,690	114	17.9%	75.0
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					37,800	7,210	4,920	5,631	(3,595)	6,956	504	17.9%	75.0

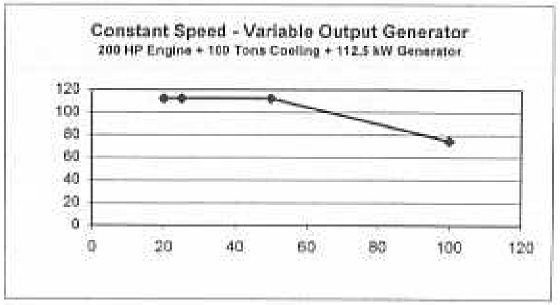
Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	6,956
Total Savings	17,005
Savings/ton Installed Cooling	170.05

Retail Store, 50000 SF
Los Angeles
200 HP constant speed engine, 100 tons cooling, 112.5 kW generator

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption when cooling needed during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   Between 20-50 tons cooling, 112.5 kW
   Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   At full cooling capacity,100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07811
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79567	0.79567
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September



Marginal costs used in analysis
- On-Peak Demand Charge: 16.4 $/kW
- On-Peak Energy Cost: 0.14896 $/kWh
- Gas Cooling Rate: 0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,638	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	53.0	99.2	14,066	1,940	1,626	2,095	(967)	2,754	126	24.7%	111.6
July	89,896	205.2	152.4	59.0	93.4	13,344	1,797	1,531	1,988	(895)	2,623	126	25.3%	105.9
Aug	92,456	223.7	152.7	76.9	75.8	13,669	1,842	1,244	2,036	(918)	2,361	138	25.3%	99.1
Sept	87,372	212.6	155.7	66.0	89.8	12,087	1,631	1,472	1,800	(813)	2,459	114	25.3%	106.0
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					53,166	7,210	5,873	7,920	(3,595)	10,198	504	25.2%	105.5

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	10,198
Total Savings	20,247
Savings/ton Installed Cooling	202.47

Retail Store, 50000 SF
Los Angeles
200 HP constant speed engine, 100 tons cooling, 112.5 kW generator
Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 200 HP gas engine runs at constant speed and fuel consumption during on-peak period
4. 1,850,000 Btu/hr fuel consumption for 200 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, variable output generator with 75 kW capacity
6. Oversized engine has HP available to operate 112.5 kW generator as follows
   - Between 0-50 tons cooling, 112.5 kW
   - Between 50-100 tons cooling, generator output varies proportionally from 112.5 kW down to 75 kW
   - At full cooling capacity, 100 tons, generator can output 75 kW
7. Below 20% cooling capacity, cooling system will cycle; only operate generator during hours when part load cooling capacity is above 20%

Southern California Edison Rate TOU-GS-2B

	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07611
Off-Peak	0.04271	0.04271

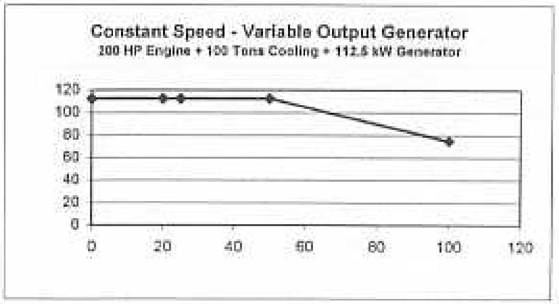
On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Southern California Gas Rate GN-10

Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314

Southern California Gas Rate G-AC Gas Cooling

All cooling gas	0.49858	N/A



Marginal costs used in analysis

On-Peak Demand Charge	16.4 $/kW
On-Peak Energy Cost	0.14896 $/kWh
Gas Cooling Rate	0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additional Gas Cost to Run Engine-Gen $	Net Add'l Savings $	Number Hours Generator Operating	Average Generator Efficiency %	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-		
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-		
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-		
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-		
June	82,682	193.5	152.2	53.0	99.2	14,066	1,940	1,626	2,095	(967)	2,754	128	24.7%	111.6
July	89,896	205.2	152.4	59.0	93.4	13,344	1,797	1,531	1,988	(896)	2,623	126	25.3%	105.9
Aug	92,456	223.7	152.7	76.9	75.8	13,669	1,842	1,244	2,036	(918)	2,361	138	25.3%	99.1
Sept	87,372	212.6	155.7	66.0	89.8	12,087	1,631	1,472	1,800	(813)	2,459	114	25.3%	106.0
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-		
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-		
Dec	79,447	193.9	0.0	0.0	0.0	-	-	-	-	-	-	-		
Totals	988,812					53,166	7,210	5,873	7,920	(3,595)	10,198	504	25.2%	105.5

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Generator	10,198
Total Savings	20,247
Savings/ton Installed Cooling	202.47

Retail Store, 50000 SF

Los Angeles

150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator

Generator operates all on-peak hours

Assumptions

1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Hybrid system is gas engine cooling (1.46 COP, 0.02 electric parasitics) and electric reciprocating cooling (0.79 kW/ton)
3. 150 HP gas engine runs at constant speed and variable output during on-peak period
4. 1,387,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Teco CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data or GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all on-peak hours
8. Chillers sized at 104 tons

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $.kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06513	0.07811
Off-Peak	0.04271	0.04271

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314

Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

Marginal costs used in analysis	
On-Peak Demand Charge	16.4 $/kW
On-Peak Energy Cost	0.14896 $/kWh
Gas Cooling Rate	0.49858 $/therm

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During Peak Period kW	Building Demand During Peak Period With Generator Operating kW	Avoided Demand During Peak Period kW	Electricity Generated kWh	Additional Engine Gas therms	Electric Demand Cost Savings $	Electric Energy Cost Savings $	Additonal Gas Cost to run Chil+Gen $	Net Additional Savings $	Number Hours Generator Operating	Average Generator Hourly Output kW
Jan	77,303	192.3	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Feb	68,838	190.2	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Mar	78,693	185.7	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Apr	77,751	198.5	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
May	84,458	207.8	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
June	82,682	193.5	152.2	117.2	35.0	4,410	771	574	657	(384)	847	126	35.0
July	89,896	205.2	152.4	117.4	35.0	4,410	792	574	657	(395)	836	126	35.0
Aug	92,456	223.7	152.7	117.7	35.0	4,830	859	574	719	(428)	865	138	35.0
Sept	87,372	212.6	155.7	120.7	35.0	3,990	714	574	594	(356)	812	114	35.0
Oct	90,514	200.7	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Nov	79,402	190.1	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Dec	79,447	163.9	0.0	0.0	0.0	-	-	-	-	-	-	-	0.0
Totals	988,812					17,640	3,135	2,296	2,628	(1,563)	3,360	504	35.0

Summary	Annual Energy $
Baseline Electric Cooling Plant	108,427
Hybrid Cooling Plant	98,378
Savings	10,049
Additional Savings with Chil+Gen	3,360
Total Savings	13,409
Savings/ton Installed Cooling	134.09

Additional Gas vs. Variable Speed Cooling	708 therms
	33.49% more
Additional Gas to Run Generator	2428 therms

Retail Store, 50000 SF
Los Angeles
150 HP constant speed-variable load engine, 100 tons cooling, 35 kW generator
Generator operates all cooling hours

Assumptions
1. Baseline system is one electric screw chiller, 0.79 kW/ton (4.45 COP) required by ASHRAE Standard 90.1-1999
2. Chiller/Cogenerator is gas engine cooling (1.46 COP, 0.02 electric parasitics) and generator
3. 150 HP gas engine runs at constant speed and variable output during on-peak period
4. 1,367,500 Btu/hr fuel consumption for 150 HP engine based on average fuel usage for Tecs CH Series chillers
5. Constant speed, constant output generator with 35 kW capacity
6. Engine fuel consumption versus % load taken from performance data on GM 7.4 Liter engine
7. Below 20% cooling capacity, cooling system will cycle; generator operates during all cooling hours
8. Chillers sized at 104 tons

Southern California Edison Rate TOU-GS-2B	Summer	Winter
Demand, $/kW		
Facilities Charge	5.4	5.4
On-Peak	16.4	N/A
Mid-Peak	2.45	0
Off-Peak	0	0
Energy, $/kWh		
On-Peak	0.14896	N/A
Mid-Peak	0.06613	0.07611
Off-Peak	0.04271	0.04271
Southern California Gas Rate GN-10		
Energy, $/therm		
First 100 therms	0.79587	0.79587
Next 4067 therms	0.64262	0.64262
All other	0.51314	0.51314
Southern California Gas Rate G-AC Gas Cooling		
All cooling gas	0.49858	N/A

On-Peak period - Noon to 6PM summer weekdays
Mid-Peak period - 8 AM to noon, 6 PM to 11 PM summer weekdays
Off-Peak period - all other hours
Summer - June through September

Marginal costs used in analysis		
On-Peak Demand Charg	16.4	$/kW
On-Peak Energy Cost	0.14896	$/kWh
Gas Cooling Rate	0.49858	$/therm
Mid-Peak Demand Charg	2.45	$/kW
Mid-Peak Energy Cost	0.06613	$/kWh

Results below are for a hybrid cooling systems where gas cooling operates during on-peak hours, electric cooling all other hours

	Building Energy Usage kWh	Building Demand kW	Building Demand During On-peak Period kW	Building Demand During On-Peak Hours With Generator Operating kW	Avoided Demand During On-Peak Period kW	Building Demand During Mid-Peak Period kW	Building Demand During Mid-Peak Hours With Generator Operating kW	Avoided Demand During Mid-Peak Period kW	Electricity Generated During On-Peak Period kWh	Electricity Generated During Mid-Peak Period kWh	Electricity Generated During Off-Peak Period kWh	Total Additional Engine Gas therms	Off-Peak Generator Additional Engine Gas therms
Jan	75,061	155.3	0.0	0.0	0.0	0.0	0.0	0.0	-	-	5,460	934	809
Feb	67,010	155.1	0.0	0.0	0.0	0.0	0.0	0.0	-	-	4,550	782	674
Mar	75,763	155.2	0.0	0.0	0.0	0.0	0.0	0.0	-	-	8,190	1,405	1,222
Apr	73,404	155.7	0.0	0.0	0.0	0.0	0.0	0.0	-	-	10,220	1,757	1,510
May	76,966	152.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	14,420	2,467	2,107
June	75,996	152.2	152.2	117.2	35.0	152.0	139.1	12.9	4,410	6,195	6,685	2,965	974
July	73,600	152.5	152.4	117.4	35.0	152.4	117.4	35.0	4,410	6,615	9,520	3,598	1,372
Aug	73,862	152.8	152.8	117.8	35.0	152.8	117.8	35.0	4,830	7,245	8,960	3,666	1,287
Sept	78,266	155.8	155.7	120.7	35.0	155.9	120.9	35.0	3,990	5,985	9,940	3,462	1,428
Oct	78,740	155.5	0.0	0.0	0.0	0.0	0.0	0.0	-	-	18,795	3,257	2,703
Nov	73,657	155.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	11,620	1,979	1,701
Dec	73,624	155.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	8,610	1,463	1,270
Totals	907,211								17,640	26,040	116,970	27,796	17,057
										Total Generated >	160,650		

	On-Peak Electric Demand Cost Savings $	Mid-Peak Electric Demand Cost Savings $	On-Peak Electric Energy Cost Savings $	Mid-Peak Electric Energy Cost Savings $	Off-Peak Electric Energy Cost Savings $	Additional Gas Cost to run Chil+Gen $	Net Additional Savings $	Number Hours Generator Operating On-Peak	Number Hours Generator Operating Mid-Peak	Number Hours Generator Operating Off-Peak	Off-Peak Additional Gas Cost to run Gen $	Off-Peak Net Savings to run Gen $
Jan	-	-	-	-	233	(466)	(232)	-	-	156	(403)	(170)
Feb	-	-	-	-	194	(390)	(196)	-	-	130	(336)	(142)
Mar	-	-	-	-	350	(701)	(351)	-	-	234	(609)	(259)
Apr	-	-	-	-	436	(876)	(439)	-	-	292	(753)	(318)
May	-	-	-	-	616	(1,230)	(614)	-	-	412	(1,051)	(435)
June	574	32	657	410	286	(1,489)	469	126	177	191	(486)	(200)
July	574	86	657	437	407	(1,794)	367	126	189	272	(684)	(277)
Aug	574	86	719	479	383	(1,836)	405	138	207	256	(642)	(259)
Sept	574	86	594	396	425	(1,736)	338	114	171	284	(712)	(288)
Oct	-	-	-	-	803	(1,624)	(821)	-	-	537	(1,347)	(545)
Nov	-	-	-	-	496	(987)	(490)	-	-	332	(848)	(352)
Dec	-	-	-	-	368	(730)	(362)	-	-	246	(633)	(266)
Totals	2,296	289	2,628	1,722	4,898	(13,658)	(1,928)	504	744	3,342	(8,504)	(3,508)
		2,585			9,248			Total Generator Hours >		4,590		

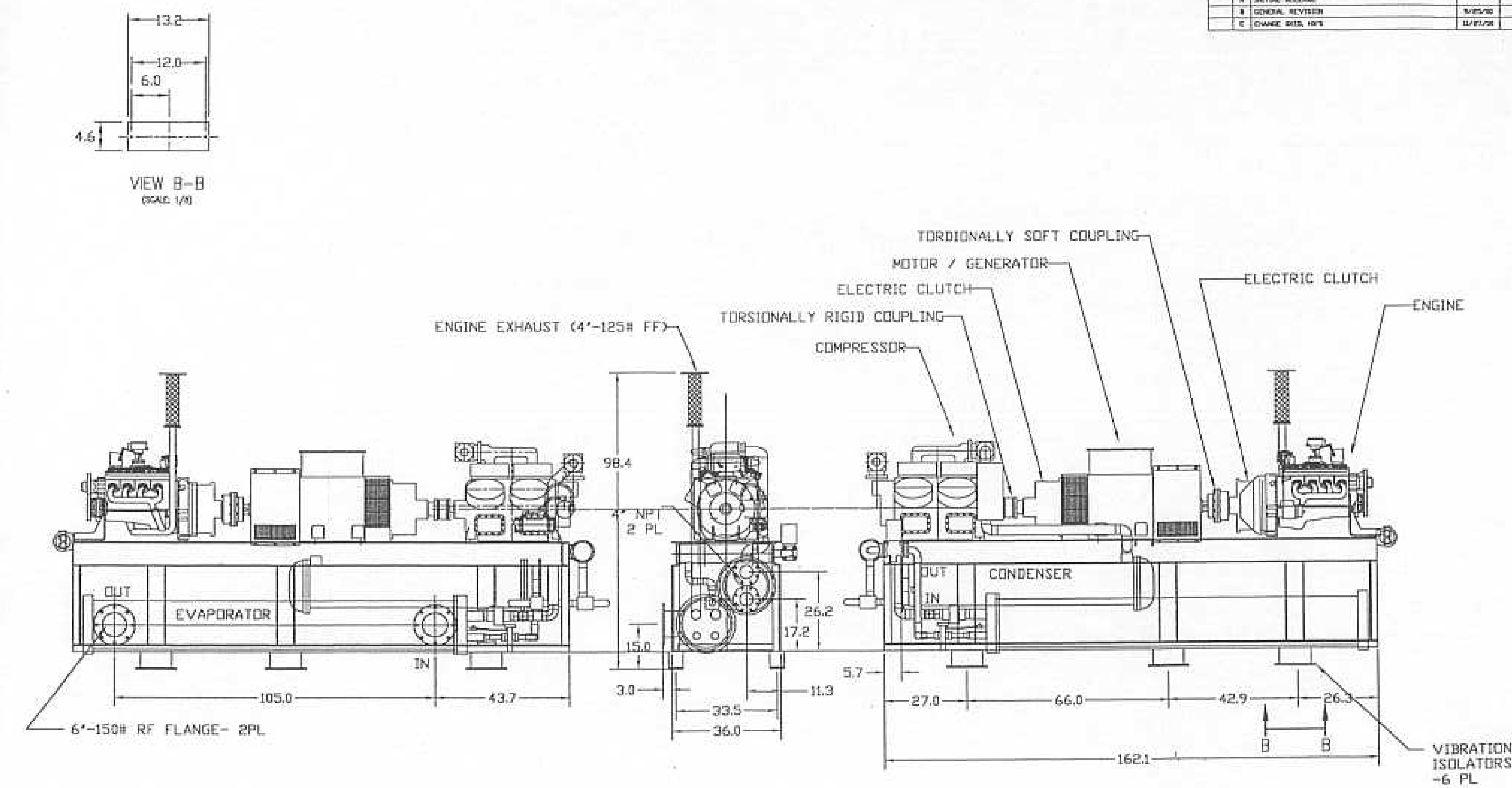
Summary	All Cooling Hours Annual Energy $	On+Mid Cooling Hours Annual Energy $
Baseline Electric Cooling Plant	108,427	108,427
All gas cooling	95,409	95,409
Savings	13,018	13,018
Additional Savings with Chil+Gen	(1,928)	1,578
Total Savings	11,090	14,596
Savings/ton Installed Cooling	111	146

Additional Gas vs. Variable Speed Cooling: 4619 therms, 37.38% more

Additional Gas to Run Generator: 23177 therms

Appendix H

Pre-Production Prints



M

EQUIPMENT RATINGS:

ELECTRIC MOTOR W/ REFRIGERATION CMPSR: 92.2 RT
NATURAL GAS ENGINE W/ REFRIG. CMPSR: 95.4 RT
NATURAL GAS ENGINE W/ AC GENERATOR: 75kW @ 208V

NOTE: RATINGS ARE SPECIFIED AT ARI 550/590-98 CONDITIONS

RELEASE FOR PRODUCTION
JOB# 2442
APPD
DATE 4-2-01

REVISIONS

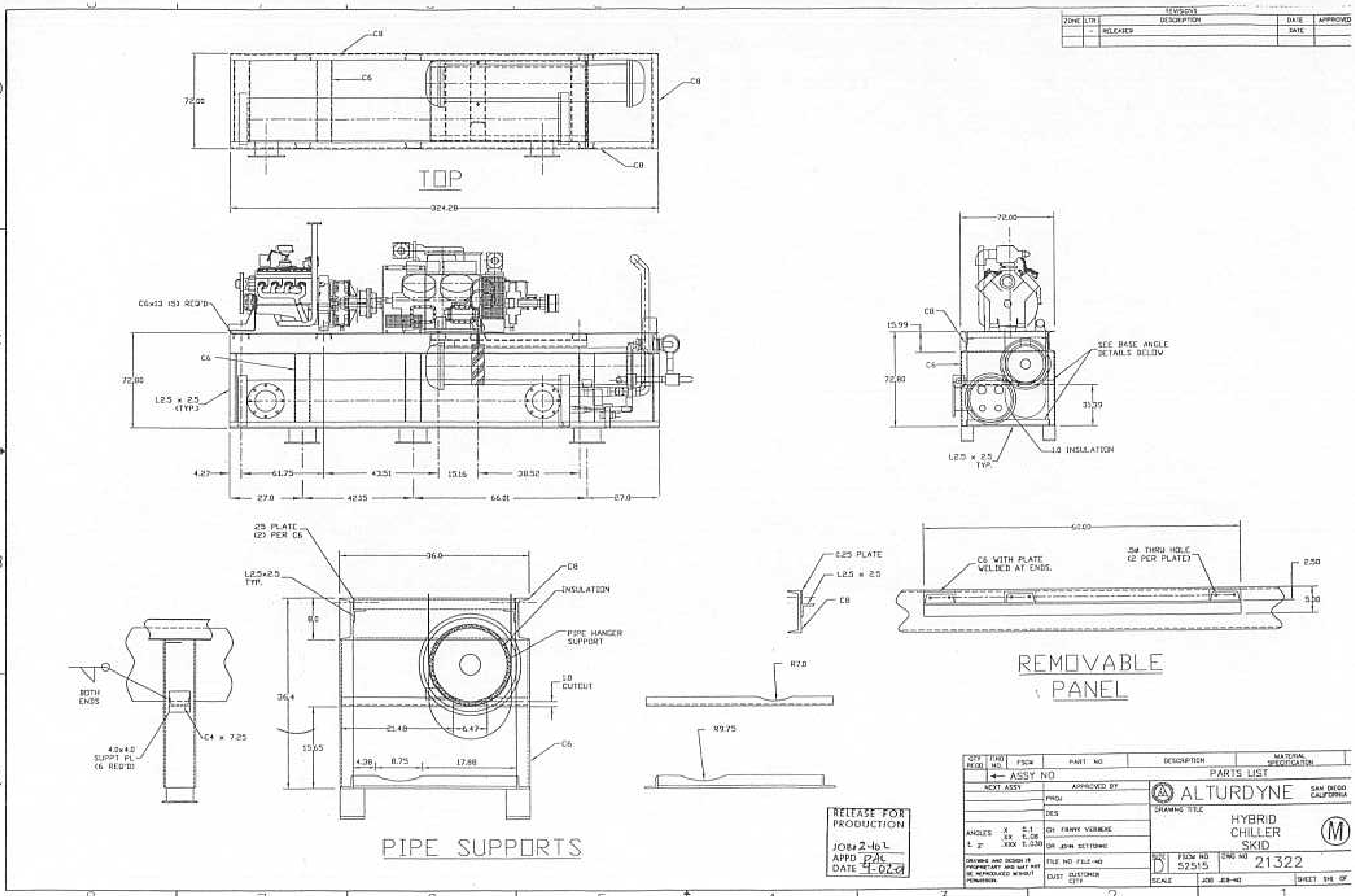
ZONE	LTR	DESCRIPTION	DATE	APPROVE
	A	INITIAL RELEASE		
	B	GENERAL REVISION	[illegible]	DJ
	C	CHANGE DIS, HX'S	[illegible]	SL

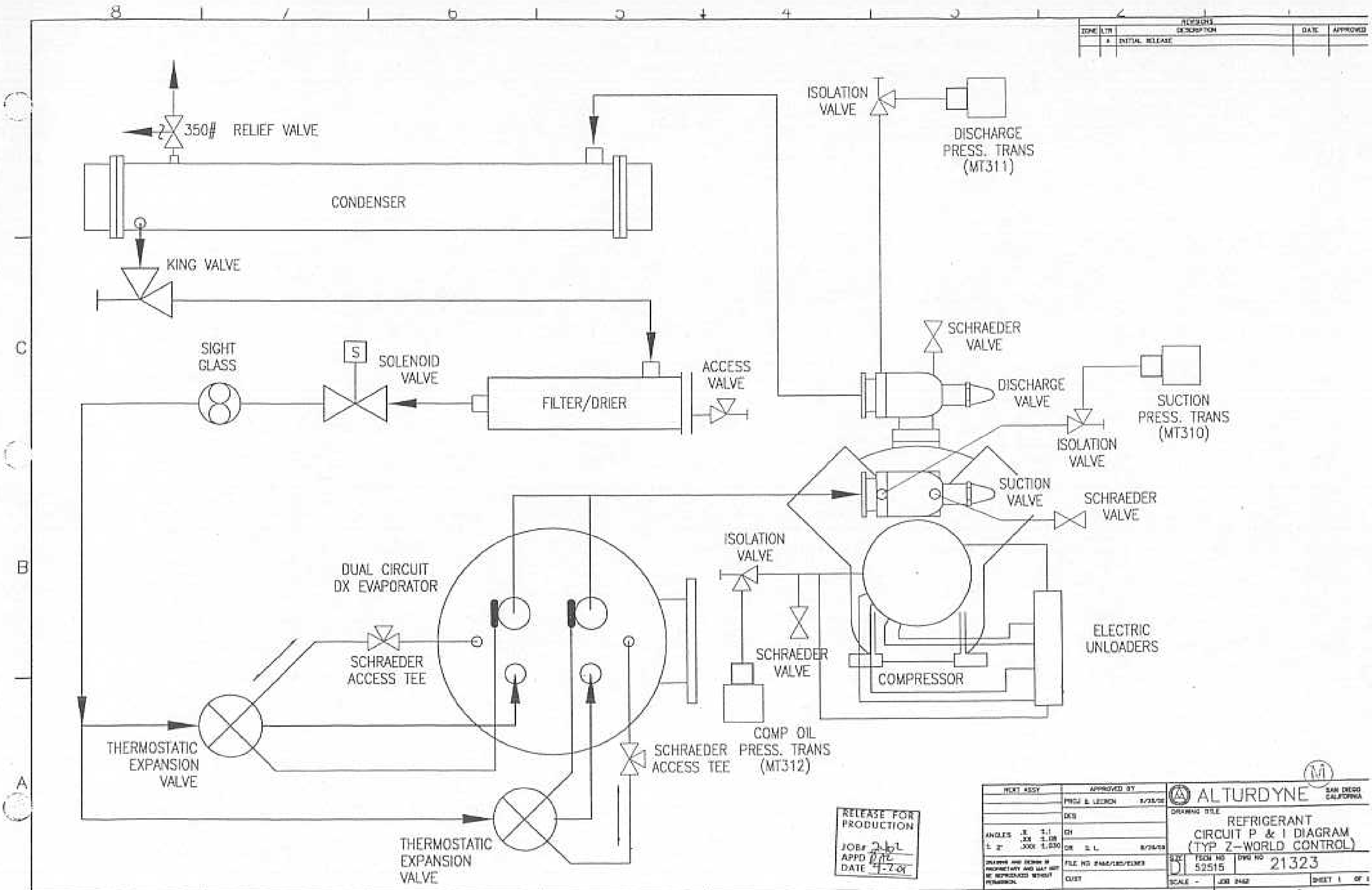
ALTURDYNE SAN DIEGO CALIFORNIA

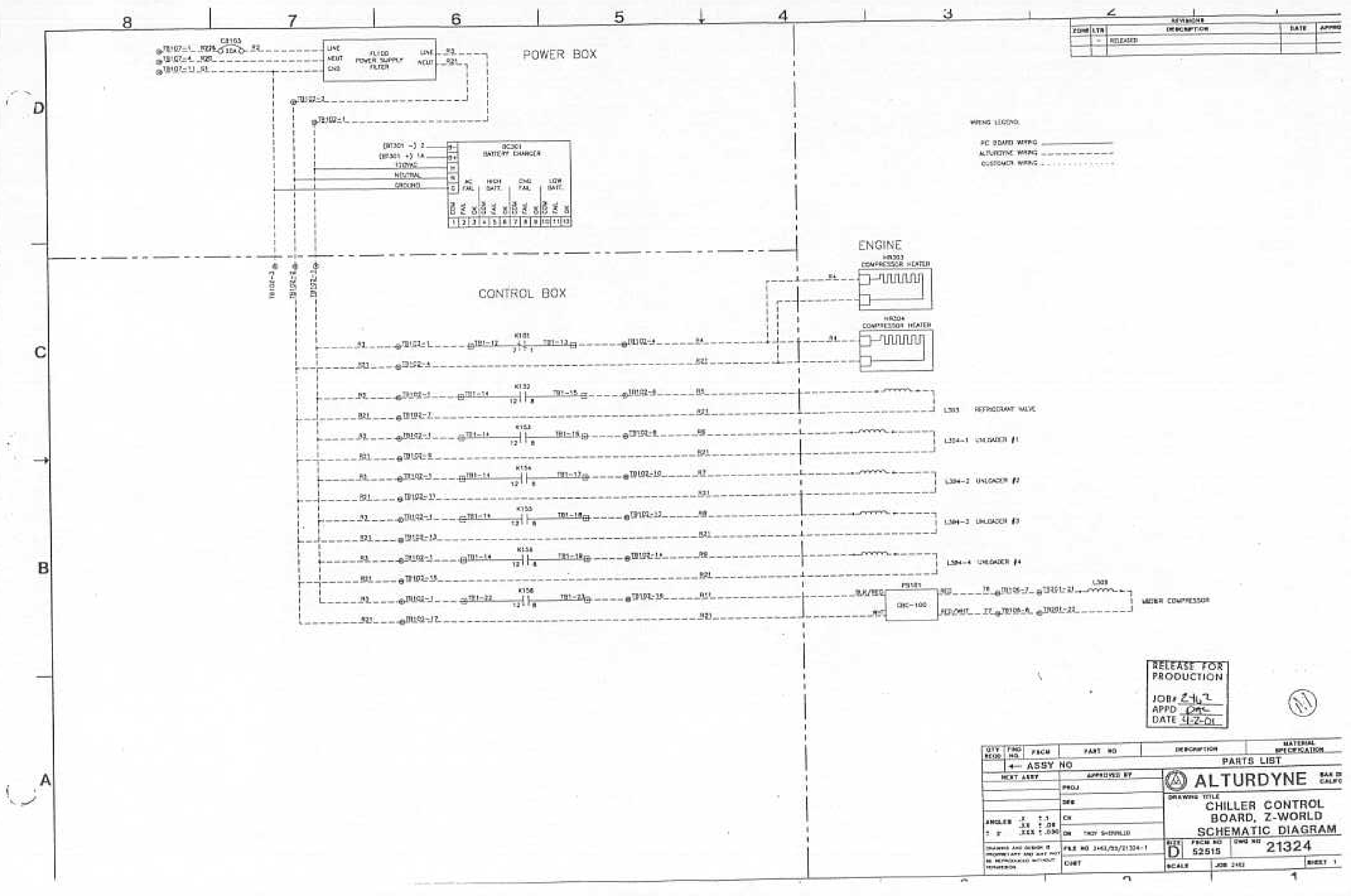
DRAWING TITLE
HYBRID CHILLER–
GAS/ELECTRIC
(MECHANICAL INTERFACE)

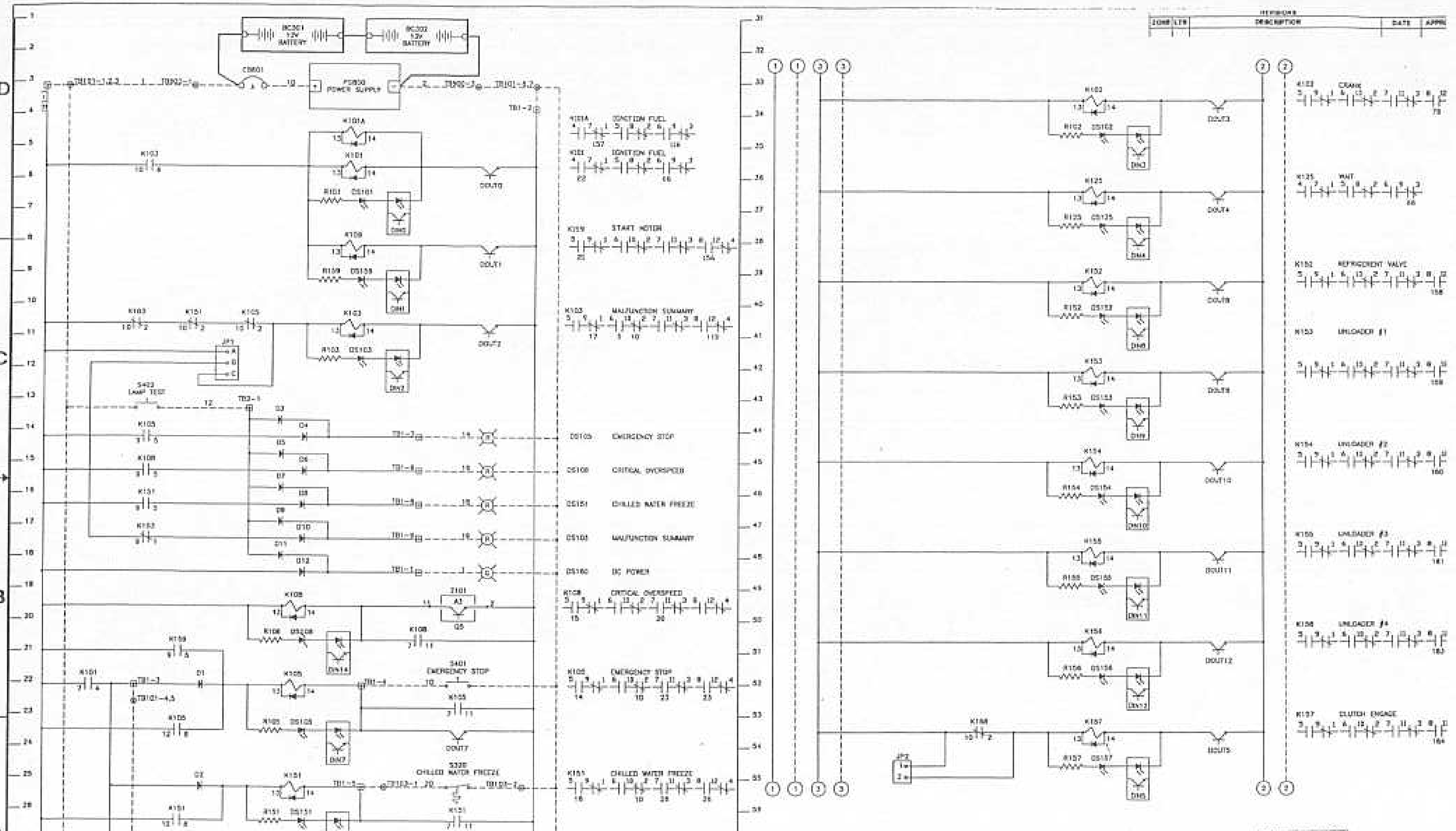
SIZE D | FSCM NO 52515 | DWG NO 21321.

SCALE 1/16 | JOB #442 | SHEET 1 OF


REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
- RELEASED DATE
TOP
C8
C6
72.00
324.28
C6x13 (5) REQ'D
L2.5 x 2.5 (TYP)
4.27
61.75
43.51
15.16
38.52
27.0
42.15
66.21
15.99
SEE BASE ANGLE DETAILS BELOW
31.39
L2.5 x 2.5 TYP.
1.0 INSULATION
.25 PLATE (2) PER C6
L2.5x2.5 TYP.
36.0
INSULATION
PIPE HANGER SUPPORT
1.0 CUTOUT
36.4
15.65
21.48
6.47
4.38
8.75
17.68
BOTH ENDS
4.0x4.0 SUPPT PL (6 REQ'D)
C4 x 7.25
PIPE SUPPORTS
0.25 PLATE
L2.5 x 2.5
R7.0
R9.75
60.00
C6 WITH PLATE WELDED AT ENDS.
.5Ø THRU HOLE (2 PER PLATE)
2.50
5.00
REMOVABLE PANEL
RELEASE FOR PRODUCTION
JOB# 2462
APPD
DATE
PARTS LIST
ASSY NO
NEXT ASSY
APPROVED BY
CH FRANK VERBEKE
DR JOHN SETTONNI
TITLE NO FILE-NO
CUST CUSTOMER CITY
ALTURDYNE
SAN DIEGO CALIFORNIA
DRAWING TITLE
HYBRID CHILLER SKID
M
SIZE D
FSCM NO 52515
DWG NO 21322
SCALE
JOB JOB-NO
SHEET
DRAWING AND DESIGN IS PROPRIETARY AND MAY NOT BE REPRODUCED WITHOUT PERMISSION.


350# RELIEF VALVE
CONDENSER
KING VALVE
ISOLATION VALVE
DISCHARGE PRESS. TRANS (MT311)
SCHRAEDER VALVE
DISCHARGE VALVE
SUCTION PRESS. TRANS (MT310)
ISOLATION VALVE
SIGHT GLASS
S
SOLENOID VALVE
FILTER/DRIER
ACCESS VALVE
SUCTION VALVE
SCHRAEDER VALVE
ISOLATION VALVE
DUAL CIRCUIT DX EVAPORATOR
SCHRAEDER ACCESS TEE
SCHRAEDER VALVE
ELECTRIC UNLOADERS
COMPRESSOR
THERMOSTATIC EXPANSION VALVE
SCHRAEDER ACCESS TEE
COMP OIL PRESS. TRANS (MT312)
THERMOSTATIC EXPANSION VALVE
RELEASE FOR PRODUCTION
ALTURDYNE
SAN DIEGO CALIFORNIA
DRAWING TITLE
REFRIGERANT CIRCUIT P & I DIAGRAM (TYP Z-WORLD CONTROL)
SIZE D
DWG NO 21323
52515


POWER BOX
POWER SUPPLY FILTER
BATTERY CHARGER
CONTROL BOX
ENGINE
COMPRESSOR HEATER
COMPRESSOR HEATER
REFRIGERANT VALVE
UNLOADER #1
UNLOADER #2
UNLOADER #3
UNLOADER #4
WIRING LEGEND
PC BOARD WIRING
ALTURDYNE WIRING
CUSTOMER WIRING
REVISIONS
RELEASED
RELEASE FOR PRODUCTION
JOB#
APPD
DATE
PARTS LIST
ASSY NO
ALTURDYNE
CHILLER CONTROL
BOARD, Z-WORLD
SCHEMATIC DIAGRAM
D
52515
21324

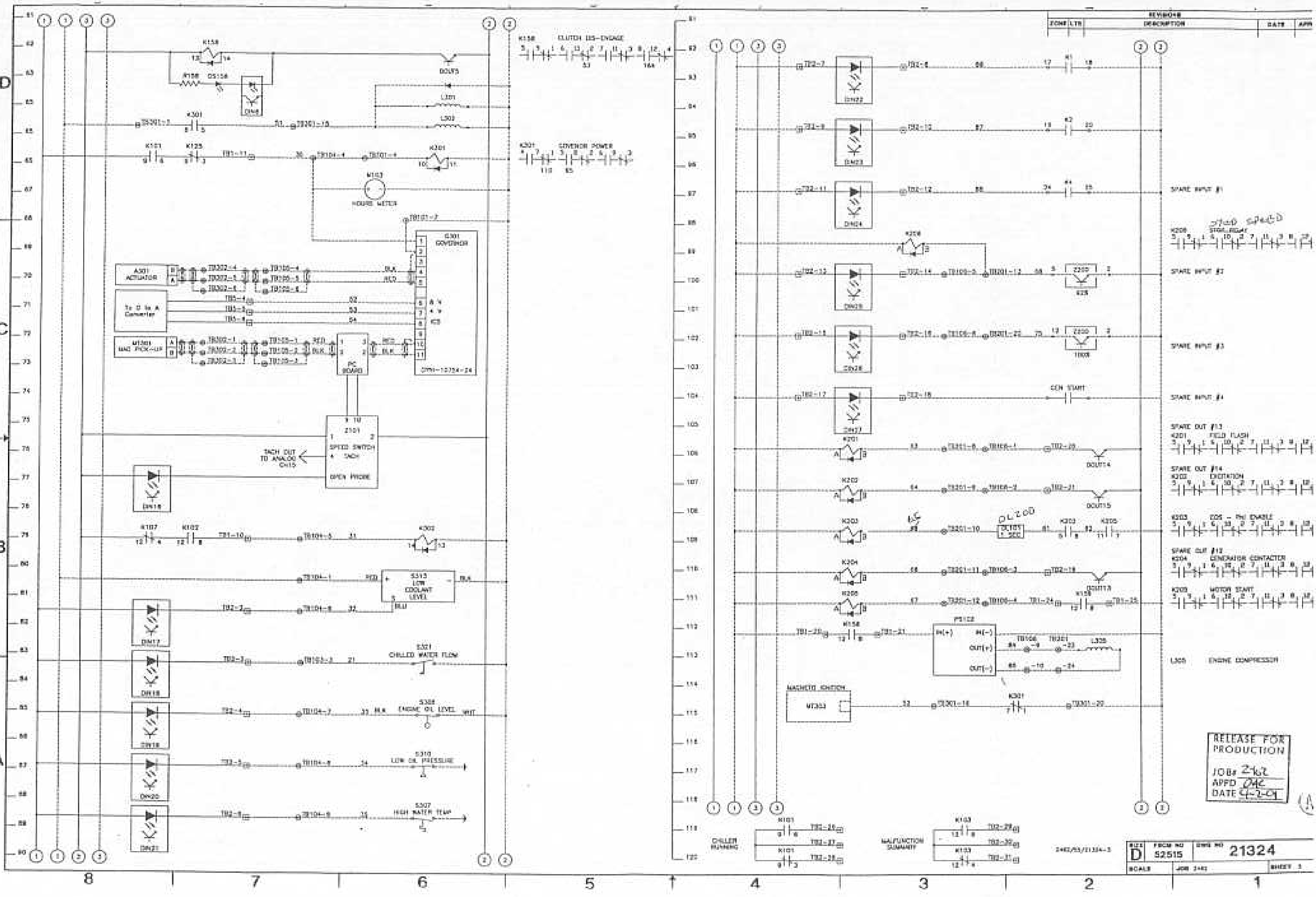


JUMPER	DESCRIPTION	JUMPER POINTS
JP1	MALF SUM/LAMP	A TO B
JP2	CLUTCH ENGAGE	TO

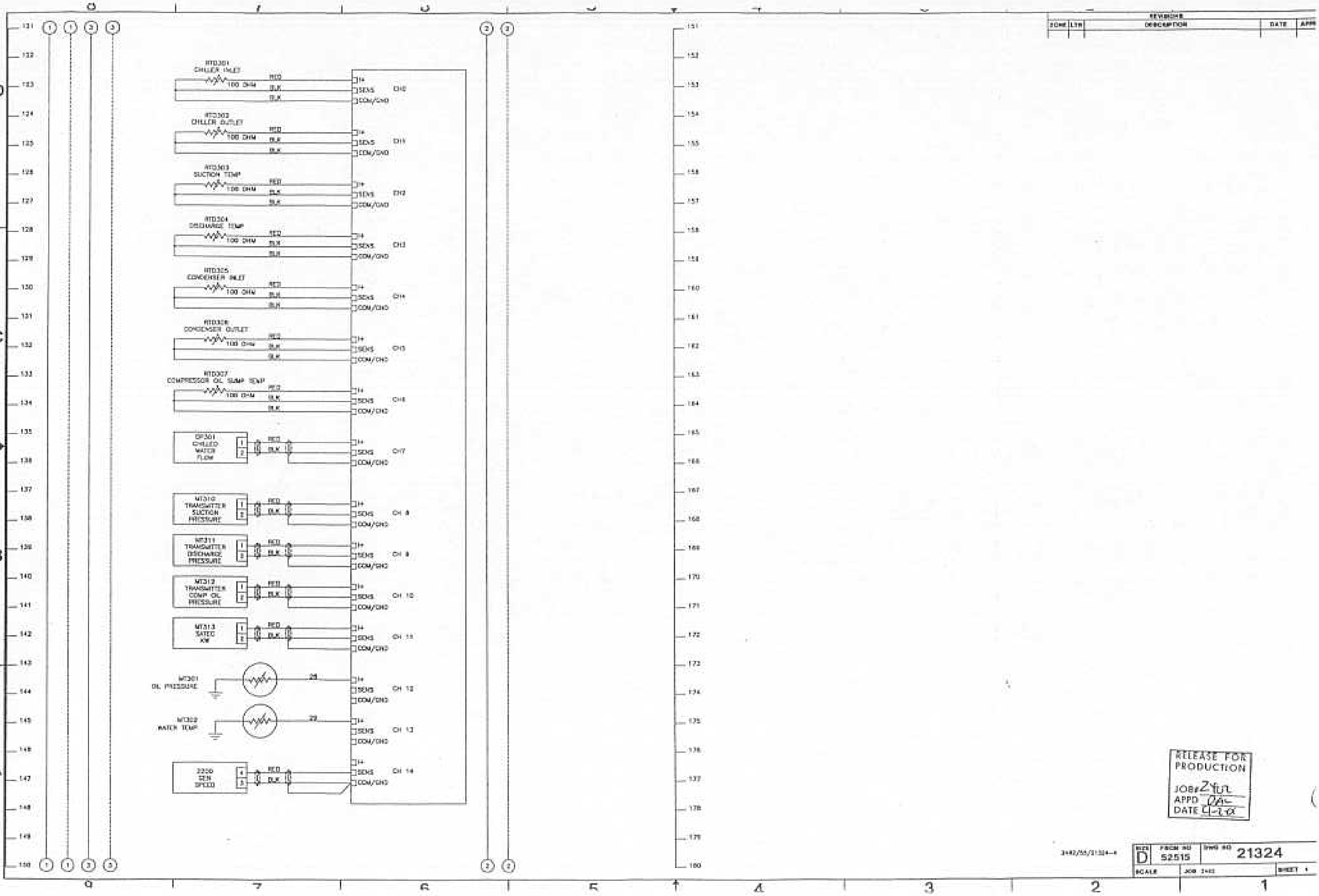
RELEASE FOR PRODUCTION
JOB# 2462
APPD DAC
DATE 4-2-01

2462/55/21324-2

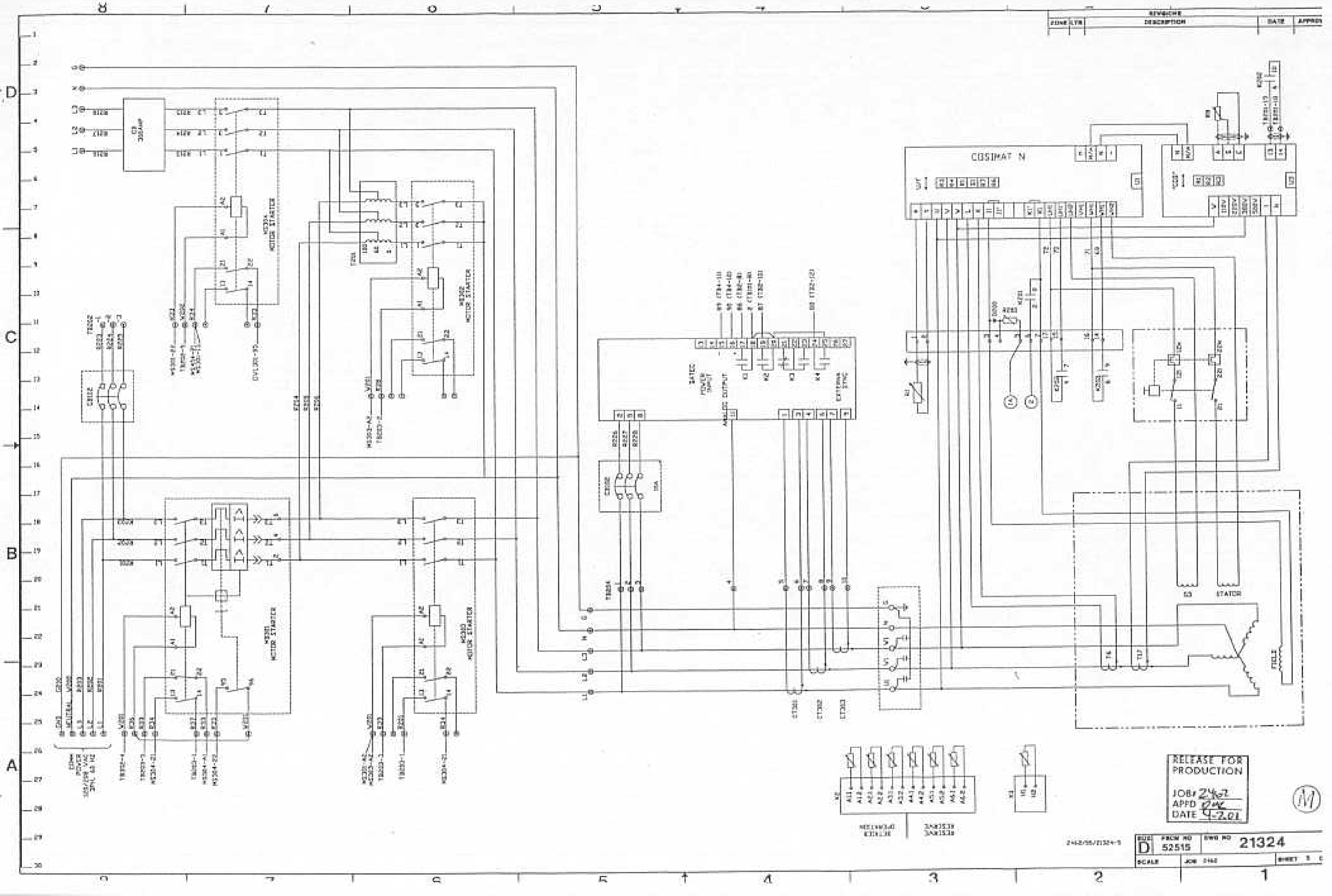
SIZE	FROM NO	DWG NO
D	52515	21324
SCALE	JOB 2462	SHEET 2



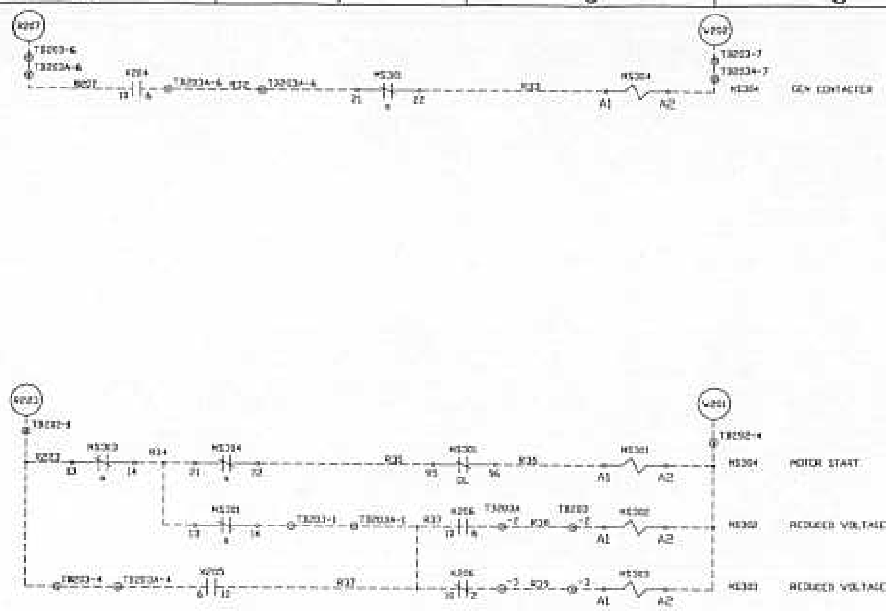
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
K158 CLUTCH DIS-ENGAGE
K301 GOVERNOR POWER
DOUT5
HOURS METER
G301 GOVERNOR
A301 ACTUATOR
To D to A Converter
MT301 MAG PICK-UP
PC BOARD
SPEED SWITCH
TACH OUT TO ANALOG CH15
OPEN PROBE
LOW COOLANT LEVEL
CHILLED WATER FLOW
ENGINE OIL LEVEL
LOW OIL PRESSURE
HIGH WATER TEMP
SPARE INPUT #1
SPARE INPUT #2
SPARE INPUT #3
SPARE INPUT #4
GEN START
FIELD FLASH
EXCITATION
GENERATOR CONTACTOR
MOTOR START
ENGINE COMPRESSOR
MAGNETO IGNITION
CHILLER RUNNING
MALFUNCTION SUMMARY
RELEASE FOR PRODUCTION
JOB#
APPD
DATE
52515
21324



REVISIONS
ZONE
LTR
DESCRIPTION
DATE
RTD301
CHILLER INLET
100 OHM
RED
BLK
BLK
I+
SENS
COM/GND
CH0
RTD302
CHILLER OUTLET
100 OHM
CH1
RTD303
SUCTION TEMP
100 OHM
CH2
RTD304
DISCHARGE TEMP
100 OHM
CH3
RTD305
CONDENSER INLET
100 OHM
CH4
RTD306
CONDENSER OUTLET
100 OHM
CH5
RTD307
COMPRESSOR OIL SUMP TEMP
100 OHM
CH6
CHILLED WATER FLOW
CH7
MT310
TRANSMITTER
SUCTION PRESSURE
CH 8
MT311
TRANSMITTER
DISCHARGE PRESSURE
CH 9
MT312
TRANSMITTER
COMP OIL PRESSURE
CH 10
MT313
SATEC
KW
CH 11
MT301
OIL PRESSURE
CH 12
MT302
WATER TEMP
CH 13
2200
GEN
SPEED
CH 14
RELEASE FOR PRODUCTION
JOB# Z4UL
APPD OAL
DATE
SIZE
D
FSCM NO
52515
DWG NO
21324
SCALE
SHEET

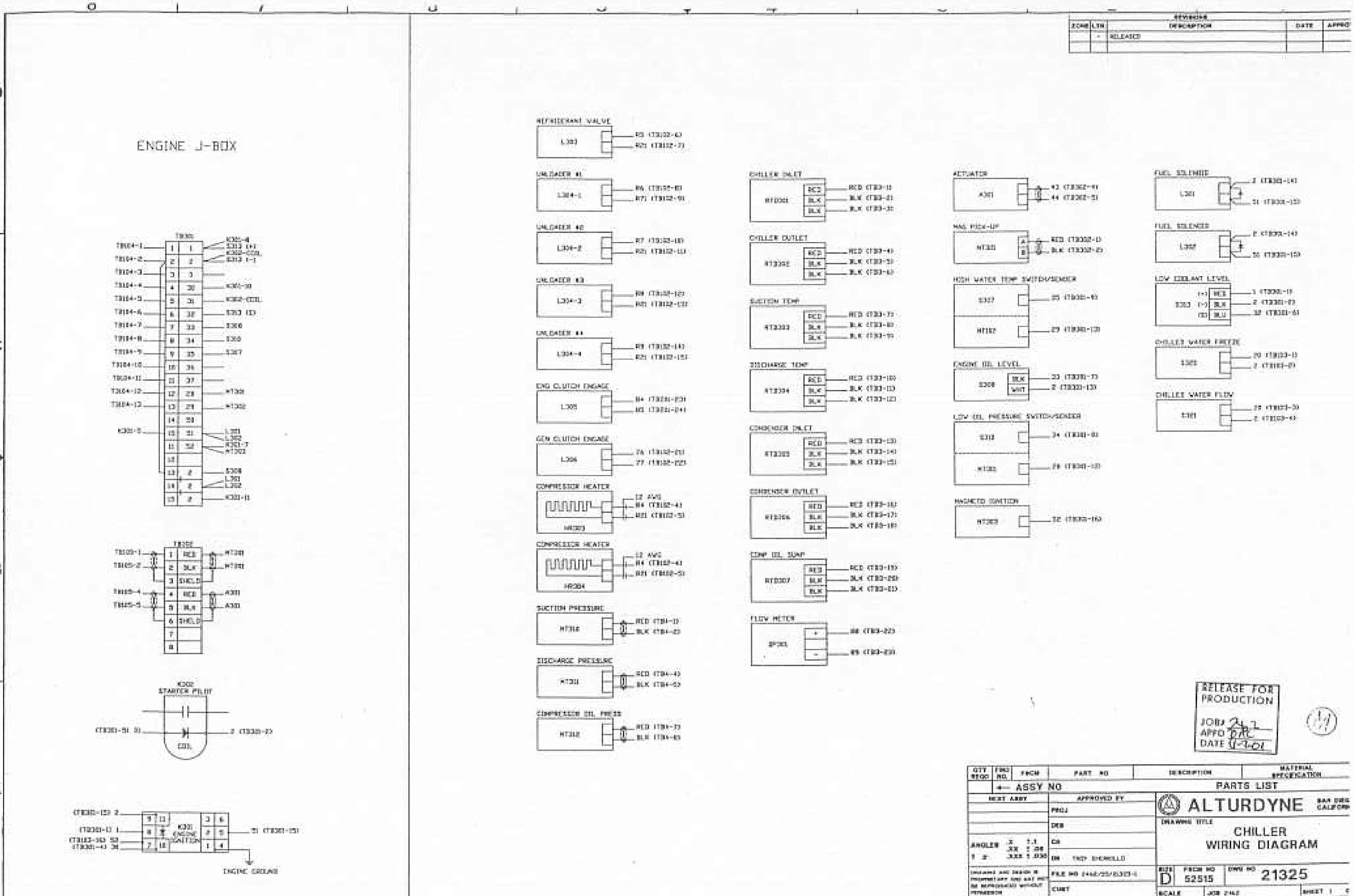


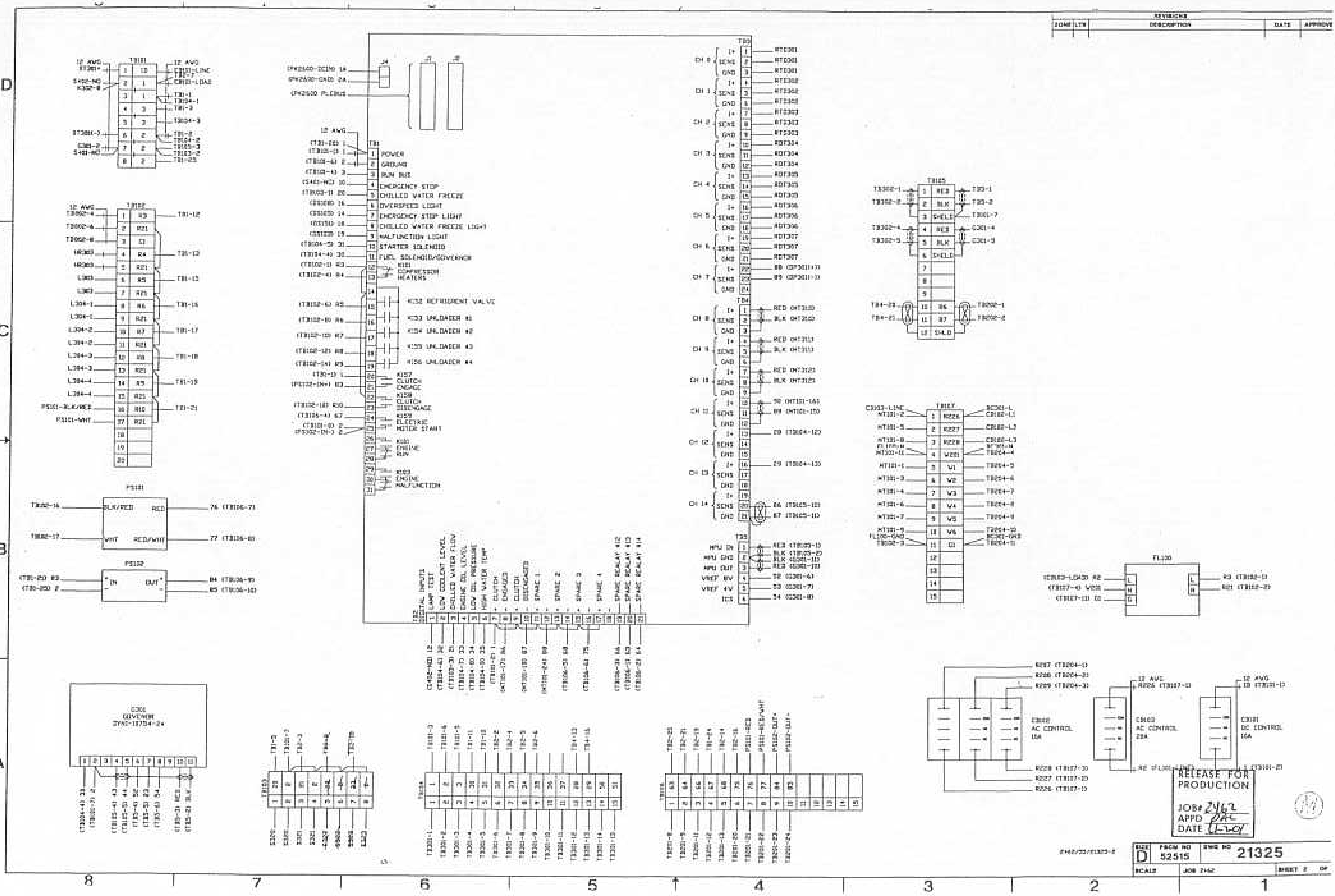
REVISIONS
ZONE LTR DESCRIPTION DATE APPROV
COSIMAT N
M304 MOTOR STARTER
M302 MOTOR STARTER
M301 MOTOR STARTER
M303 MOTOR STARTER
CB201 300AMP
CB202
CB203
STATOR
FIELD
CT301
CT302
CT303
RELEASE FOR PRODUCTION
JOB# 2462
APPD
DATE 4-2-01
SIZE D
FSCM NO 52515
DWG NO 21324
SCALE
JOB 2462
SHEET 5



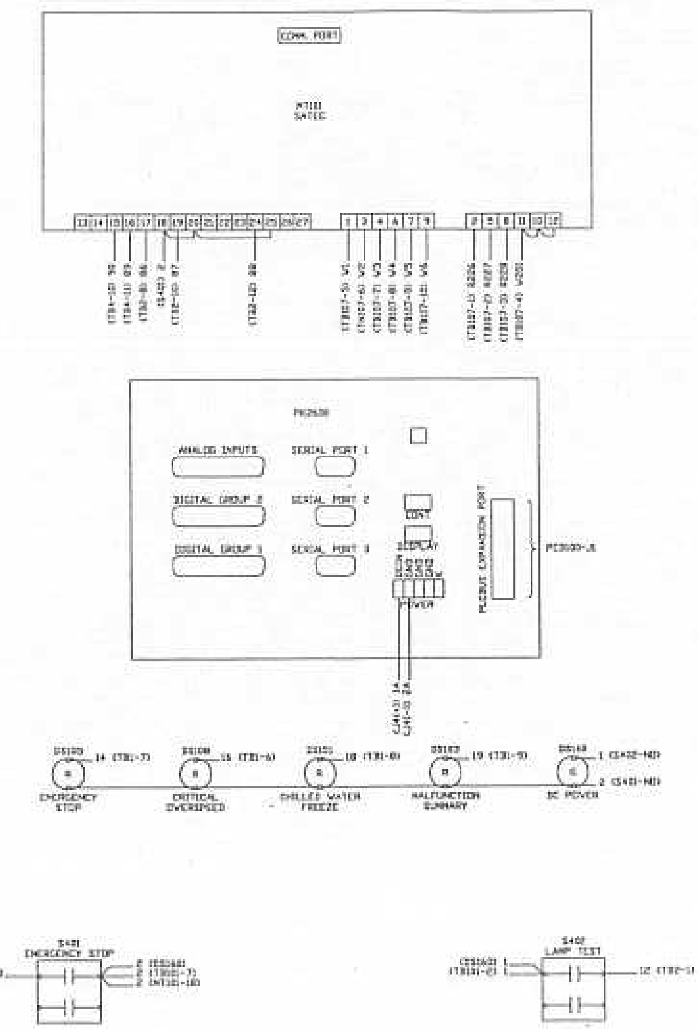
RELEASE FOR PRODUCTION
JOB# 2462
APPD DA
DATE 4-2-01

SIZE	FSCM NO	DWG NO
D	52515	21324
SCALE	JOB 2462	SHEET


ENGINE J-BOX
REFRIGERANT VALVE
UNLOADER #1
UNLOADER #2
UNLOADER #3
UNLOADER #4
ENG CLUTCH ENGAGE
GEN CLUTCH ENGAGE
COMPRESSOR HEATER
SUCTION PRESSURE
DISCHARGE PRESSURE
COMPRESSOR OIL PRESS
CHILLER INLET
CHILLER OUTLET
SUCTION TEMP
DISCHARGE TEMP
CONDENSER INLET
CONDENSER OUTLET
COMP OIL SUMP
FLOW METER
ACTUATOR
MAG PICK-UP
HIGH WATER TEMP SWITCH/SENDER
ENGINE OIL LEVEL
LOW OIL PRESSURE SWITCH/SENDER
MAGNETO IGNITION
FUEL SOLENOID
LOW COOLANT LEVEL
CHILLED WATER FREEZE
CHILLED WATER FLOW
STARTER PILOT
ENGINE GROUND
RELEASE FOR PRODUCTION
PARTS LIST
ASSY NO
ALTURDYNE
CHILLER
WIRING DIAGRAM
DWG NO 21325
FSCM NO 52515
SIZE D

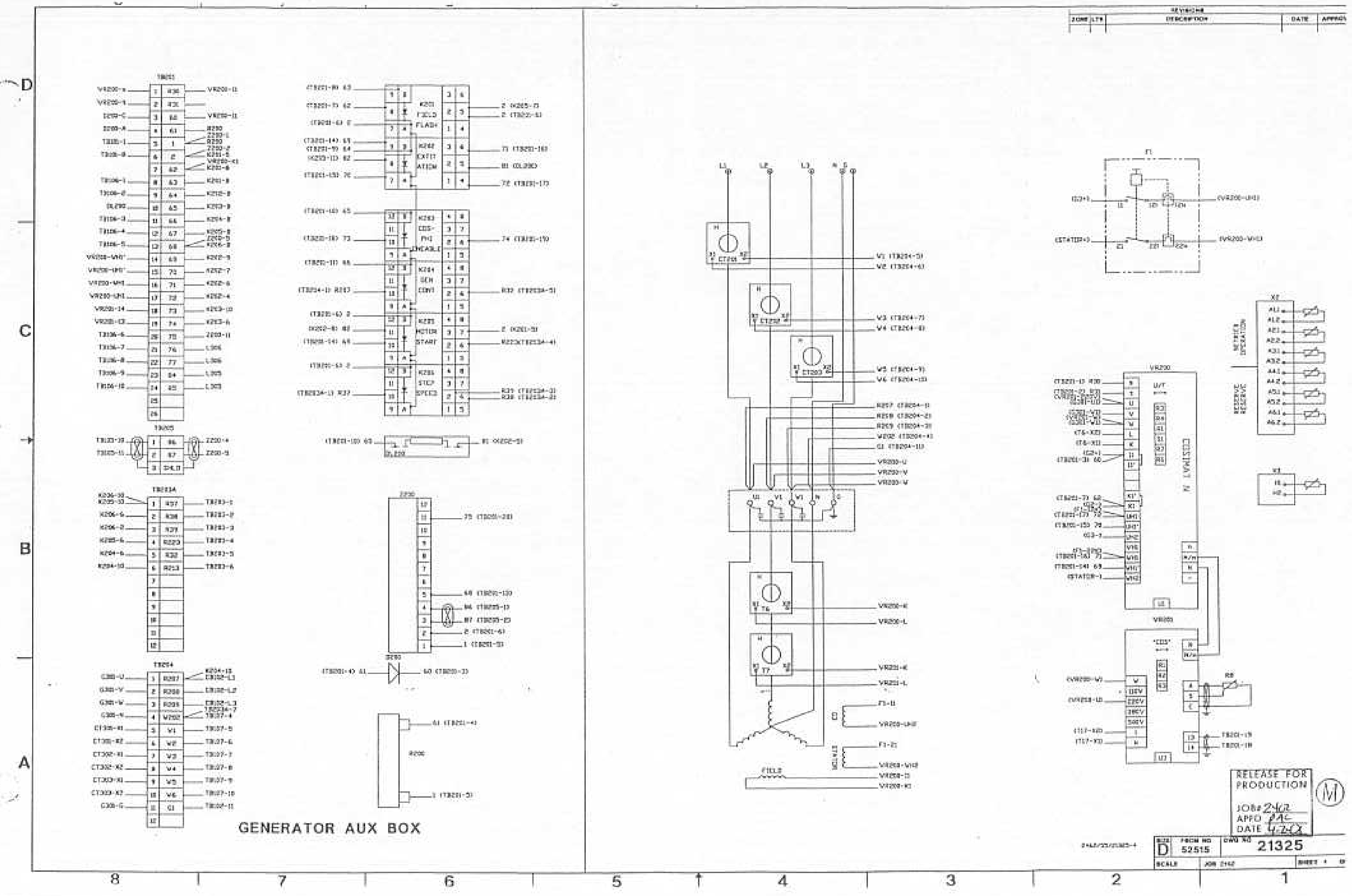


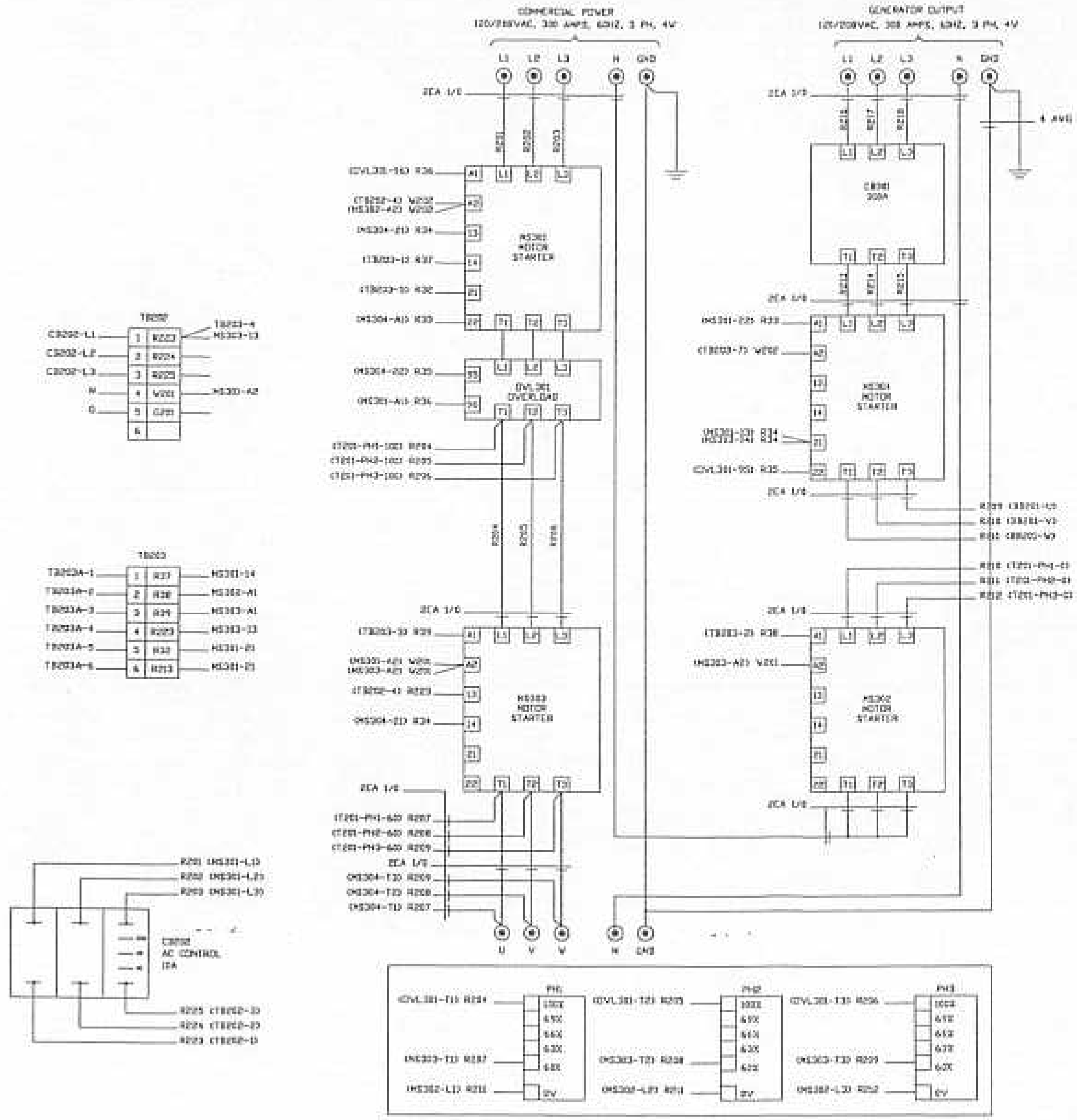
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
J4
J1
J2
TB1
POWER
GROUND
RUN BUS
EMERGENCY STOP
CHILLED WATER FREEZE
OVERSPEED LIGHT
EMERGENCY STOP LIGHT
CHILLED WATER FREEZE LIGHT
MALFUNCTION LIGHT
STARTER SOLENOID
FUEL SOLENOID/GOVERNOR
K151 COMPRESSOR HEATERS
K152 REFRIGERANT VALVE
K153 UNLOADER #1
K154 UNLOADER #2
K155 UNLOADER #3
K156 UNLOADER #4
K157 CLUTCH ENGAGE
K158 CLUTCH DISENGAGE
K159 ELECTRIC MOTOR START
K161 ENGINE RUN
K163 ENGINE MALFUNCTION
DIGITAL INPUTS
LAMP TEST
LOW COOLANT LEVEL
LOW CHILLED WATER FLOW
ENGINE OIL LEVEL
LOW OIL PRESSURE
HIGH WATER TEMP
CLUTCH ENGAGED
CLUTCH DISENGAGED
SPARE 1
SPARE 2
SPARE 3
SPARE 4
SPARE RELAY #12
SPARE RELAY #13
SPARE RELAY #14
TB3
TB4
TB5
MPU IN
MPU GND
MPU OUT
VREF 8V
VREF 4V
ICS
TB101
TB102
TB105
TB106
TB107
TB201
TB204
PS101
PS102
FL100
G301 GOVERNOR
CB102 AC CONTROL 10A
CB103 AC CONTROL 20A
CB101 DC CONTROL 10A
12 AWG
RELEASE FOR PRODUCTION
JOB# 2462
APPD
DATE
SIZE D
FSCM NO 52515
DWG NO 21325
SCALE
JOB 2462
SHEET 2 OF



RELEASE FOR PRODUCTION
JOB# 2162
APPD
DATE 9-1-01

SIZE	FSCM NO	DWG NO
D	52515	21325
SCALE	JOB 2162	SHEET 3


GENERATOR AUX BOX
RELEASE FOR PRODUCTION
52515
21325



MOTOR START BOX

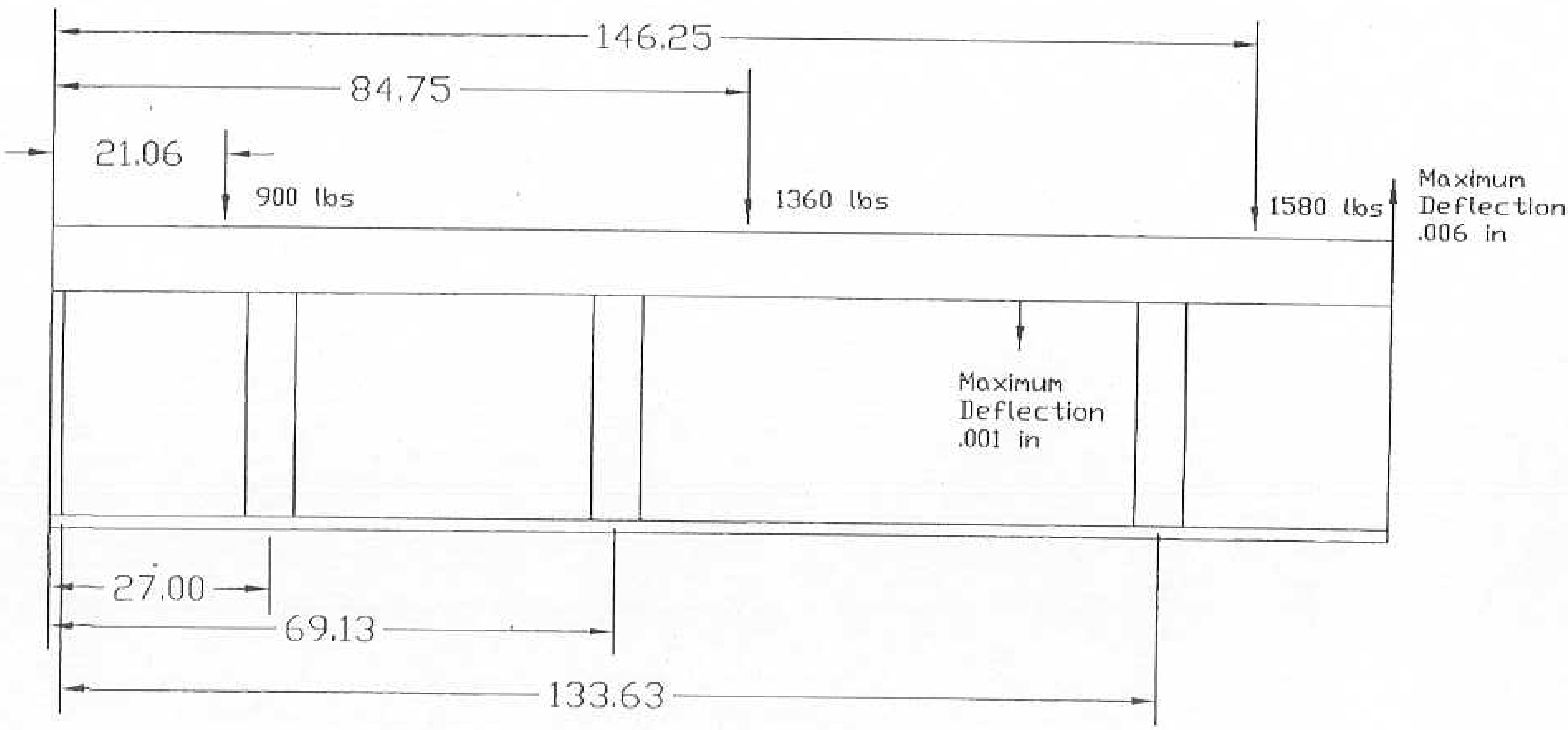
RELEASE FOR PRODUCTION
JOB# 2462
APPD
DATE 4-2-01

SIZE	FSCM NO	DWG NO
D	52515	21325

Appendix I

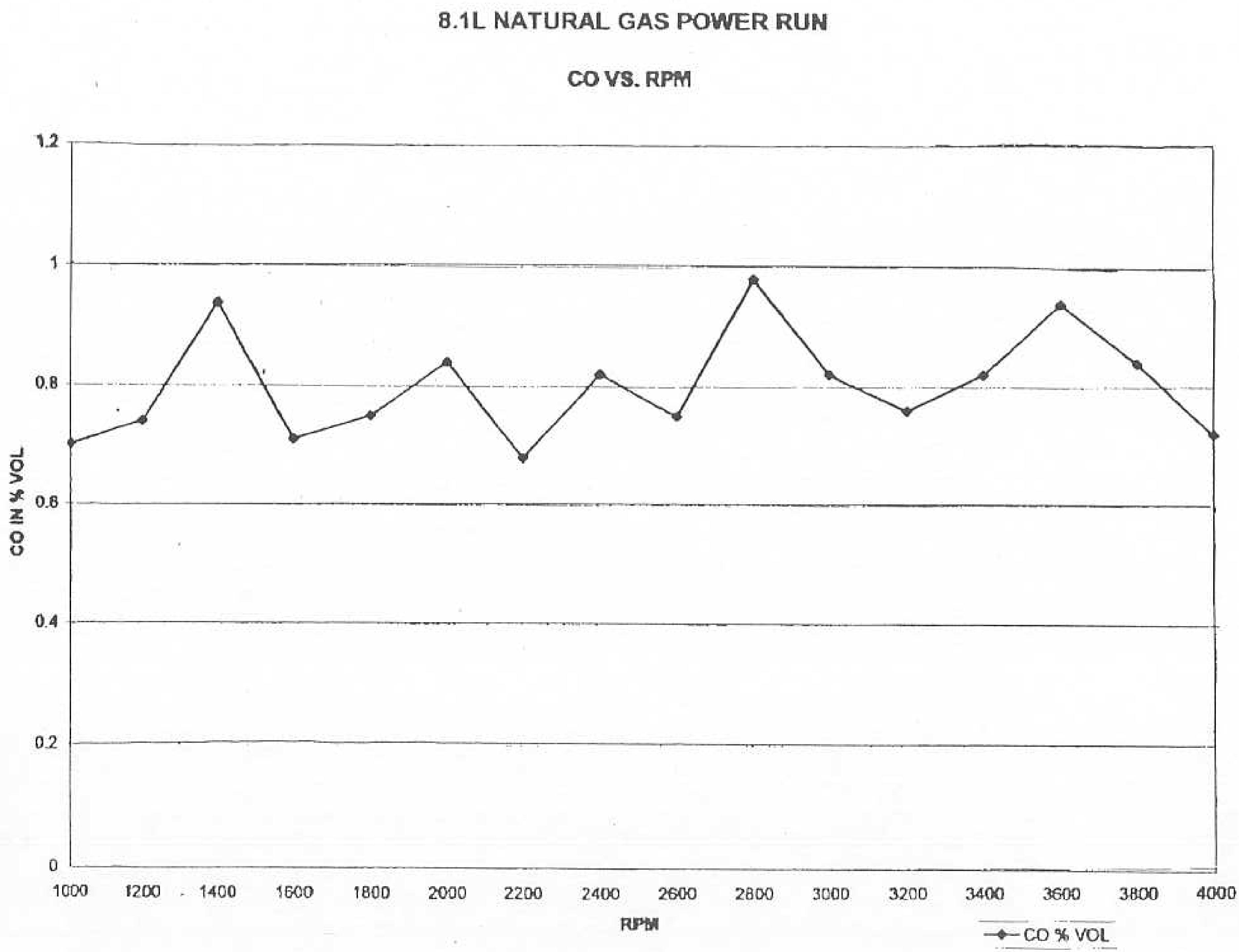
Stress Analysis Sketch

CHILLER SKID STRESS ANALYSIS
JOB:2462



Appendix J

Emissions Graphs

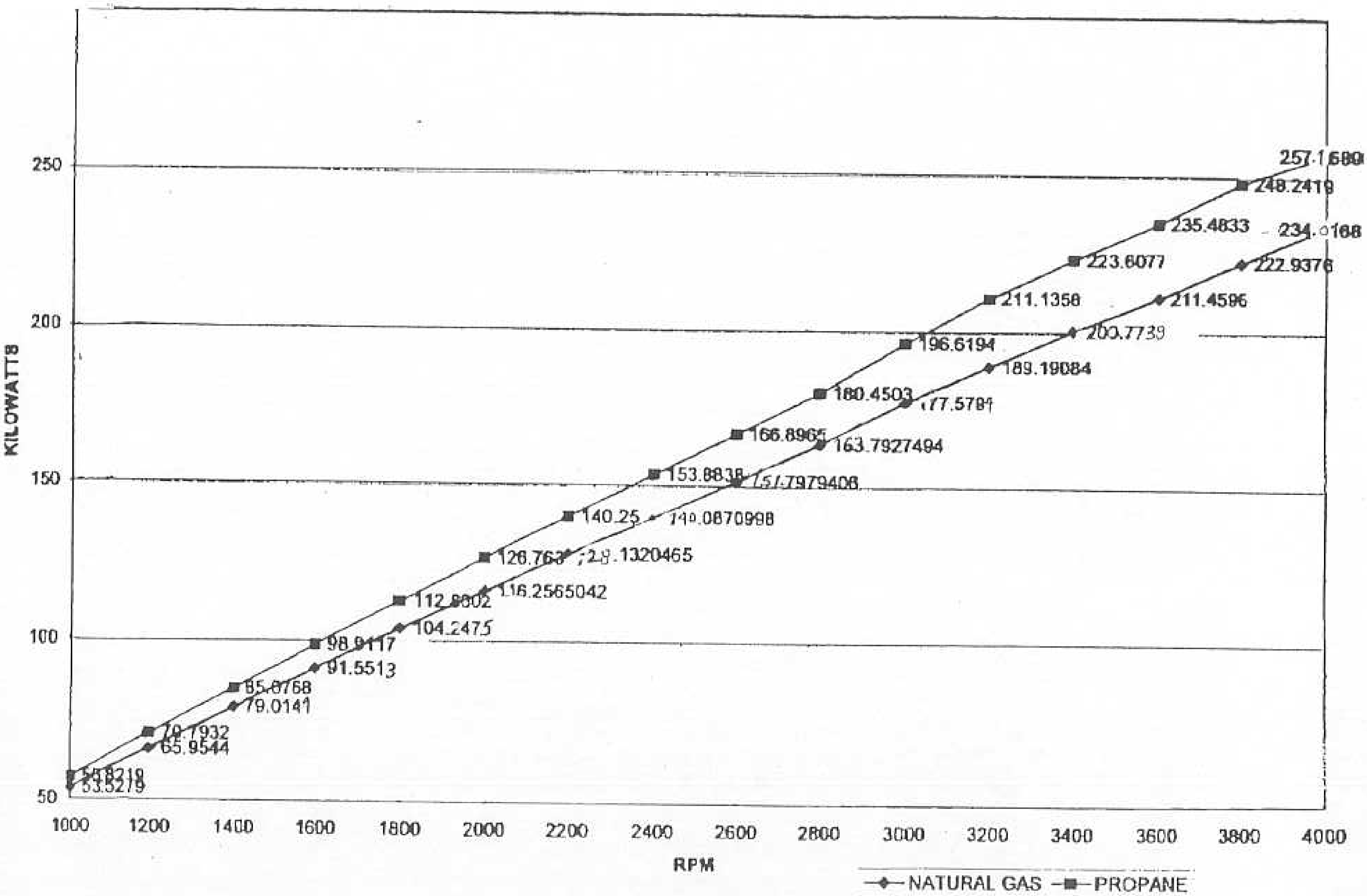


INDUSTRIAL ENGINE SYSTEMS

Appendix K

Power Output vs. Engine Speed Graph

8.1L ALTERNATE FUEL COMPARISON
WOT POWER
KILOWATTS VS. RPM



INDUSTRIAL ENGINE SYSTEMS