GAS-FUELED ENGINE-DRIVEN AIR CONDITIONING SYSTEMS FOR COMMERCIAL BUILDINGS

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INTRODUCTION

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 packaged system has been designed, fabricated, and operated satisfactorily in the laboratory and in a 450-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 83,600 units with cooling capacities greater than 5 tons. Of that, 1,601 absorption cooling systems were sold with a total capacity of 528,000 tons, representing 27.6 percent of the total market. In 1984, nearly 134,000 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 shouldered primarily by the commercial building segment, which has little political or economic recourse. The utilities, faced with hostile regulatory review and permitting procedures, are unwilling to invest in new plant construction. Demand may exceed generating capacity in many areas of the country and necessitate brown-outs or curtailment. Gas costs, on the other hand, have stabilized and even decreased for certain regions. Gas supply is now sufficient into the next century at reasonable costs. The commercial market is clearly positioned to consider gas cooling as a viable alternative.

Direct-fired absorption chiller/heater systems have made significant in-roads into the commercial market. These Japanese systems are nearly 40 percent more efficient than their single-effect predecessors. Unfortunately, the tumultuous foreign exchange market has placed these units at a severe disadvantage. The high first cost of absorption systems can only be justified in those regions of the United States with extremely high electric rates.

ENGINE-DRIVEN COOLING SYSTEMS

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 per shaft horsepower. The gas engine has an efficiency of 30 percent (HHV), which is comparable to the efficiency of an electric generation plant. The engine chiller should achieve a coefficient of performance (COP) of 1.7, a 70 percent improvement over direct-fired absorption chillers. Additionally, the engine chiller can leverage the advances in electric chiller technology to obtain a very competitive first cost.

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 those 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 would capitalize on Tecogen's experience in packaged cogeneration systems and utilize the 454-cubic-inch Chevrolet engine used in their best-selling 60-kW package. The mass-produced automotive engine has very low cost and excellent durability. Several engines have exceeded 20,000 hours of operation. Waste heat from the engine jacket and exhaust can be recovered as hot water for pool heating, domestic water heating, and space heating. The hot water can also drive an optional absorption chiller to produce a supplemental 30-35 tons of cooling.

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, an economizer, and condenser and evaporator bundles. The engine chiller has produced 142 tons of

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cooling at a coefficient of performance (COP) of 1.4 at ARI 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 installed at Elliot Hospital in Manchester, New Hampshire, to evaluate actual system operations 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

Site	System	Application
Budget Inn, Cleveland	Engine Chiller	Hotel
Bleyle of America, Atlanta	Engine Chiller	Manufacture
Panhandle Eastern, Kansas City	Engine/Absorption	Office
Bristol Wyndham, Washington	Engine/Ht Recovery	Hotel
Grossmont Center, San Diego	Engine Chiller	Office
NIGAS Division HQ, Chicago	Engine Chiller	Office
Santa Monica Bay Towers, Los Angeles	Engine	Apartment

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 in 15 minute intervals. A central data acquisition system will retrieve the data daily and correlate fleet statistics. The field test will also provide valuable information on installation costs and procedures, and maintenance costs.

ECONOMICS OF ENGINE-DRIVEN 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 charge, demand ratchet, and energy cost. Hours of use are typically determined by cooling degree days or equivalent full load hours (EFLH) 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 cooling in Chicago. Figures 2-7 illustrate 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 ratchet have significant impact of the attractiveness of the system

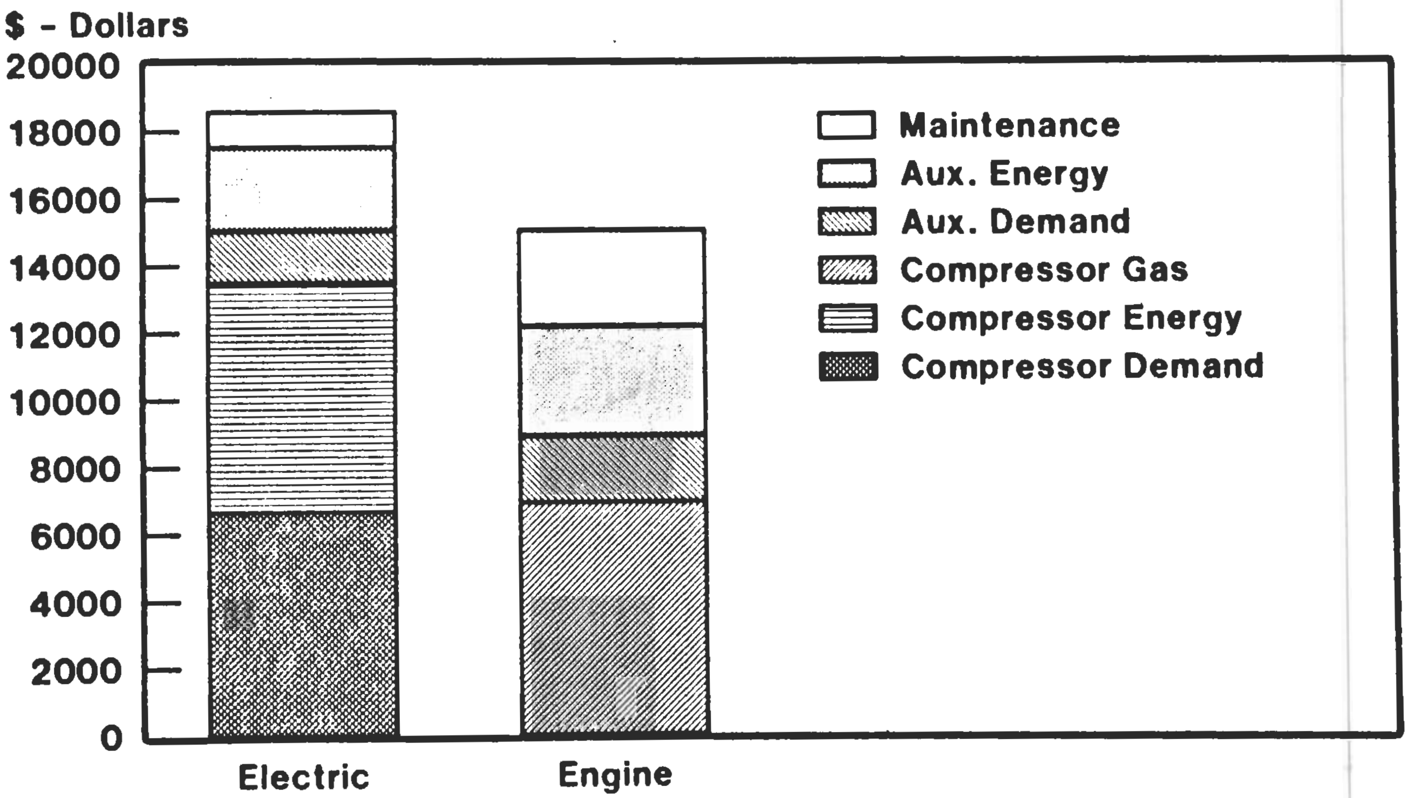
FUTURE ENGINE-DRIVEN COOLING SYSTEMS

The GRI development program has been expanded to a range of gas engine-driven cooling systems, from 15-ton DX packages to 500-ton liquid chillers. Tecogen is currently developing a 500-ton chiller which uses a Carrier 17DK twin open-drive centrifugal compressor package. Each compressor will be driven with a tuned induction 454-cubic-inch Chevrolet engine. A COP of 1.9 is targeted. A.G.A. Laboratories is working with Thermo King Corporation to develop a 15-ton rooftop package based on Thermo King'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 incorporation 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 multiple compressor engine-driven refrigeration package for supermarkets is undergoing field tests in Los Angeles.

The 150-ton engine-driven chiller package should be commercially available as early as 1988. The 500-ton package and engine-driven unitary packages should be available in 1989.

ELECTRIC VS GAS CHILLER ANNUAL OPERATING COST COMPARISON



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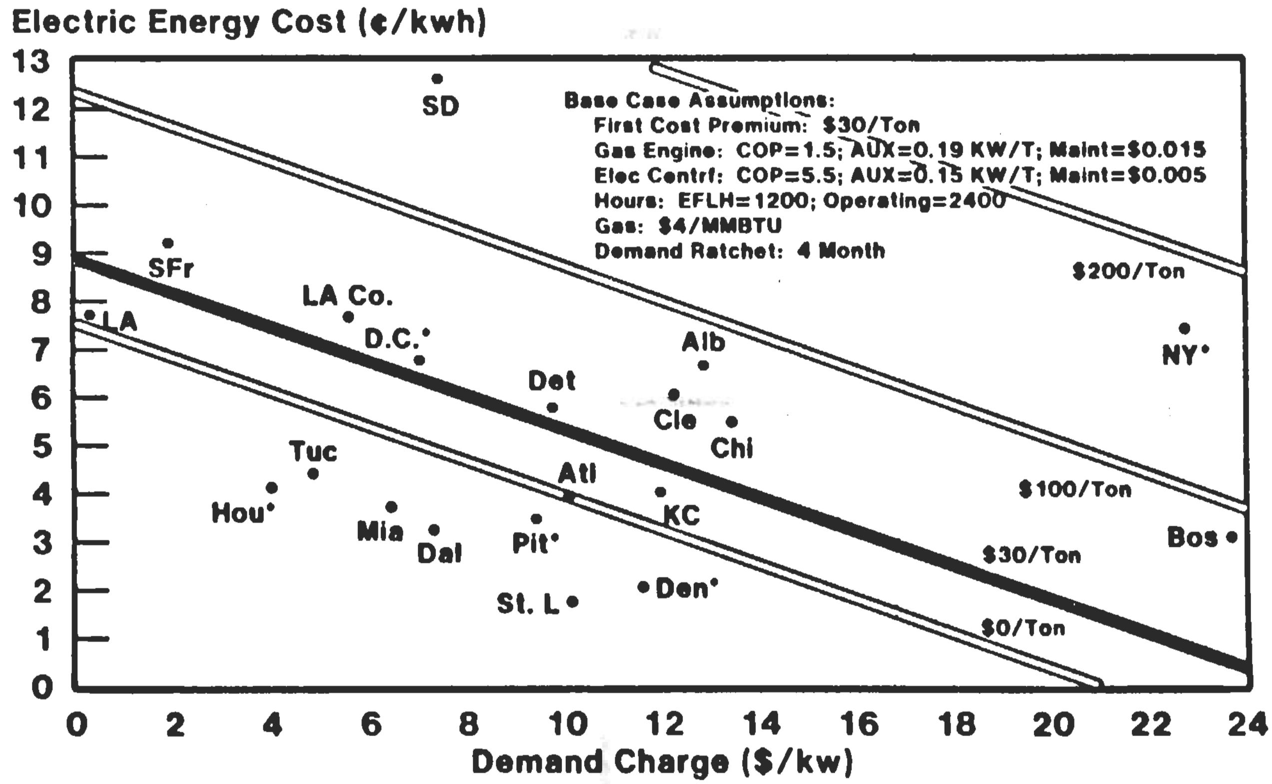
SENSITIVITY TO FIRST COST



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

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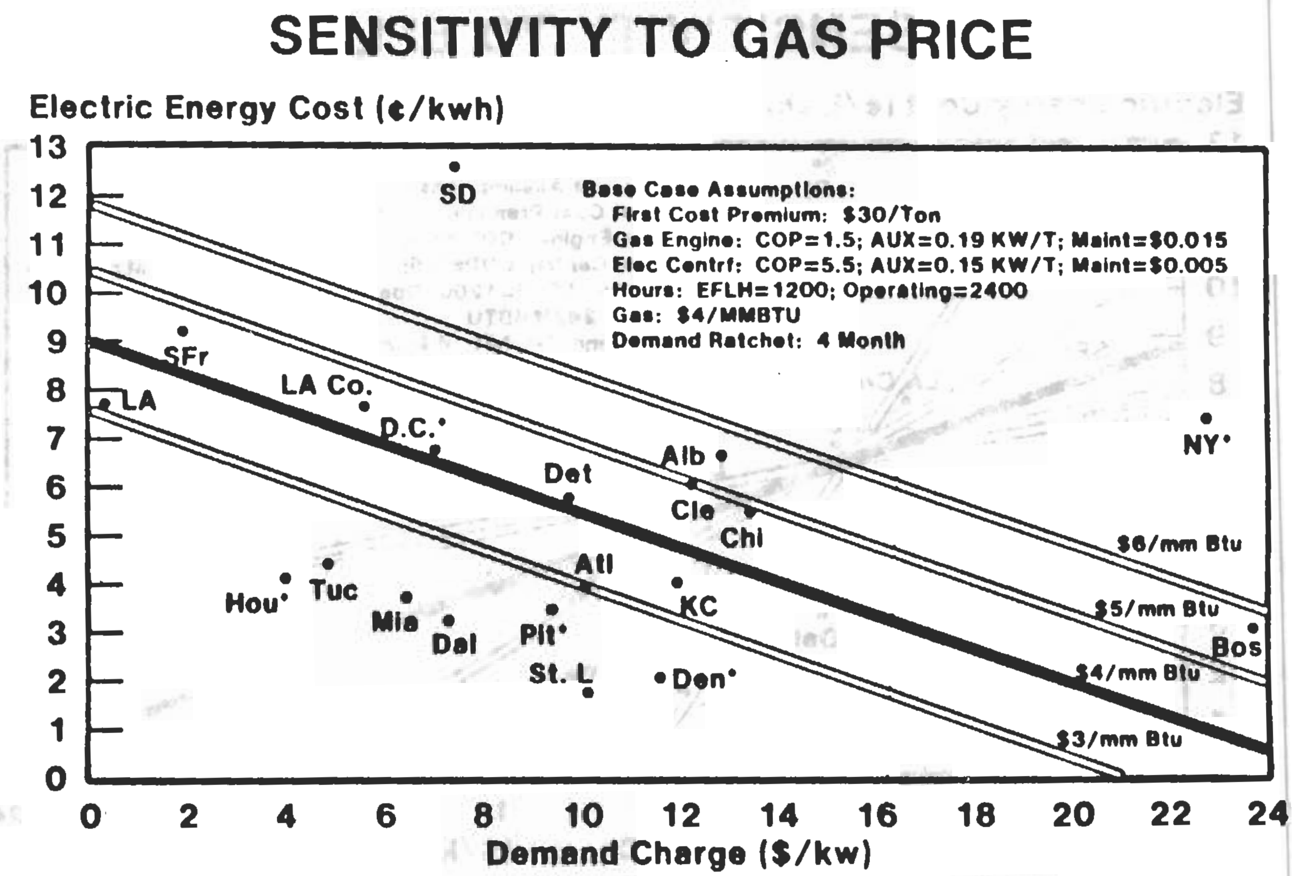

Summer, 1985 Rates, Large Commercial Buildings. No Taxes or Surcharges Included
* Ratchet Charges Applicable

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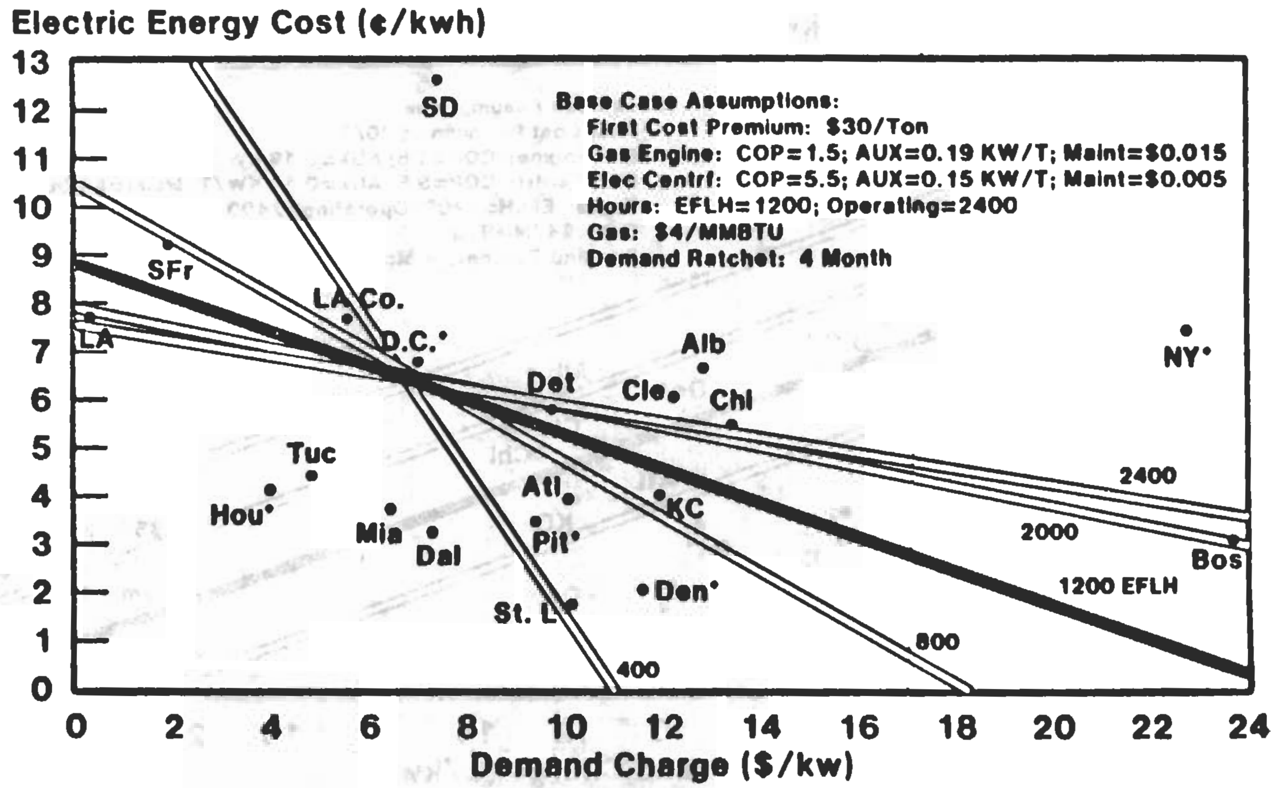
SENSITIVITY TO EFLH



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* Ratchet Charges Applicable

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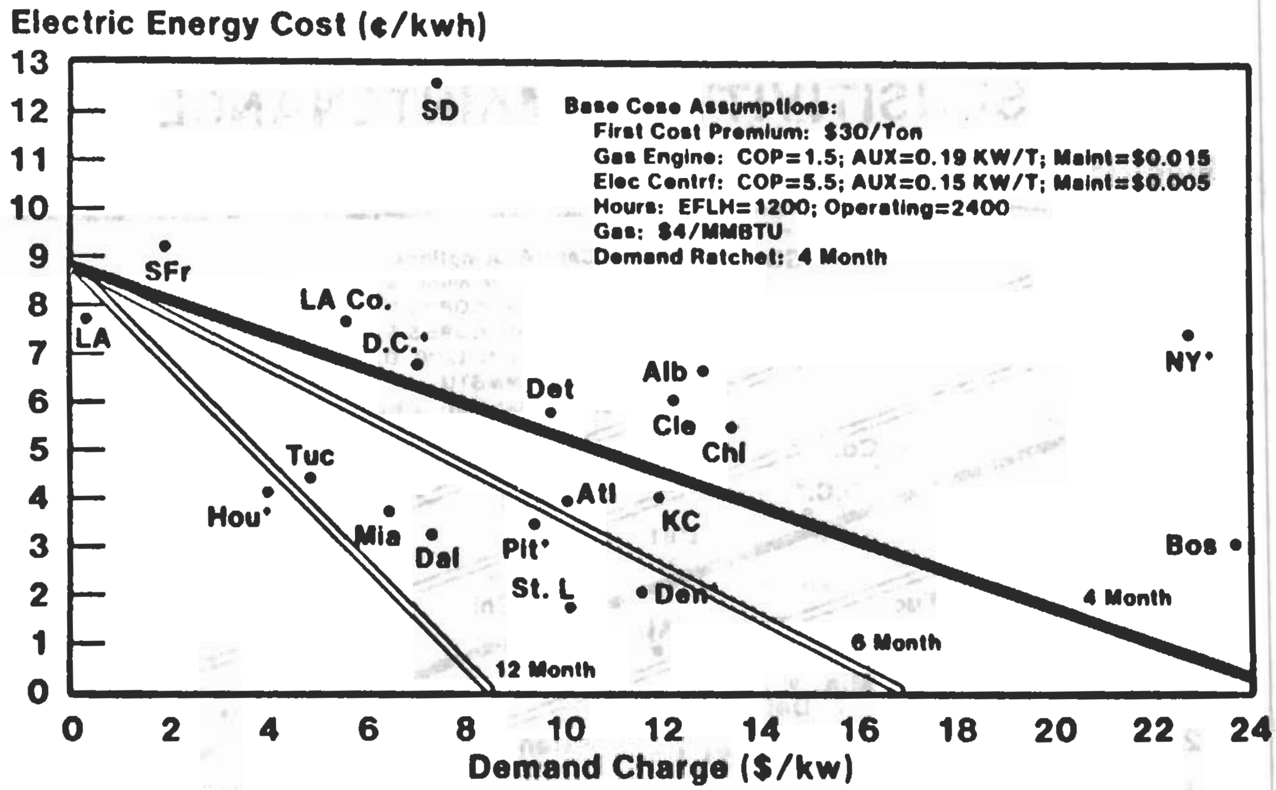
SENSITIVITY TO DEMAND RATCHET



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* Ratchet Charges Applicable

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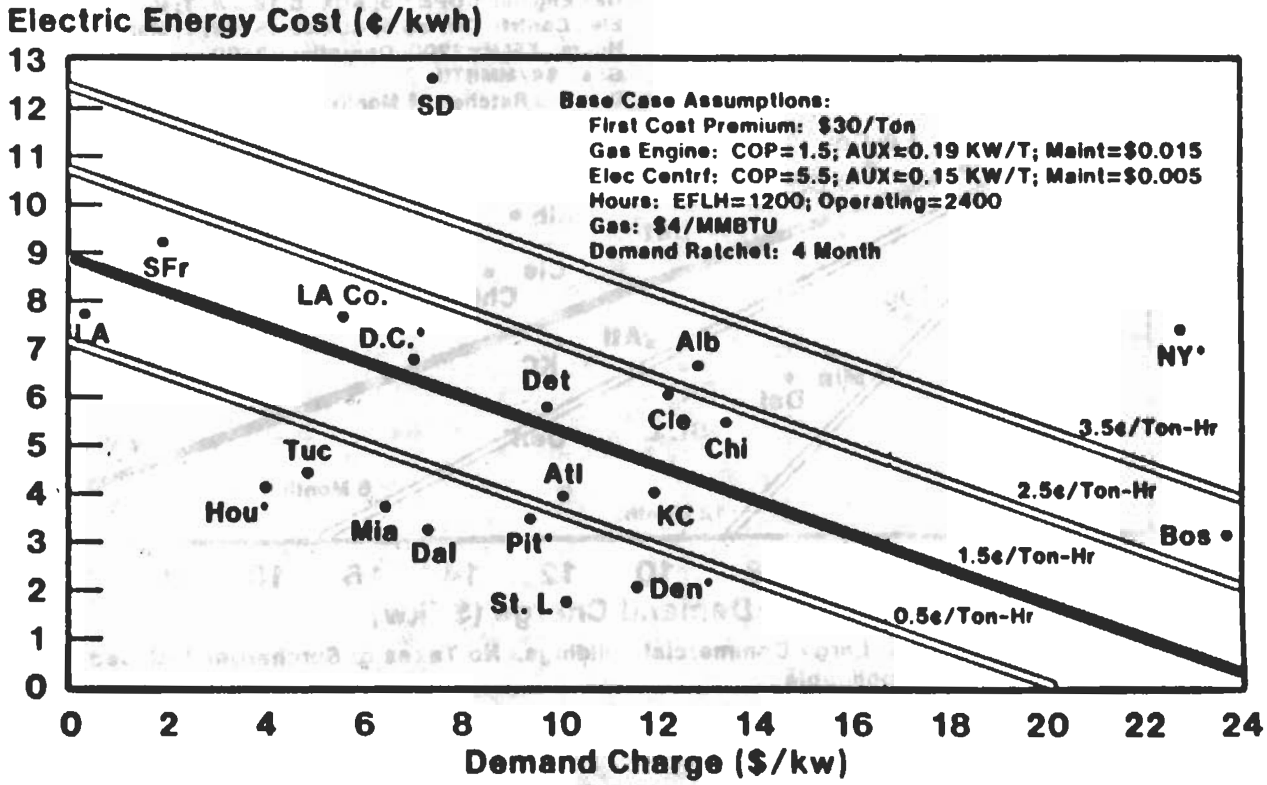
SENSITIVITY TO MAINTENANCE



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* Ratchet Charges Applicable

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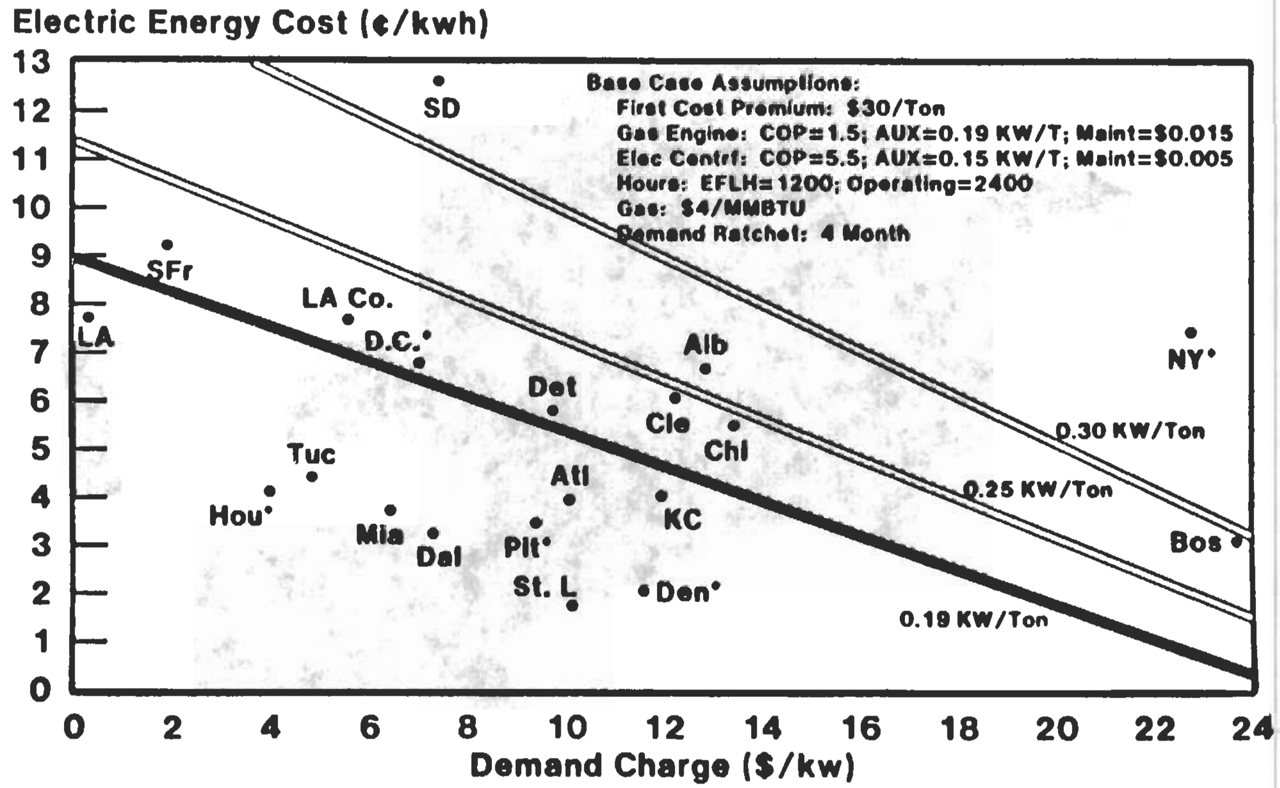
SENSITIVITY TO AUXILIARY POWER REQUIREMENTS



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* Ratchet Charges Applicable

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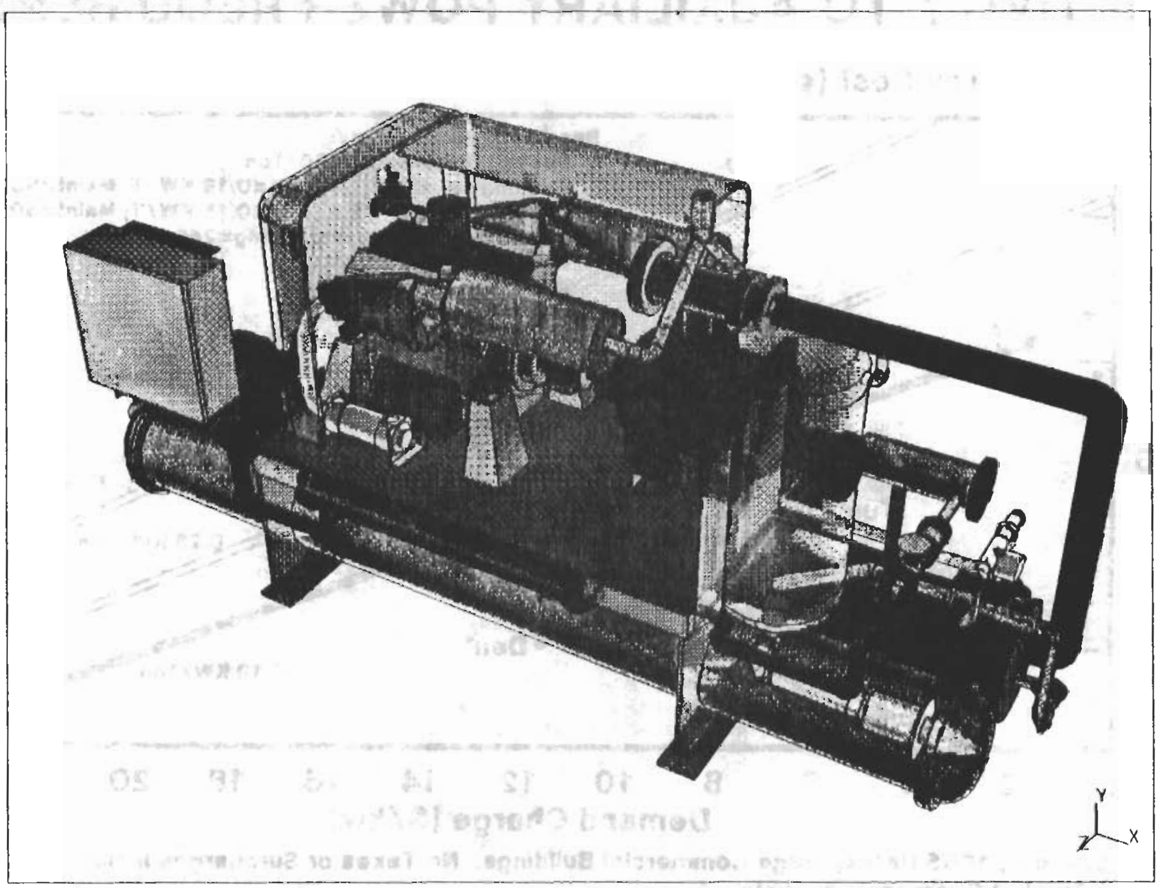
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