INTRODUCTION

In 1985, the Gas Research Institute (GRI) initiated a program to develop seven-site prototype engine-driven water chilling systems for commercial buildings. The packaged systems have been designed, fabricated, and operated satisfactorily in the laboratory and in a 435-bed hospital. The engine chiller has been redesigned to improve performance, increase capacity, and reduce the footprint, and is undergoing field tests at seven sites to verify performance and reliability.

COMMERCIAL COOLING MARKET

In 1967, the commercial market purchased approximately 33,600 units with cooling capacities greater than 5 tons. Of these, 1,600 absorption cooling systems were sold with a total capacity of 528,000 tons, representing 37.6 percent of the total market. In 1989, nearly 139,000 units were purchased, but only 82 absorption machines, 27,100 tons, were sold. Gas cooling represented only 0.8 percent of the market.

Several factors can be credited for this significant loss to the natural gas industry: Electric prices declined in real dollars. The performance of electric-motor driven vapor compression cooling systems improved and the equipment prices decreased. Gas costs escalated rapidly and supplies were assumed to be inadequate. Maintenance costs for electric systems were low and reliability good.

In recent years, these trends have begun to reverse. Electric prices have escalated rapidly as capital-intensive nuclear power plants have been added to the utility rate base. These increases have been offset partially by the commercial building segment, which has little political or economic recourse. The utilities, faced with hostile regulatory review and permit procedures, are unwilling to invest in new supplemental 30-35 tons of cooling.

Direct-fired absorption chillers have succeeded significantly in recent years. Nearly 25 years later, many of these systems are still operating. These systems demonstrated high reliability when properly maintained.

In 1985, the Gas Research Institute (GRI) initiated a program with Tecogen, Inc., to develop a nominal 150-ton gas-fueled engine-driven water chiller for commercial buildings. The engine chiller would capitalize on Tecogen's expertise in packaged cogeneration systems and utilize the mass-produced automotive engine has very low cost and excellent performance and a nominal 150-ton gas-fueled engine-driven water chiller for commercial buildings. The engine chiller can be designed to improve performance, increase capacity, and reduce the footprint, and is undergoing field tests at seven sites to verify performance and reliability.

Absorption is not the only gas-fired air conditioning option. A gas-fueled engine can drive a refrigeration compressor, replacing an electric motor, and achieve the same performance and reliability.

ENGINE-DRIVEN COOLING SYSTEMS

Gas engine-driven cooling systems were very popular in the early Sixties. Major engine manufacturers, such as Caterpillar, Waukesha, and Continental, marketed their products to numerous packagers, such as Ready Power, Gascool, and ComfortTemp. Approximately 2,000 engine-driven systems were sold to commercial and industrial firms. Nearly 25 years later, many of these systems are still operating. These systems demonstrated high reliability when properly maintained.

However, poor maintenance often resulted in catastrophic failure and system removal.

In 1985, the Gas Research Institute (GRI) initiated a program with Tecogen, Inc., to develop a nominal 150-ton gas-fueled engine-driven water chiller for commercial buildings. The engine chiller can be designed to improve performance, increase capacity, and reduce the footprint, and is undergoing field tests at seven sites to verify performance and reliability.

The engine chiller has been designed and tested with several different components. The current system is comprised of the Chevrolet engine, a Howden screw compressor, advanced microprocessor controls, an oil separator, and condenser and evaporator bundles.

The engine chiller has produced 142 tons of cooling. The engine chiller has produced 142 tons of cooling.
cooling at a coefficient of performance (COP) of 1.4 to 1.6 under full load conditions. The chiller is rated at an engine speed of 2920 rpm and output of 147 horsepower. The engine can vary its speed from 1000 rpm to 3300 rpm to meet varying load conditions. The variable speed operation greatly improves the part-load performance of the chiller and permits the chiller to exceed rated capacity for short periods. The microprocessor controls are equipped with an RS-232 port for telecommunications. It is possible to remotely monitor the chiller, run diagnostics, and correct problems, greatly reducing costs for service calls.

The original design for the engine chiller was experimentally tested at Elliot Hospital in Manchester, New Hampshire, to evaluate actual system operating and installation procedures. The chiller system, including the absorption package, exhibited an average COP approaching 2.0. The engine chiller supplements a 500-ton electric centrifugal chiller, which is greatly oversized for the hospital cooling requirements. The hospital is predicting a 30 percent reduction in cooling costs. Additionally, the engine chiller is much quieter than the electric centrifugal.

The preliminary results of the field experiment were integrated into a new design that radically simplified the package and improved its performance. The new design is being tested in a seven unit field test during the summer of 1987. Units will be tested in three configurations: simple mechanical chiller, engine chiller with heat recovery, and engine chiller with absorption bottoming. The units are installed in several commercial applications, including hotels, manufacturing facilities, and office buildings.

### Tecochill CH-150 Field Test

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<th>Site</th>
<th>System</th>
<th>Application</th>
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<td>Engine Chiller</td>
<td>Hotel</td>
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<td>Cleveland</td>
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<td>Boyle Arc.</td>
<td>Engine Chiller</td>
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<td>Panhandle E.</td>
<td>Engine/Absorp.</td>
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<td>Kansas City</td>
<td>Engine/Rec.</td>
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<td>Breton Weyburn</td>
<td>Engine Chiller</td>
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<td>Washing DC</td>
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<td>Santa Monica</td>
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The field test should verify the performance of the engine chiller in real world applications. The microprocessor controls will monitor and record critical operating data for 15 minute intervals. A central data acquisition system will gather the data daily and correlate with statistical analysis. The field test will also provide valuable information on installation costs and procedures, and maintenance costs.

### Economics of Engine-Directed Chillers

**Market assessments and economic analyses have demonstrated that a huge potential for gas-fueled engine-driven cooling systems exists, especially in regions of the United States that have high electric demand charges.** The superior part-load performance of the engine chiller, coupled with its minimal electric requirements, makes it an ideal peaking unit.

Several factors influence the ultimate cost of cooling commercial buildings. Electric costs must be differentiated into demand charges, demand rates, and energy costs. Costs of these factors are typically determined by the cooling degree days or equivalent full load hours (SPLH) for specific regions. Equipment performance must consider chiller COP and auxiliary electric loads required for pumps, fans, and controls. Maintenance costs must be considered. Figure 1 compares the cost of electric and gas-cooled chiller in Chicago. Figure 2 illustrates the impact on a national scale of varying these factors. The diagonal line represents a three-year payback on the cost premium over competitive electric systems. Cities above the diagonal line have more attractive, shorter paybacks. Clearly, the first cost, hours of use, and demand rate have significant impact on the attractiveness of the system.

### Future Engine-Driven Cooling Systems

The GRI development program has been expanded to a range of gas engine-driven cooling systems, from 15-ton NH packages to 500-ton liquid chillers. GRI is currently developing a 500-ton engine-driven chiller package which uses a Carrier 291M twin open-drive centrifugal compressor package. Each compressor will be driven with a tuned induction 454-cubic-inch overhead engine. A.C.A. Laboratories is working with Thermo King Corporation to develop a 15-ton rooftop package based on the Tecochill's truck-trailer refrigeration system. Thermo King has manufactured engine-driven refrigeration systems for 48 years and has a nationwide service network.

Additionally, GRI is evaluating systems for low-temperature refrigeration and process applications. The incorporating of waste heat-driven absorption chillers to subcool liquid refrigerant further improves the cooling performance of the advanced system and reduces engine/compressor size. A COP of 1.9 is targeted. A.C.A. Laboratories is working with Thermo King to develop a 25-ton packaged absorption unit.

The preliminary results of the field test verify the performance of the engine chiller. The microprocessor controls will monitor and record critical operating data for 15 minute intervals. A central data acquisition system will gather the data daily and correlate with statistical analysis. The field test will also provide valuable information on installation costs and procedures, and maintenance costs.
ELECTRIC VS GAS CHILLER
ANNUAL OPERATING COST COMPARISON

$ - Dollars
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0

Maintenance
Aux. Energy
Aux. Demand
Compressor Gas
Compressor Energy
Compressor Demand
SENSITIVITY TO FIRST COST

Electric Energy Cost (¢/kwh)

Demand Charge ($/kw)

Summer, 1985 Rates, Large Commercial Buildings. No Taxes or Surcharges Included
*Ratchet Charges Applicable
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SENSITIVITY TO GAS PRICE

Electric Energy Cost ($/kWh)

Demand Charge ($/kw)

SENSITIVITY TO EFLH

Electric Energy Cost (¢/kwh)

Base Case Assumptions:
First Cost Premum: $30/ton
Gas Engine: COP=1.5, AUX=0.15 kW/T; Maint=$0.015
Elec Centrif: COP=5.5, AUX=0.15 kW/T; Maint=$0.005
Hour: EFLH=1200, Operating=2400
Gas: $4/MMBTU
Demand Rates: 4 Month

Summer, 1985 Rates, Large Commercial Buildings. No Taxes or Surcharges Included

Ratchet Charges Applicable

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SENSITIVITY TO DEMAND RATCHET

Electric Energy Cost ($/kwh)

Base Case Assumptions:
- First Cost Premium: $30/Ton
- Gas Engine: COP=1.5, AUX=0.1, KW/T, Maint. $0.015
- Gas Turbine: COP=5.5, AUX=0.15 KW/T, Maint. $0.005
- Hours: EF=1.9; Operating=$2400

Summer, 1985 Rates, Large Commercial Buildings, No Taxes or Surcharges Included
- Ratchet Charges Applicable

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SENSITIVITY TO MAINTENANCE

Base Case Assumptions:
- First Cost Premium: $30/Teq
- Gas Engine: COP=1.5; AE=0.10 kW/T; Maint=$0.115
- Electric: COP=5.5; AE=0.15 kW/T; Maint=$0.005
- Hours: ETLH=1200; Operating=2400
- Gas: $4/MMBtu
- Demand Rate: 4 Month
- Summer, 1985 Rates, Large Commercial Buildings. No Taxes or Surcharges Included
- Ratchet Charges Applicable

0 2 4 6 8 10 12 14 16 18 20 22 24
Electric Energy Cost (¢/kwh)

0 2 4 6 8 10 12 14 16 18 20 22 24
Demand Charge ($/kw)

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SENSITIVITY TO AUXILIARY POWER REQUIREMENTS

Electric Energy Cost ($/kwh)

- Base Case Assumptions:
  - First Cost Premium: $30/Ton
  - Gas Engine: COP=3.5; AUX=0.19 KW/T; Maint=$0.015
  - Elec Centrifugal: COP=5.5; AUX=0.15 KW/T; Maint=$0.005
  - Hours: CFL 1200; Operating=2400
  - Gas: $4/MMBTU
  - Demand Rate: 4 Month

- 0.19 KW/Ton
- 0.35 KW/Ton

Summer, 1985 Rates, Large Commercial Buildings. No Taxes or Surcharges Included

- Ratchet Charges Applicable

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