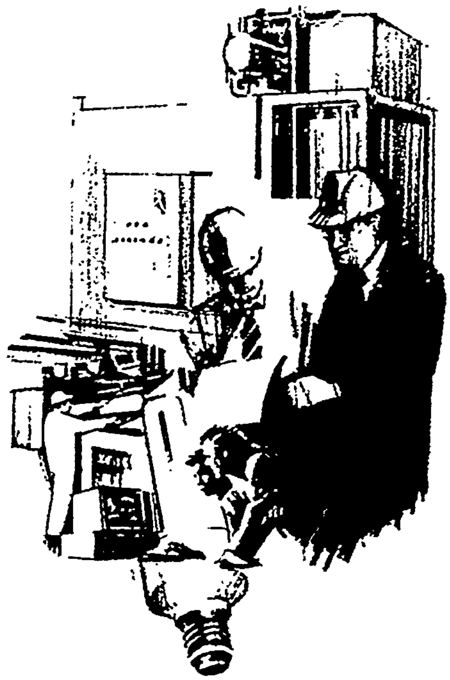
PNL-10864 Vol. 2
UC-1600

Field Monitoring and Evaluation of a Residential Gas-Engine-Driven Heat Pump

Volume 2 - Heating Season



November 1995

Prepared for the U.S. Department of Energy
Federal Energy Management Program
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

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J. D. Miller

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Pacific Northwest Laboratory
Richland, Washington 99352

Preface

The Federal government is the largest single energy consumer in the United States; consumption approaches 1.5 quads/year of energy (1 quad = 10^{15} Btu) at a cost valued at nearly $10 billion annually. The U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) supports efforts to reduce energy use and associated expenses in the Federal sector. One such effort, the New Technology Demonstration Program (NTDP), seeks to evaluate new energy-saving U.S. technologies and secure their more timely adoption by the U.S. government.

Pacific Northwest Laboratory (PNL)[a] is one of four DOE national multiprogram laboratories that participate in the NTDP by providing technical expertise and equipment to evaluate new, energy-saving technologies being studied and evaluated under that program.

This two-volume report describes a field evaluation that PNL conducted for DOE/FEMP and the U.S. Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP) to examine the performance of a candidate energy-saving technology—a gas-engine-driven heat pump. The unit was installed at a single residence at Fort Sam Houston, a U.S. Army base in San Antonio, Texas, and the performance was monitored under the NTDP. Participating in this effort under a Cooperative Research and Development Agreement (CRADA) were York International, the heat pump manufacturer; Gas Research Institute (GRI), the technology developer; City Public Service of San Antonio, the local utility; American Gas Cooling Center (AGCC); Fort Sam Houston; and PNL.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830 by Battelle Memorial Institute.

Summary

Through its Office of Federal Energy Management Program (FEMP), the U.S. Department of Energy (DOE) provides technical and administrative support to Federal agency programs directed at reducing energy consumption and cost in Federal buildings and facilities. One such program is the New Technology Demonstration Program (NTDP).

In this context, NTDP is a demonstration of a U.S. energy-related technology at a Federal site. Through a partnership with a Federal site, the utility serving the site, a manufacturer of an energy-related technology, and other organizations associated with these interests, DOE can evaluate new technologies. Through the results of the program, Federal agency decision makers have more hands-on information with which to validate a decision to utilize a new technology in their facilities. The partnership of these interests is secured through a Cooperative Research and Development Agreement (CRADA).

The purpose of the Fort Sam Houston/Triathlon demonstration is to evaluate the performance and cost-effectiveness of the Triathlon gas heat pump (GHP) in the Federal sector. This is done by measuring the performance of the candidate unit and comparing it to the measured performance of conventional heating, ventilating, and air-conditioning (HVAC) systems currently in the residences at the base. The energy consumption, thermal measurements, and maintenance records will be primary elements in the life-cycle cost analysis of potential savings from the candidate unit.

The NTDP project at Fort Sam Houston (San Antonio, Texas) features a 3-ton gas-engine-driven heat pump. A single-cylinder, four-stroke, 5-hp engine fueled by natural gas drives the heat pump's compressor. A distinctive feature of the technology is an inherent load-matching capability. The heat pump can vary engine speed and blower fan speed, and thereby dynamically control capacity to balance with thermal loads. This balance minimizes the need for cycling and reduces the associated thermal losses, fluctuations in room temperature and humidity, and equipment wear. The unit produces added heating capacity and improved supply-air temperatures through engine-waste heat recovery. The Triathlon GHP is manufactured by York International.

Three test houses at the Fort were used for the field comparison of the Triathlon against conventional residential HVAC systems. The houses were chosen to have identical structural design and solar exposure and to be occupied by families with one or two children. Two of the houses currently have HVAC systems that represent the best available at the Fort. This includes pulse-combustion furnaces and air conditioners with scroll compressors. A third house represents the worst case, with the oldest of the Fort's conventional air conditioners and furnaces. These HVAC systems bracket the range of equipment performance currently at the Fort and typically found in many other residential installations at Federal facilities.

Baseline measurements on the three comparison units started in August 1993. One of the comparison units was replaced with the Triathlon GHP in June 1994. Side-by-side monitoring of the Triathlon GHP and the two remaining comparison systems continued through June 1995. Monitoring of the Triathlon GHP continues through the end of December 1995.

Performance maps, based on field data, were developed for the existing residential furnaces and air conditioners monitored at Fort Sam Houston. These maps present a common basis for comparisons between the GHP and the existing equipment. The comparisons are done by projecting (mapping) the field-measured characteristics of the comparison units onto the actual loads and operating conditions seen by the GHP. This approach supplements a pre/post-measure evaluation by decoupling the measured equipment performance from the effects of different envelope characteristics, occupant behavior, and weather. Details of the technical approach used in the evaluation, including instrumentation and methodology, are presented in Volume 1 of this report.

A comparative life-cycle cost (LCC) analysis of the Triathlon was based on field measurements of the GHP and existing systems at Fort Sam Houston. A simple method was developed to project the results of the field study to other climates (characterized by heating degree-days [HDD] and cooling degree-days [CDD]) and other comparison AC/furnace systems. The monitored performance of the most efficient existing system served as the basis for projections to other commercially available AC/furnace systems as characterized by seasonal energy efficiency rating (SEER) and annual fuel utilization efficiency (AFUE).

Findings from the summer-cooling test demonstrated the Triathlon GHP to be a reliable system. There were no forced outages during the cooling test, giving the unit a 100% reliability record during the summer. However, the GHP did have two significant downtimes during the heating-season test, resulting in less than 100% availability. These outages were the result of component failures identified as well known preproduction[a] design deficiencies that have been corrected in all Triathlon production units.

The occupants concluded that the GHP provided good comfort levels with acceptable levels of operating noise. Monitoring of indoor humidity during cooling operation showed nearly identical average humidity levels (and associated comfort) by the Triathlon and comparison air conditioners during the summer test. Monitoring of indoor temperatures during heating operation showed the variable-speed GHP to provide better temperature control than the comparison systems.

Throughout the cooling and heating test seasons, the GHP operated at the manufacturer's anticipated performance levels. This test unit showed normal operating behavior relative to a

(a) The unit secured and installed was a preproduction model, allowing the results of this project to be available concurrent with the availability of production units.

computer simulation of the GHP. The cooling-season and heating-season test results demonstrated GHP performance levels slightly above those established in the Phase I Field Test program conducted by the unit's developers. The GHP demonstrated a thermal coefficient of performance (COP) of 1.128 during the summer-cooling test and 1.278 during the winter-heating test.

The GHP yielded a reduction in cooling-energy costs over the conventional air conditioners at Fort Sam Houston. In a normal summer at the San Antonio test house, the GHP uses 41.5 kcf of gas and 864 kWh of electricity. This amount of fuel costs $224[a] and corresponds to a savings of $37 to $59 over the three comparison air conditioners in this field test. The savings relative to the best of the comparison units (10.45 SEER) was $37 (14.2%).

The GHP demonstrated a reduction in heating-energy costs from those recorded for the condensing furnaces existing at the base. In a normal winter at the San Antonio test house, the GHP uses 27.9 kcf of gas and 510 kWh of electricity. This amount of fuel costs $147[b] and corresponds to a savings of $33 (18.3 % of Unit 1 consumption; AFUE = 97.0%) to $101 (40.6% of Unit 3 consumption; AFUE = 69.2%) over the costs recorded for the three comparison furnaces in this field test.

However, on a total operating cost basis, the Triathlon does not offer annual savings at Fort Sam Houston when compared with the most efficient of the systems in the field comparison. Lower than national-average electricity prices, $100 higher maintenance costs, and a mild winter climate, all contribute to higher annual-operating costs for the GHP when compared to the field units 1 and 2 and 9.8% savings in annual-operating costs over Unit 3, which was built in 1975 (EER = 7.5, AFUE = 69.2%).

The LCC of the Triathlon was compared to the LCC of three commercially available AC/furnace systems[c] at six federal bases. Of the six bases analyzed, the GHP was found cost-effective at two—Willow Grove Naval Air Station (NAS) in Philadelphia and Fort Irwin near Barstow, California. Both sites had effective-electricity rates more than twice the

(a) Based on internal commercial gas and electricity rates established at Fort Sam Houston.
(b) Based on internal commercial gas and electricity rates established at Fort Sam Houston.
(c) Assumed system costs:

	Triathlon	System A	System B	System C
SEER, Btu/wh	----	10.2	15.6	12.2
AFUE, %	----	97	97	80
Annual maintenance, $	175	75	75	75
Installed cost, $	8000	4018	5917	3500

national average and rates structured to include ratcheted-demand charges. Willow Grove NAS yielded the highest LCC savings ($984 over a 15.6 SEER air conditioner and a 97% AFUE furnace) for the GHP due to high racheted-demand charges coupled with a significant heating season and higher than national-average gas prices. At a lower price ($6000 installed) and lower annual maintenance cost ($150), Fort Drum and Fort Dix are also shown to be cost-effective locations.

Although the standard Triathlon evaluated in this analysis is generally not selling at single-unit prices below $6,000, a 2-pipe version (using electric-resistance back-up heat in substitution for the standard gas-boiler auxiliary heater) can offer as much as a $1,000 reduction in price. This version is potentially less efficient in the heating mode (no engine waste-heat recovery) but could be the cost effective choice in locations with mild heating seasons. This substitution potentially reduces LCC for the Triathlon to a level competitive at the remaining two bases, Fort Stewart and Fort Sam Houston.

Abbreviations, Acronyms, and Initialisms

AFUE	annual fuel utilization efficiency
AGCC	American Gas Cooling Center
BLCC	Building Life-Cycle Cost (computer program)
Btu	British thermal unit
CDD	cooling degree-day
COP	coefficient of performance
CRADA	Cooperative Research and Development Agreement
DAS	data acquisition system
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EER	energy efficiency rating (ratio)
FEMP	Federal Energy Management Program
GHP	gas heat pump
GRI	Gas Research Institute
HDD	heating degree-day
HVAC	heating, ventilating, and air conditioning
k	thousand
kWh	kilowatt-hour
LCC	life-cycle cost
M	million
NAS	Naval Air Station
NCDC	National Climatic Data Center
NIST	National Institute of Standards and Technology
NTDP	New Technology Demonstration Program
PNL	Pacific Northwest Laboratory
SEER	seasonal energy efficiency rating
SERDP	Strategic Environmental Research and Development Program
SLP	Super Large Power
TP_COP	test period coefficient of performance

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Introduction

The purpose of the New Technology Demonstration Program (NTDP) is to install and evaluate new U.S.-developed energy technologies at Federal facilities and evaluate their performance. Through the results of the program, Federal agency decision makers have more hands-on information with which to consider a new technology and validate any decision to utilize it in their facilities. The NTDP seeks to identify new energy-saving technologies, determine which have the broadest application in, and benefit to, the Federal sector, and then shorten the deployment time for those technologies that prove beneficial to the Federal market by providing a demonstration of the energy savings potential and the cost-effectiveness of these new technologies in the Federal sector. The NTDP supports Federal facilities in their effort to meet goals established in Executive Order 12902[a] and the Energy Policy and Conservation Act.[b]

The purpose of the Fort Sam Houston/Triathlon demonstration is to evaluate the performance and cost-effectiveness of the Triathlon gas heat pump (GHP) in the Federal sector. This is done by monitoring the performance of the candidate unit and comparing it to that of the conventional HVAC systems currently in the residences at the base. The energy consumption, thermal measurements, and maintenance records will be primary elements in life-cycle cost analysis of potential savings from the candidate unit.

The NTDP project at Fort Sam Houston (San Antonio, Texas) features a 3-ton gas-engine-driven heat pump. A single-cylinder, four-stroke, 5-hp engine fueled by natural gas drives the heat pump's compressor (Harnish et al. 1991). A distinctive feature of the technology is an inherent load-matching capability. The heat pump can vary engine speed and blower fan speed, and thereby dynamically control capacity to balance with thermal loads. This balance minimizes the need for cycling and reduces the associated thermal losses, fluctuations in room temperature and humidity, and equipment wear. The unit produces added heating capacity and improved supply-air temperatures through engine-waste heat recovery. The Triathlon GHP is manufactured by York International.

(a) "Each agency shall develop and implement a program with the intent of reducing energy consumption by 30 percent by the year 2005, based on energy consumption per-gross-square-foot of its buildings in use, to the extent that these measures are cost-effective."

(b) "Not later than January 1, 2005, each agency shall, to the maximum extent practicable, install in Federal buildings owned by the United States all energy and water conservation measures with payback periods of less than 10 years. . ."

Baseline measurements on three comparison units at the Fort started in August 1993. One of the comparison units was replaced with the Triathlon GHP in June 1994. Side-by-side monitoring of the Triathlon and the two remaining comparison units continued through June 1995. Monitoring of the Triathlon GHP continues through the end of December 1995.

This volume is the second of a two-volume report on the Fort Sam Houston/Triathlon demonstration. Triathlon GHP performance during the 1994-1995 field test is described. The scope of Volume 1 encompassed descriptions of the methodology, instrumentation, and analysis used in this field evaluation. Results obtained during the 1994 cooling season were also featured in Volume 1. In Volume 2, the Triathlon's heating season performance is emphasized. A life-cycle cost analysis based on both the heating and cooling performance measurements is presented, as are recommendations for Fort Sam Houston and Federal facilities in the United States.

Background

The Background section in Volume 1 (Miller 1995) describes the features of the Triathlon GHP, the conventional air-conditioning/furnace systems used in comparison, and the demonstration site. Photographs of the installed unit and test house are also shown in Volume 1. Heating specifications for the GHP and the conventional furnace systems are given here in Table 1. Additional background information is presented in this volume in Appendix A. Appendix A includes descriptions of the fundamental concepts behind the GHP operation, descriptions of the Triathlon features, applications, and system specifications.

Table 1. Manufacturers' Rated Heating Performance of Test Units

	Date Built	Type	Output Capacity, kBtu/h	COP	AFUE, %
Triathlon	1993	Gas Heat Pump	53.5	1.4	----
Unit 1	1991	Condensing Furnace	38.8	----	97.0
Unit 2	1991	Condensing Furnace	38.8	----	97.0
Unit 3	1975	Noncondensing Furnace	51.9	----	69.2

Comparative Energy Analysis

The goal of the energy analysis is to compare the measured thermal performance of the Triathlon GHP with that of the three conventional air-conditioner/furnace systems in the field study. Ideally this is done under equivalent operating conditions and thermal loads. Because the houses and occupants' behavior vary to some degree from site to site, a performance mapping and projection technique is needed to present the results of all of the systems from a common basis. The mapping allows the performance of the comparison units to be projected to the conditions recorded at the house with the Triathlon. As a result, the projected performance of the comparison units can be compared directly with the measured performance of the Triathlon.

A simplified version of the mapping methodology presented in Volume 1 on the cooling performance is used in the comparative analysis of the GHP and three conventional furnaces during the 1994-1995 heating season. For several reasons outlined in Appendix B, duty-cycle performance maps are not used for the comparison units. Instead, when calculating the projected energy use of the comparison units under the loads and operating conditions of the Triathlon, a test-period coefficient of performance (TP_COP) is used.[a] This is equivalent to assuming the effect of part-load degradation on the comparison systems do not change if the units are operated under different levels of loading. As a result, the gas energy projections for the conventional systems are simply made by dividing the total recorded load of the GHP during the heating-season test by the TP_COP of the comparison unit.

Similarly, fan energy of the comparison units is projected based on the measured ratio of total test-period fan electricity to total test-period gas consumption. This ratio of fan energy to gas consumption is assumed to be constant under different thermal loading. As a result, the projected fan energy is this electric-to-gas-energy ratio multiplied by the projected gas consumption.

(a) Because of an instrumentation failure, the furnace output capacity and corresponding TP_COP can not be directly calculated for Unit 3. However, because the gas consumption data was available, the TP_COP is calculated by estimating the total test-period load on Unit 3. This estimate of Unit 3 loads is done with a HDD correction of the measured Triathlon loads. The floating points for the two houses are assumed to differ only from thermostat settings. This difference is estimated by the average difference in the room temperature when the furnaces were running. The HDDs for Unit 3 are calculated based on this floating point estimate and records of outdoor temperatures. The ratio of the HDDs for the two houses serve as the correction factor to estimate Unit 3 loads from the Triathlon loads.

The final step in the comparative analysis is to project the results during the 1994-1995 heating season to a normal San Antonio winter. The projection is done with a HDD correction factor in a way similar to that described in Volume 1 (Miller 1995). To make the HDD projection to a normal weather year, the floating point temperature of the house with the GHP is estimated. A plot of load versus the temperature differential across the envelope is shown for a range of days in the middle of the heating season (Figure 1). The zero-load point is at a differential of -8.7°F which corresponds to an outdoor temperature of 66.5°F (average indoor temperature of 75.2°F). Using this base temperature of 66.5°F and temperature records from the test site, HDD of 1569 are calculated for the 1994-1995 heating-test season. Heating degree-day records for San Antonio are interpolated to give 2252 relative to the 66.5°F base. The resulting correction factor to convert from the 1994-1995 heating-test season to a normal San Antonio heating season is 1.43.

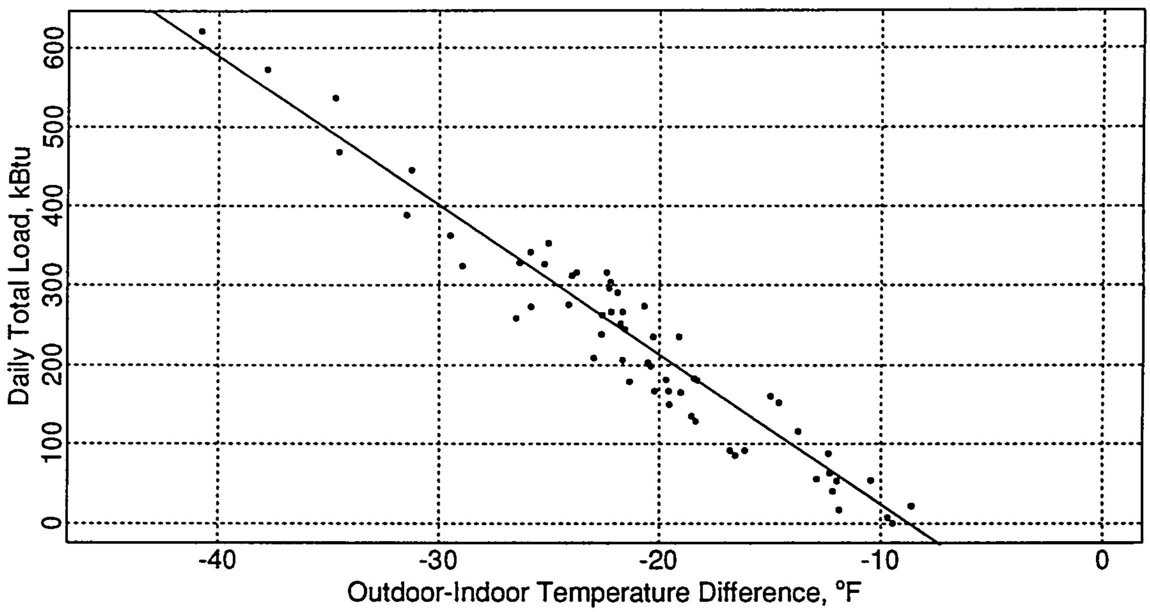

Figure 1. Regression of Load Against Temperature Difference, House 1, 1994-1995 Heating Season

Heating Season Energy and Performance Results

Events During Testing

To best present the results of the monitoring, it is useful to start with a brief history of the equipment and data logger downtime, and maintenance during the testing periods. This provides the rationale behind any subsetting of the data.

Gas Heat Pump Operation

The GHP began heating operation on October 26, 1994, and continued with heating cycles through April 26, 1995. The availability of the unit was less than 100% as a result of two outages: a discharge flange gasket leak and a failed starter motor. Both component failures were identified as well known preproduction[(a)] design deficiencies that have been corrected in all Triathlon production units. Additional descriptions of the downtimes are given in Appendix C.

Comparison Units

The three comparison units were monitored for two complete heating seasons starting in 1993 and ending in 1995. Heating cycles generally started in October and ended in April (mid-May in 1995). There was no furnace downtime during this 2-year period. However, instrumentation problems developed in all three comparison-unit loggers during the 1993-1994 heating season and again in one of the loggers during the 1994-1995 heating season. The failure affected the measurements of supply fan on-time and resulted in no output capacity measurements from the affected loggers.

Weather Characteristics

A distribution of the outdoor operating temperatures for the Triathlon GHP during the 1994-1995 heating test season is illustrated in Figure 2. The trace in the plot is essentially an outline of a histogram of outdoor operating temperatures normalized so that the area under the curve is equal to 1. The data here represents when the GHP is running (i.e., hours during which there is no call for heating are not included in the distribution). The mean operating temperature is represented with a vertical line.

(a) The unit secured and installed was a preproduction model, allowing the results of this project to be available concurrent with the availability of production units.

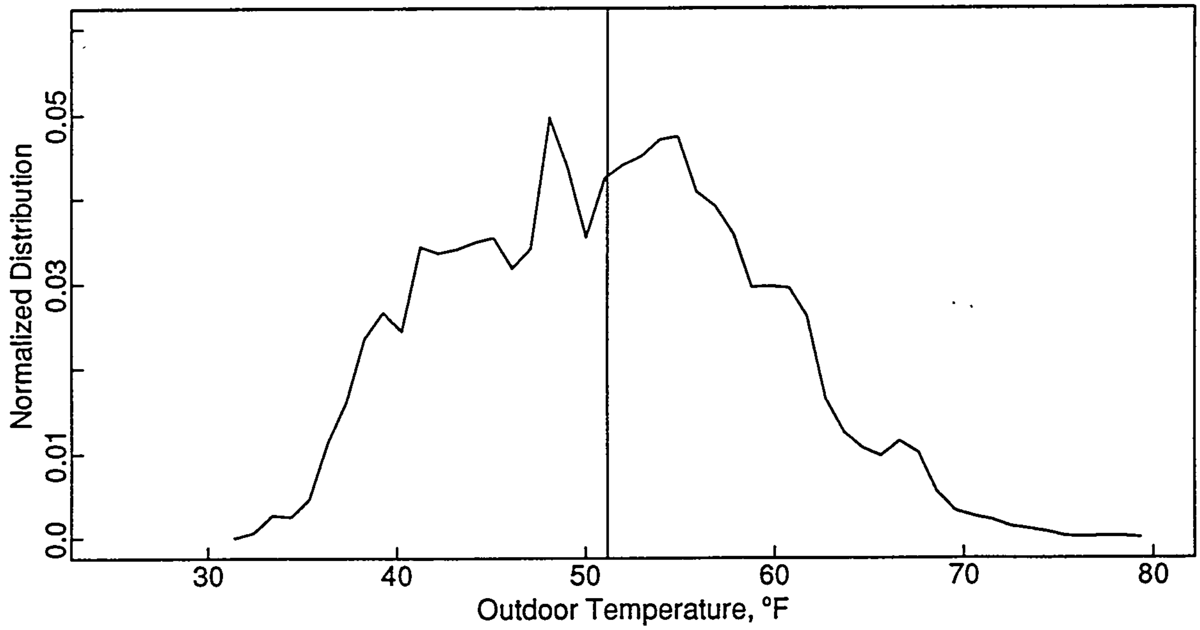

Figure 2. Distribution of Outdoor Operating Temperatures at House 1 During 1994-1995 Heating Season

Triathlon Thermal Performance

The Triathlon GHP demonstrated normal performance during the 1994-1995 heating season. Throughout this test, the unit operated within the bounds of normal behavior as determined by a computer simulation (Fisher and Rice 1986a,b) of the unit (see Appendix D). The GHP demonstrated seasonal performance levels slightly above those established in previous field testing conducted by the GHP developers (York and Battelle 1993).

During the 1994-1995 heating season, the GHP consumed 19.8 MBtu of natural gas and provided 25.3 MBtu of heating output. The overall system gas TP_COP including the auxiliary heater[(a)] operation was 1.28. The auxiliary heater ran for a total of 24.7 hours. During 5.4 h of the 24.7 h, the auxiliary heater was operating in assistance to the heat pump. This was not because of loads beyond the heat pump capacity but rather because of occupant-initiated thermostat changes that called for full capacity from the GHP system. For the

(a) When supplemental heat is required, the GHP meets the added load with a gas fired auxiliary boiler (heating COP, 0.82; capacity, 65 kBtu/h). The boiler is contained in the outdoor unit and circulates hot fluid to the water glycol radiator contained in the indoor unit. In extreme cold, the system controls shut down the heat pump and the auxiliary boiler is the sole source of heating.

remaining 19.3 h, the auxiliary heater ran with the heat pump off. This use of the auxiliary as the sole source of heat resulted from two periods of downtime for the heat pump (see Events During Testing) and was not triggered by a cold-temperature shutdown of the heat pump. During cycles without auxiliary heat, the TP_COP was 1.35.

Plots illustrating the effect of outdoor temperature (and associated loading) on COP are shown in Figures 3 through 6. Figures 4 and 5 show the significant performance degradation that results when loads are small and the unit must start cycling because it cannot further lower its speed. This is seen in Figure 5 as a general decline in heating COP with increasing outdoor temperature. Figure 5 also illustrates the fact the unit was forced to cycle throughout a majority of the heating test and would have demonstrated higher COPs in a more severe winter climate. Figure 6 shows cooling COPs increasing with decreasing temperatures[a] until the unit starts to cycle below roughly 75°F.

Additional performance indicators are shown in Table 2 and Appendix C. All cost estimates are based on internal (to the base) gas and electric prices at Fort Sam Houston (0.0488 $/kWh; 4.3863 $/kcf). Additional cost analyses, under different pricing assumptions, are presented in the Life-Cycle Cost Analysis section.

Comparison Units' Performance

The 1994-1995 heating-season performance of the comparison furnaces was consistent with the manufacturers' AFUE ratings. The Unit 2 (pulse combustion) had a TP_COP of 94.3%. Unit 3 had a TP_COP of 66.9%. Additional performance indicators are presented in Tables 3 and 4 and Appendix B.

Comparison Units' Projected Performance

The measured performance of the comparison units was projected onto the operating loads seen by the Triathlon GHP. The projection was based simply on the measured TP_COP of the comparison units (see the Comparative Energy Analysis section). These projected energy numbers are the consumptions that would be seen during the 1994-1995 heating season if these units had been installed instead of the Triathlon GHP. These projections are summarized in Table 5.

(a) Throughout the variable speed range of the GHP, the increases in cooling COP resulting from decreases in temperatures can be associated with improvements in efficiency from decreasing speeds (and loads) and improvements in heat pump heat transfer from decreasing temperatures.

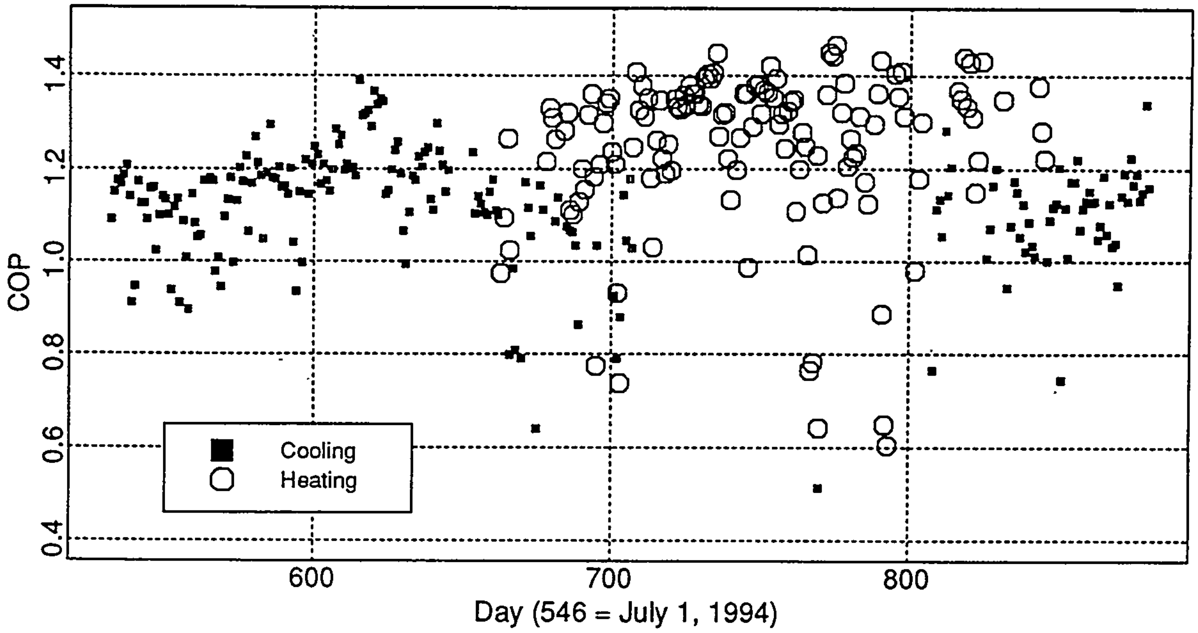

Figure 3. Daily Average COP Versus Day Throughout Triathlon Cooling- and Heating-Season Testing

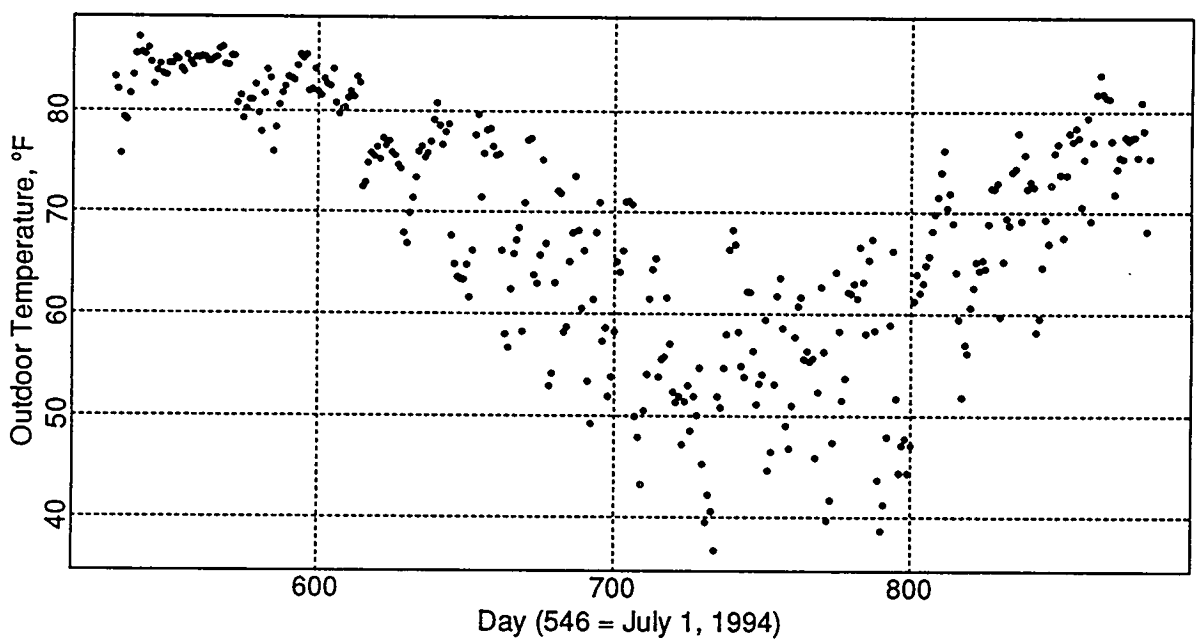

Figure 4. Daily Average Outdoor Temperature Versus Day Throughout Triathlon Cooling- and Heating-Season Testing

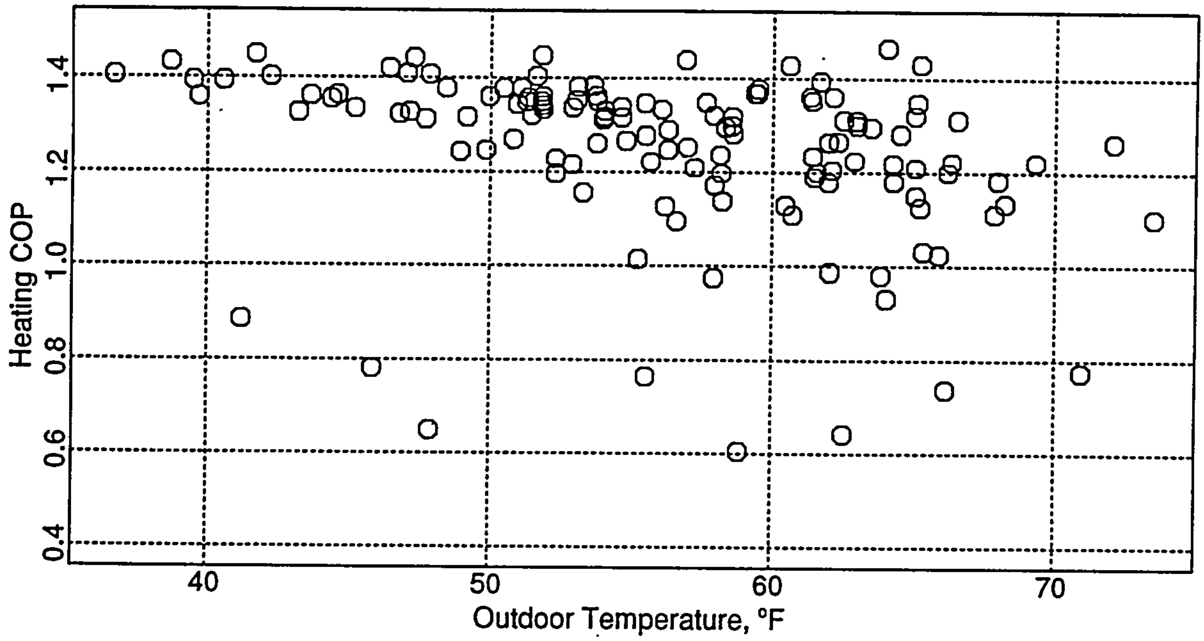

Figure 5. Daily Average Heating COP Versus Daily Average Outdoor Temperature

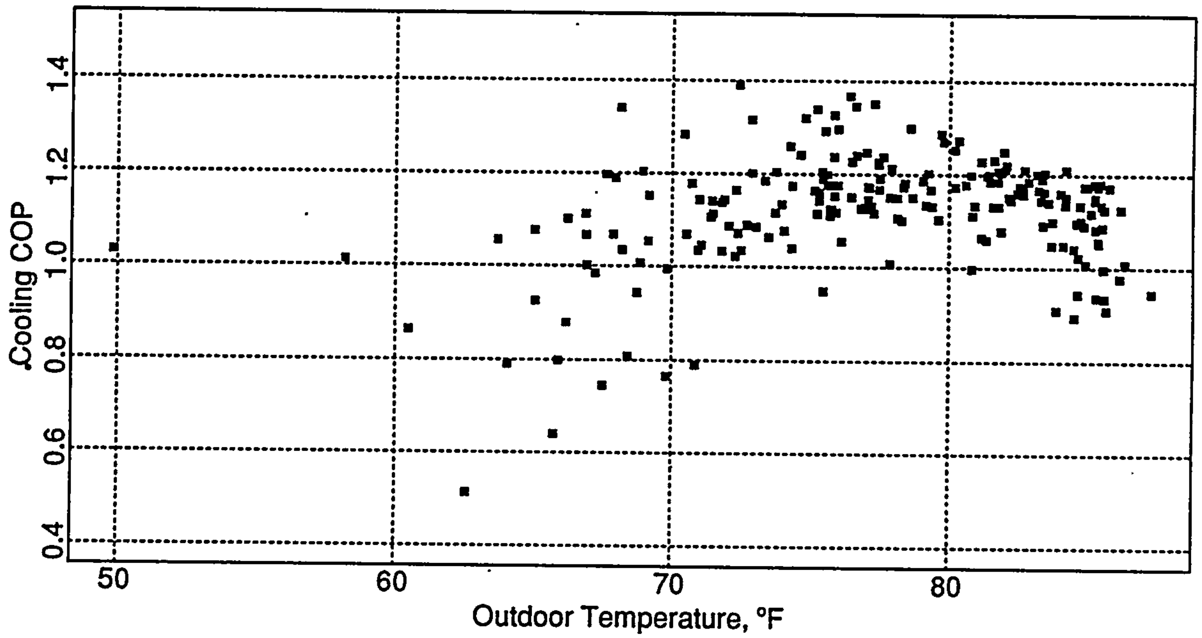

Figure 6. Daily Average Cooling COP Versus Daily Average Outdoor Temperature

Table 2. Triathlon GHP 1994-1995 Heating-Season Test Performance (October 26, 1994, through April 30, 1995)

Parameter	Value
Total time, h	4488.0
Data time, h	4406.1 (98.2%)
Engine time (cooling and heating), h	1234.6 (28.0%)
Availability, %	97.0
Engine cycles	2760
Defrost cycles	1
Auxiliary heater cycles	272
Average outdoor temperature,°F	51.2
Minimum outdoor temperature,°F	32.7 (01/05/95)
Average indoor temperature,°F	75.7
Peak heating day, kBtu	671 (3/2/95)
Heating engine time, h	1020
Heating engine and auxiliary time, h	1045
Electricity use, kWh	359.3
Refrig. output, MBtu	19.2
Coolant output, MBtu	6.1
Total output, MBtu	25.3
Gas use, MBtu	19.8
TP_COP	1.278
Gas use, $	85.27
Electricity use, $	17.37

Table 3. Comparison Furnace Performance in the 1993-1994 Heating Test Season

	Unit 1	Unit 2	Unit 3
Average indoor temperature,°F	75.2	----	72.8
Gas, kcf	28.6	46.7	40.2
Electricity, kWh	276	400	175
Gas, $	125.34	204.84	176.18
Electricity, $	13.46	19.51	8.52

Table 4. Comparison Furnace Performance in the 1994-1995 Heating Test Season

	Unit 2	Unit 3
Average indoor temperature,°F	70.2	73.8
Gas, kcf	21.3	31.4
Output, MBtu	20.3	21.4
TP_COP, %	94.3	66.9
Electricity, kWh	167	173
Gas, $	93.25	137.67
Electricity, $	8.17	8.46

Table 5. Heating Season Energy Use of Comparison Furnaces Projected onto GHP Loads

	Unit 2	Unit 3
Gas, kcf	26.3	37.1
Electricity, kWh	207	205

Savings

The 1994-1995 Triathlon heating season energy consumptions (Table 2) and the 1994-1995 projected performance (Table 5) of the comparison units can be corrected to normal weather year results using the HDD ratio of 1.435 (see Comparative Energy Analysis section). Table 6 summarizes these normal San Antonio heating-season energy consumptions and the corresponding savings of the Triathlon relative to the comparison units. The negative savings on electricity results because the GHP has an outdoor fan in addition to the indoor blower. Together they generally consume more electricity than a blower fan during a heating season because of longer runtime and higher power draw (at high speeds) when compared to the conventional furnaces. The negative savings on electricity decreases the energy-cost savings of the GHP from 25.9% (relative to Units 1 and 2), if only gas consumption is considered, to 18.3%, when both gas and electricity are considered. The cooling season results from Volume 1 (Miller 1995) are presented in Table 7 using internal base fuel prices. Together, Tables 6 and 7 lead to the total annual operating costs shown in Table 8.

Total annual operating costs include total normal year fuel costs for heating and cooling, as well as the yearly maintenance costs. The comparison units were assumed to require $75 of annual maintenance; this represented roughly an hour of labor and no parts. The GHP yearly maintenance generally requires $175 of annual maintenance;[a] this represents 1 hour of labor and engine parts such as oil, spark plugs, oil filter, and air filter.

Table 8 shows that when maintenance costs and the low electricity rates available to the Fort Sam Houston base (Super Large Power Service, SLP commercial rates) are taken into consideration, the GHP yields negative savings, on a total operating cost basis, relative to the conventional test units 1 and 2. Operating costs at Fort Sam Houston calculated under other fuel pricing assumptions are presented in the next section.

(a) A local San Antonio dealer developed a quotation for the annual maintenance of the Triathlon. The dealer estimated $271.09 based on his current labor rates and standard mark-up for parts. This price was not used in the analysis because it does not reflect general dealer pricing as anticipated by York. York believes dealers will sacrifice normal profits on maintenance parts to preserve LCC cost viability of the unit and their corresponding profits associated with the $8,000 sale price. York also thought the labor estimate from the dealer was slightly high. If the profit on parts is removed and the labor is reduced by 10% to 15%, the dealer quotation would agree well with the $175 anticipated by York.

Table 6. Normal Year Heating Season Consumption and Savings by Triathlon Unit Relative to Comparison Furnaces

	Triathlon	Units 1 & 2	Unit 3
Gas, kcf	27.9	37.8	53.3
Gas savings, kcf	----	9.8	25.4
Electricity, kWh	510.9	297.5	294.4
Electricity savings, kWh	----	-213.4	-216.6
Total energy cost, $	147.3	180.2	248.4
Savings, $	----	32.9	100.8
Savings, %	----	18.3	40.6

Table 7. Normal Year Cooling Season Consumption and Savings by Triathlon Unit Relative to Comparison Air Conditioners

	Triathlon	Unit 1[(a)]	Unit 1[(b)]	Unit 2	Unit 3
Gas, kcf	41.5	----	----	----	----
Electricity, kWh	863.5	5663	5351	5768	5799
Energy cost, $	224.1	276.4	261.1	281.5	283.0
Savings, $	----	52.3	37.1	57.4	58.9
Savings, %	----	18.9	14.2	20.4	20.8

(a) Pre/post.
(b) Mapped.

Table 8. Normal Year Annual Energy Consumption and Annual Operating Cost Savings

	Triathlon	Unit 1	Unit 2	Unit 3
Electricity, kWh	1374.4	5804.5[a]	6065.5	6093.4
Gas, kcf	69.4	37.8	37.8	53.3
Operating cost, $	546.4	524.0	536.7	606.0
Savings, $	----	-22.4	-9.7	59.7
Savings, %	----	-4.3	-1.8	9.8

(a) Calculated as the sum of the heating electricity and cooling electricity for Unit 1 where the cooling electricity has been estimated as the average of the Unit 1 pre/post and mapped results.

Occupant Comfort

The occupants reported in a post-test interview that the Triathlon had provided good comfort during the heating and cooling test periods. They observed that the house was drafty during the heating season but did not attribute this to the Triathlon GHP. The startup and running sounds from the outdoor section of the Triathlon were the greatest concern of the occupants. Although they said these sounds did not disturb them when they were inside the house, they were concerned about disturbing their neighbors. They commented that the nature of the startup sounds reminded them of a lawnmower. They were pleased with the small amount of sound coming from the indoor fan (due to the variable-speed operation).

While humidity control[a] is not an issue during the heating season, fluctuations in room temperature caused by cycling of the heating equipment can noticeably affect comfort. Figure 7 shows room temperatures (15-minute averages) during 5-day periods of constant thermostat settings (no changes by the occupant) for each of the three test houses. The outdoor temperature during these time periods is shown in the "Weather" plot in Figure 7. The plots show that the Triathlon was able to maintain a temperature within a range of 0.3°F for a period of nearly 1 day. This is a significant improvement over the best 1-day spread of 0.7°F for Unit 2 and 2.5°F for Unit 3.

(a) See section on occupant comfort in Volume 1 for discussion of humidity control.

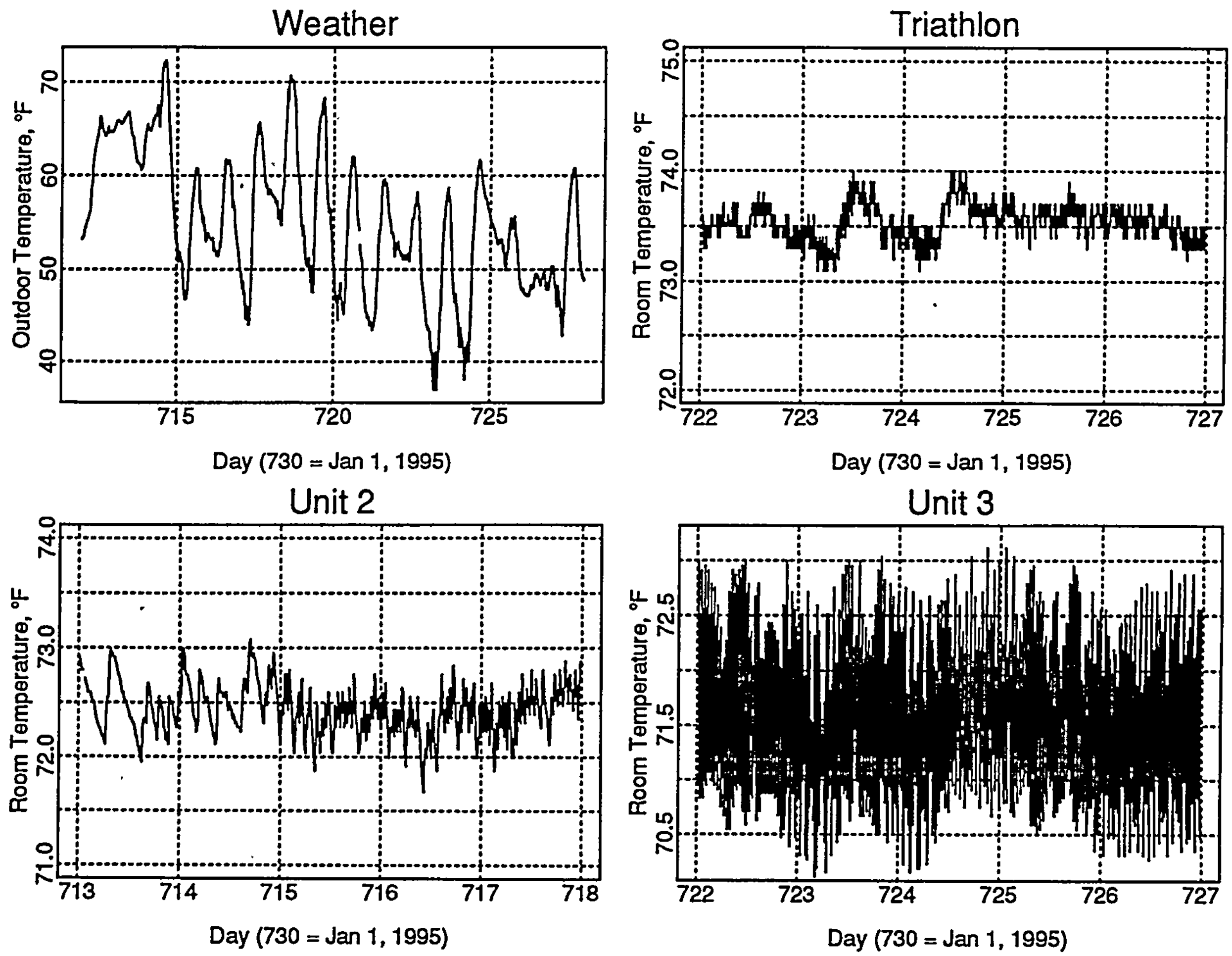

Figure 7. Temperature Control: Room Temperature During Periods of Constant Thermostat Settings

Life-Cycle Cost Comparison

The goal of the life-cycle cost analysis is to take the thermal performance results established in the field study, project them to several commercially available AC/furnace systems (including a high-efficiency unit), and make a LCC comparison under different fuel pricing and climate situations. The analysis was conducted based on the monitored performance of the GHP and the existing conventional systems at the base. The methods presented here allow the Triathlon to be compared against any conventional AC/furnace system characterized by SEER and AFUE rating factors.[a] The comparisons can be made in any climate location characterized by CDD and HDD factors.

The methods developed here are intended to usable by any energy engineer. The calculations of energy use and costs can be done with a hand calculator or spreadsheet. Calculations of LCC are done on a personal computer with the publicly available NIST analysis program BLCC (Peterson 1993). The simplicity of this approach is intended to promote additional investigation of the GHP cost-effectiveness under fuel pricing and climate scenarios outside of those considered in this report.

The LCC analysis of the Triathlon GHP and of three conventional AC/furnace systems was conducted for six locations including Fort Sam Houston. The six locations were chosen to reflect the diversity of fuel pricing and climates at U.S. Federal facilities. The first of the three conventional systems represents the high-efficiency end of the market in AC/furnace systems. The second reflects a 1995 cost for a system very similar in specification to the monitored Units 1 and 2. The third system has moderate efficiencies for both heating and cooling and represents the most common 3-ton unit sold in San Antonio. The installed price quotations for these three systems and the Triathlon were obtained from a San Antonio HVAC dealer (Table 9)[b].

(a) Electric heat pumps (EHPs) were not available for monitoring at Fort Sam Houston. As a result, LCC could not be established in a way similar to that done for the AC/furnace systems. This precluded EHPs from consideration in this field-based LCC analysis. It is clear that in the locations where the GHP has the lowest LCC (because of high electric rates), EHPs would not be chosen over the GHP. However, in locations where the GHP does not have the lowest LCC (because of moderate to low electric rates), EHPs may be chosen over conventional AC/furnace systems.

(b) Prices for units A and C do not include a thermostat with set-back features (standard with the Triathlon). An upgrade that includes set-back was quoted at $130.

Table 9. Characteristics of Comparison Units in LCC Analysis

	Triathlon	Unit A	Unit B	Unit C
SEER, Btu/wh	----	10.2	15.6	12.2
Cooling capacity, kBtu/h	36.0	33.8	37.0	35.8
AFUE	----	97	97	80
Heating output capacity, kBtu/h	53.5	53.0	57.0	53.0
Annual maintenance, $	175	75	75	75
Installed cost, $	8000	4018	5917	3500

Cooling energy use in the LCC analysis of the three conventional units was calculated based on the cooling-test season results of field Unit 1 (Table 7). The average of the pre/post and the mapping results of Unit 1, for a normal cooling season, formed the basis for the energy calculations (5507 kWh). For systems with SEERs different from the 10.45 SEER system that was monitored, a simple SEER ratio correction is applied to the measured energy use. For example, the energy use of the high-efficiency unit is calculated as shown in Equation (1). Similarly, the furnace gas and electricity usage of Unit 2 during a normal San Antonio heating season (Table 6) are the basis for estimating the heating energy use for all conventional-system units in the LCC comparison (38.53 MBtu, 297.5 kWh). A simple AFUE ratio is used to scale the gas and electric energy usage of furnaces systems having efficiencies other than the 97% AFUE of Unit 2.

$$ELEC_{HE} = ELEC_{Unit2} \; (SEER_{Unit2} / SEER_{HE}) \tag{1}$$

where $ELEC_{HE}$ = electricity consumption projected to a high-efficiency unit based on SEER correction
$ELEC_{Unit2}$ = electricity consumption of Unit 2
$SEER_{Unit2}$ = SEER of Unit 2
$SEER_{HE}$ = SEER of high-efficiency unit.

The energy use of all four units in the LCC analysis is then adjusted for climate. As different locations are considered, changes in CDD from those at the San Antonio test site are estimated to affect the cooling-season energy usage as shown in Equation (2). In a similar way, the impact on heating-season energy is estimated with HDD. All HDD and CDD are calculated for base 67°F, which is approximately the floating point temperature seen during winter and summer at the house with the Triathlon. The construction and insulation of the house are assumed constant throughout the analysis in that no adjustments are made to account for different construction practices in northern climates. Also, no adjustments are made to account for changes in system efficiency as affected by climate (outdoor temperature).[a] In other words, this simplified approach projects the energy use at test house 1 from San Antonio to other locations by assuming that energy use scales linearly with thermal load as estimated by CDD and HDD factors.

$$E_{newlocation} = E_{STX}(CDD_{newlocation}/CDD_{STX}) \tag{2}$$

where $E_{newlocation}$ = energy projected to a new climate based on a CDD correction
E_{STX} = energy consumption at San Antonio
$CDD_{newlocation}$ = CDDs at new location
CDD_{STX} = CDDs at San Antonio.

Peak power draw was calculated for use in estimating electricity demand charges. Peak power draw for both the GHP and Unit 1 were estimated by plotting the daily peak power over most of the 1994 summer. Daily peak power is derived from a smoothed time-series so as to remove cycling variations in the power time series. The time series of Unit 1 is a mapped series that represents the power usage of the Unit 1 as if it had been operating under the same conditions as the Triathlon. The resulting peak power for each day is shown in Figure 8. For comparison units with SEER values differing from Unit 1, the peak power draw is estimated by using a scaling factor composed of the ratio of SEER values [similar to how energy is scaled in Equation (2)].

These estimates of peak power are not intended to represent the maximum continuous power draw possible during the summer. Instead, they reflect the fact that HVAC systems are generally oversized and therefore, if cycling variations are averaged out, draw less than their rated power requirements.

(a) It is thought this assumption does not overstate the performance of the GHP in northern climates. The San Antonio performance is considered a reasonable representation of national GHP heating performance because although thermal conditions were mild in terms of outdoor temperature, they were quite severe in terms of part-load-degradation losses.

More complex analysis methods such as temperature-bin analysis are available for projecting performance to other climates. Performance results from chamber measurements on the Triathlon, over a wide range of outdoor temperatures, are presented in Appendix E. These could potentially be used in a temperature-bin-based comparative analysis.

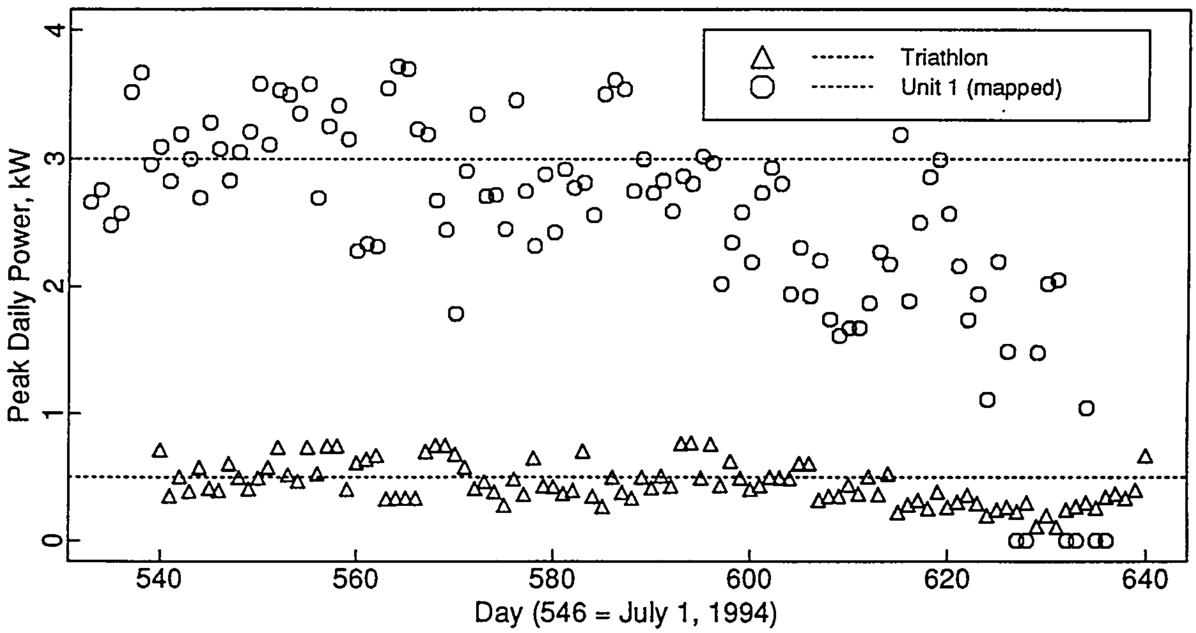

Figure 8. Peak Daily Power During 1994 Cooling Season

In calculating demand charges, a modifying factor of 0.75 was used to reflect the fact that a group of houses generally does not hit peak load simultaneously. This diversity or spread in the time of peak load will be minimal in the hottest parts of the summer and increases as the summer loads decrease. The 0.75 is intended to roughly represent the average of this behavior over the cooling season.

For sites where the electricity billing is ratcheted, the demand rate is applied at 100% during the four summer-season months and at some fraction of the peak summer power during the other eight months. For example, at Fort Sam Houston with an SLP service rate, the eight-month off-summer period is charged at 80% of the highest measured peak demand established during the previous summer-period months (June through September). For sites where the demand billing is not ratcheted, the demand rate is applied only to the four summer-season months.

Energy costs for Fort Sam Houston were calculated using three pricing assumptions: 1) the residential/retail rates established in Volume 1 (Miller 1995); 2) the internal rates established at the base; and 3) the raw commercial rate schedules established by City Public Service of San Antonio (see Table 10). The external rates for Fort Sam Houston were derived by applying a one-year average of the monthly adjustments (average adjustment March 1994 through April 1995 was -0.005427 $/kWh for electricity and -0.02567 $/kcf for gas) to the rates of 0.0240 $/kWh and 4.38 $/kcf. The external rates also included demand charges as described above with eight months of ratcheted demand charges at 80% of the summer peak.

For the five sites other than Fort Sam Houston, energy costs were determined using existing Federal and DOE reports (Dixon et al. 1992; Armstrong and Conover 1993; Richman et al. 1994; Winiarski 1995).[a] Specific energy price assumptions used are identified in Table 10.

A 15-year life was assumed for the Triathlon GHP and all comparison units. The economic parameters used in the cost analysis were

- analysis basis: Federal Analysis--Energy Conservation Projects
- study period: 15 years (1995-2009)
- discount rate: 3.0% real (exclusive of general inflation).

Table 10. Gas and Electric Prices Used in LCC Analysis

	Elec, \$/kWh	Gas, \$/MBtu	Demand, \$/kW	Ratchet, %
Fort Sam (Internal)	0.0488	4.300	0.00	0
Fort Sam (External)	0.0186	4.275	10.40	80
Fort Sam (Residential)	0.0581 0.0632	4.174	0.00	0
Willow Grove	0.0299	5.490	23.70	80
Fort Dix	0.0874	5.600	9.84	0
Fort Drum	0.0483	6.100	5.51	0
Fort Irwin	0.1013	4.979[a]	21.25	50
Fort Stewart	0.0250	3.000	8.85	95

[a]The Fort Irwin heating fuel price is based on a propane price of 0.473 \$/gal and a heating value of 95,000 Btu/gal.

(a) Fuel rates for Fort Dix were based on information obtained during a January 1995 telephone conversation with Jersey Central Power and Light.

LCC Analysis Results

To be cost-effective in comparison to conventional AC/furnace systems, the Triathlon must recover higher purchase costs and higher annual maintenance costs through energy cost savings. Five factors beyond energy efficiency promote GHP energy cost savings:

1. ratio of electricity price to gas price
2. absolute gas and electricity prices
3. ratio of demand charges to base rate electricity charges
4. heating thermal loads
5. cooling thermal loads.

The GHP is most cost-effective in locations where there are relatively high values in all five factors. These factors can serve as indicators for identifying locations with potental for high GHP energy cost savings. Although it is not necessary to have high values in all five, the two bases in this analysis where the Triathlon showed LCC savings over all three comparison systems had relatively high values in four of five indicators.

Fuel pricing indicators are illustrated in Figure 9, in which effective electricity prices[a] are plotted against gas prices. This is done for each of the four systems based on the cost and energy analysis described earlier. The lowest of the four points at each location represents the rate the Triathlon pays (low demand charges), and the highest point represents the least efficient air-conditioner system (high demand charges). The vertical spread in the points for a given location reflects Indicator 3 and illustrates the difference in effective pricing caused by demand charges. The ratio of effective electricity price to gas price for the least efficient air conditioner, Indicator 1, is illustrated by the slopes of the dotted lines leading back to the origin. The national average gas and electricity prices charged commercial customers in October 1994 (*Energy User News* 1995) are shown with vertical and horizontal bars. Thermal load indicators, HDD and CDD, are illustrated in Figure 10.[b]

Results of the LCC calculations, including heating and cooling season energy cost savings and annual operating cost savings, are shown for the six facilities in Tables 11 through 18. The cooling and heating energy cost savings do not include the annual maintenance costs. Demand charges for the whole year (included ratcheted charges in the winter) are lumped into

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(a) An effective electricity price is the total (heating and cooling) of all charges for electricity (including demand charges) divided by the total electric energy usage.

(b) CDD and HDD for cities other than San Antonio were obtained from a National Oceanic and Atmospheric Administration database of annual degree-days (Owenby, Ezell, and Heim 1992).

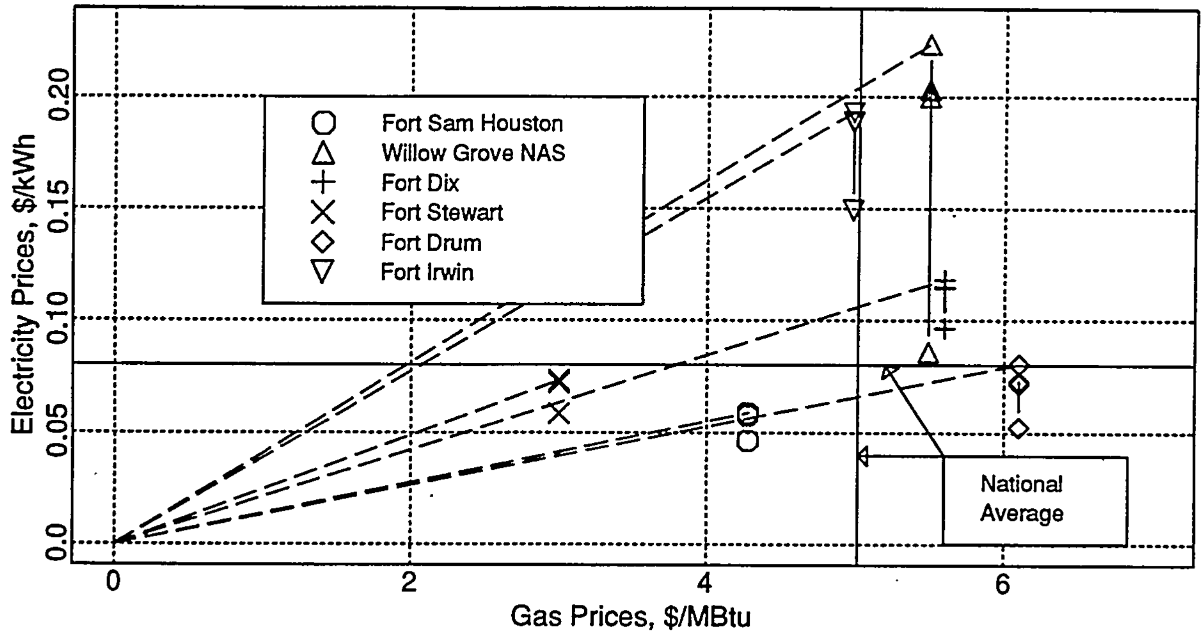

Figure 9. Effective Fuel Prices by Location for Four HVAC Systems

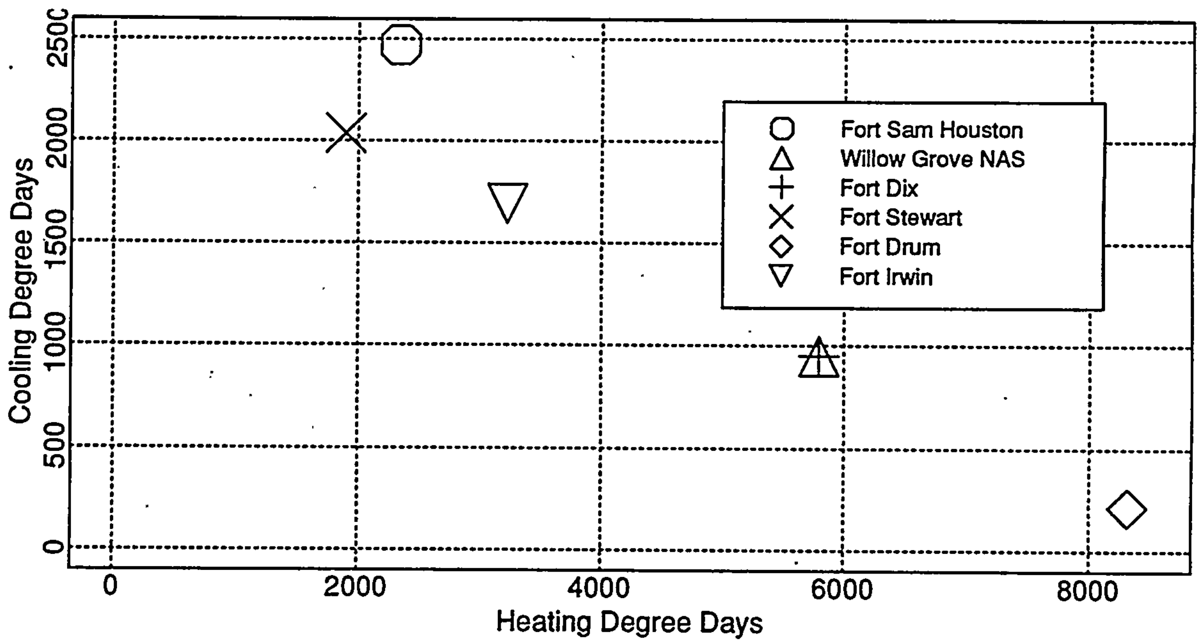

Figure 10. Degree-Days by Location

the cooling savings. The total of cooling, heating, and maintenance costs are included in the annual operating cost savings. The system with the lowest LCC is labeled with an asterisk (*) in the LCC row. An example calculation and more detailed listings of intermediate results leading to these savings and LCCs are given in Appendix F.

The analysis for Willow Grove NAS (Table 11) and Fort Irwin (Table 12) both indicate the Triathlon to have a lower LCC than the three comparison systems. Both bases had high energy-cost savings mainly because of relatively high values in all three fuel cost indicators coupled with significant heating and cooling loads.

Willow Grove NAS has an ideal combination of energy-cost saving indicators for yielding high GHP savings. Electricity rates are structured to have low base rates ($/kWh) with high demand charges ($/kW). This results in a large difference in the effective costs between gas and electric cooling. As a result, relatively low summer thermal loads yield high cooling energy savings for the Triathlon. Also, low base-rate electricity charges ($/kWh) reduce the performance penalty the Triathlon receives from having higher[a] parasitic energy usage (fan electricity) during the winter. Finally, a strong winter coupled with higher than average gas prices yields good heating season savings.

The Triathlon at Fort Irwin also achieves high energy-cost savings with a somewhat different combination of fuel-price and thermal-load indicators in comparison to those at Willow Grove NAS. The ratio between effective electricity prices and gas prices is high for electric systems at Fort Irwin as they are also at Willow Grove NAS. However, the emphasis on demand charges is less. The result, when compared to Willow Grove NAS, is slightly higher cooling energy savings, but they are achieved because an increase in thermal cooling loads compensates for the reduction in price advantage. The lower winter thermal load, lower gas prices, and higher base-rate electricity all cause a significant reduction in heating-energy-cost savings. The net result is that the GHP shows less LCC advantage over the high-efficiency AC/furnace system at Fort Irwin than at Willow Grove NAS.

Generally, as pricing advantages diminish, the GHP depends more on its inherent thermal-efficiency advantage in the heating season. This must be coupled with relatively high HDDs and gas prices to achieve LCC savings. Fort Dix (Table 13) and Fort Drum (Table 14) both illustrate the difficulties for the Triathlon in competing strictly based on its COP advantage in a heating-season dominate climate. In both cases, the GHP is outperformed on a LCC basis by all three comparison systems. The low-cost AC/high-efficiency furnace system yields the LCC minimum.

(a) In comparison to furnaces.

Table 11. Life-Cycle Cost Analysis for Willow Grove Naval Air Station (Philadelphia, Pennsylvania, HDD = 5792, CDD = 950)

	GHP	10.2/97[a]	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	441.36	222.24	337.59
Annual heating energy cost savings, $	----	125.89	125.89	246.39
Annual operating cost savings, $	----	467.25	248.12	483.97
Life-cycle cost, $	18,421*	20,139	19,405	19,993

[a]The numeric column headings indicate the efficiency of the air conditioner and furnace (e.g., SEER = 10.2, AFUE = 97).

Table 12. Life-Cycle Cost Analysis for Fort Irwin (Barstow, California, HDD = 3226, CDD = 1692)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	515.46	244.28	387.03
Annual heating energy cost savings, $	----	40.90	40.90	108.49
Annual operating cost savings, $	----	456.36	185.18	395.53
Life-cycle cost, $	17,478*	19,373	17,787	18,137

Table 13. Life-Cycle Cost Analysis for Fort Dix
(Trenton, New Jersey, HDD = 5792, CDD=950)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	145.45	48.41	99.49
Annual heating energy cost savings, $	----	97.17	97.17	229.34
Annual operating cost savings, $	----	142.62	45.58	228.83
Life-cycle cost, $	18,758	16,577*	17,310	17,269

Table 14. Life-Cycle Cost Analysis for Fort Drum
(Watertown, New York, HDD = 8319, CDD = 212)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	40.21	14.53	28.05
Annual heating energy cost savings, $	----	188.99	188.99	384.83
Annual operating cost savings, $	----	129.20	103.51	312.88
Life-cycle cost, $	20,282	18,164*	19,754	20,126

Fort Dix illustrates the impact of the electricity pricing on LCC. Willow Grove NAS and Fort Dix have similar climate indicators and gas prices but substantially different electricity rates. The result is a large reduction in demand charges and corresponding cooling-energy cost savings. Heating-energy cost savings are reduced from those at Willow Grove NAS because of higher base-rate electricity costs and corresponding higher heating electricity costs (fan energy).

Fort Sam Houston has relatively low values in all fuel-price and thermal-load indicators except cooling loads. As shown in Figure 9, the Fort Sam Houston electricity rate is well below the national average and is also the lowest of the six bases considered in the analysis. Also, Fort Sam Houston has a relatively low effective-electricity rate to gas rate ratio. Only Fort Drum's is slightly lower. Finally, the demand charge at Fort Sam Houston has a relatively small impact in lowering the effective electricity rates for the Triathlon.

The LCC calculations for Fort Sam Houston indicate that a system with a moderately efficient air conditioner and a conventional (noncondensing) furnace is the most cost-effective of the four systems considered in the analysis. This is the combination that the local HVAC dealer identified as the best-selling unit in the San Antonio area. Under all three fuel pricing scenarios, the Triathlon had the highest life-cycle cost of the four systems and, therefore, showed negative life-cycle savings relative to the other three conventional systems (see Tables 16, 17, and 18). This analysis suggests that when Fort Sam Houston purchases new residential heating and cooling systems, it invest more in cooling performance and less in heating performance relative to the most efficient of the existing AC/furnace systems at the base.

Fort Stewart was similar to Fort Sam Houston in having high CDDs and low fuel-price indicators. As was the case for Fort Sam Houston, the analysis indicates the system composed of a low-efficiency furnace combined with a moderate-efficiency AC to have the minimum LCC.

To illustrate the relative contributions from the components of operating and life-cycle costs, bar charts are shown in Figures 11 and 12 for the six locations. The annual operating costs, used to calculate the cost savings in Tables 11 through 15 and 17, are shown in Figure 11. Each annual operating cost bar is segmented to show the components: maintenance, cooling, demand, and heating costs. The LCC data from Tables 11 through 15 and 17 is shown as a bar chart in Figure 12. Each LCC bar is segmented into components: purchase, maintenance, and energy costs.

All LCC calculations above have been based on the installed prices and annual maintenance costs in Table 9. These retail costs, quoted by a HVAC dealer in San Antonio, do not necessarily represent local retail costs at the other five locations, or potential discounts offered to a facility because of volume buying. Also the retail costs do not account for future changes as influenced by a maturing market and manufacturing methods. To address these uncertainties in the LCC analysis, the results have been presented in Tables 19 through 21 in a form that is nearly independent on the installed prices and annual maintenance costs of Table 9.

Table 15. Life-Cycle Cost Analysis for Fort Stewart (Hinesville, Georgia, HDD = 1894, CDD = 2034)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	192.00	69.88	134.16
Annual heating energy cost savings, $	----	20.95	20.95	42.94
Annual operating cost savings, $	----	112.94	-9.17	77.11
Life-cycle cost, $	13,281	10,579	10,997	9,655*

Table 16. Life-Cycle Cost Analysis Results for Fort Sam Houston Using Internal Base Energy Prices (San Antonio, TX, HDD=2341, CDD=2471)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	51.50	-43.81	6.37
Annual heating energy cost savings, $	----	34.17	34.17	73.95
Annual operating cost savings, $	----	-14.33[a]	-109.64	-19.69
Life-cycle cost, $	15,136	10,980	11,651	10,416*

[a]This estimate of operating cost savings is slightly different from that shown in Table 8 in the Savings section. This calculation is done for a SEER of 10.2 (not 10.45). Also, for simplicity in this analysis, the HDD estimate is based at 67°F (not 66.45°F).

Table 17. Life-Cycle Cost Analysis for Fort Sam Houston Using External Commercial Energy Prices (HDD = 2341, CDD = 2471)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	108.64	-10.64	52.15
Annual heating energy cost savings, $	----	40.68	40.68	78.31
Annual operating cost savings, $	----	49.51	-69.76	30.60
Life-cycle cost, $	14,986	11,693	12,054	10,943*

Table 18. Life-Cycle Cost Analysis for Fort Sam Houston Using Residential Energy Prices (equivalent to those used in Volume 1; HDD = 2341, CDD = 2471)

	GHP	10.2/97	15.6/97	12.2/80
Annual cooling energy cost savings, $	----	129.53	6.20	71.13
Annual heating energy cost savings, $	----	30.84	30.84	70.20
Annual operating cost savings, $	----	60.38	-62.95	41.33
Life-cycle cost, $	15,102	11,953	12,260	11,200*

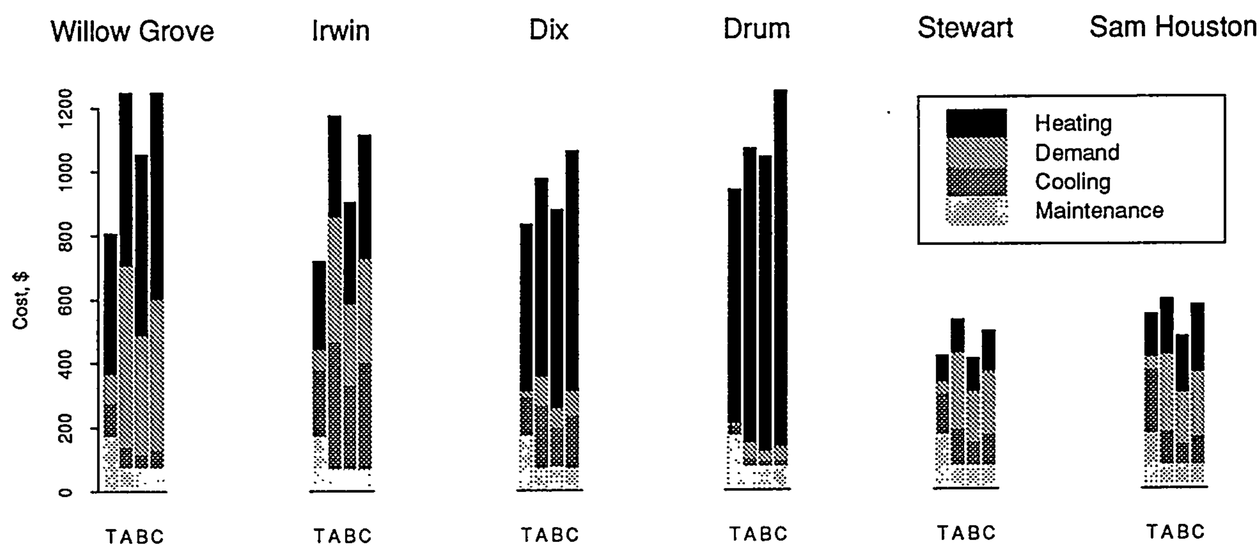

Figure 11. Annual Operating Cost of the Triathlon GHP and Comparison Units A, B, and C

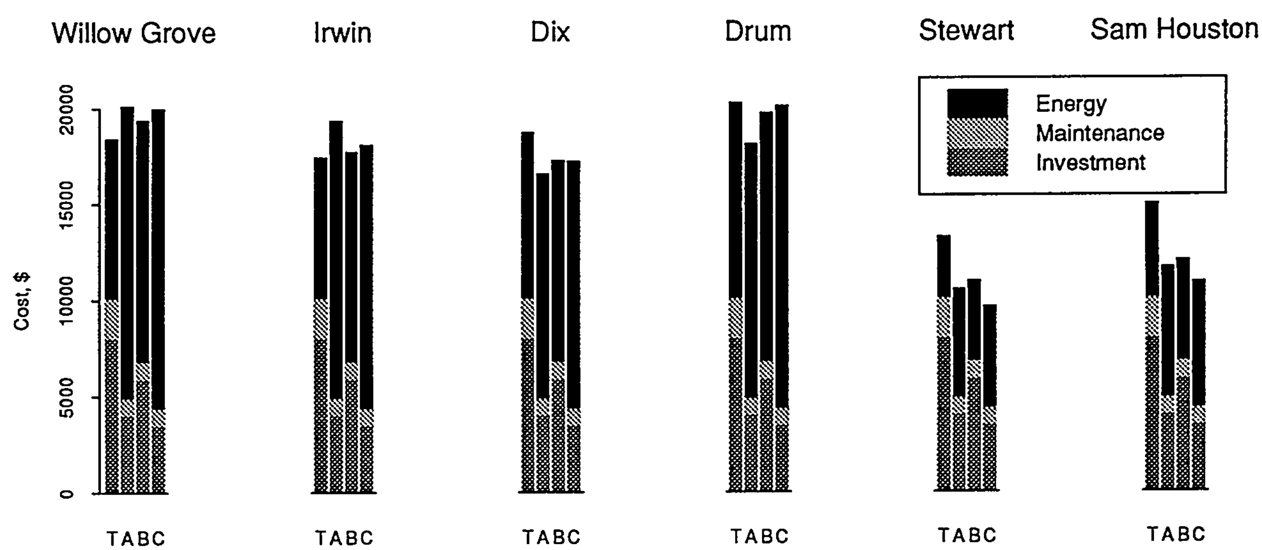

Figure 12. Life-Cycle Cost of the Triathlon GHP and Comparison Units A, B, and C

Tables 19 and 20 show a cost-effective price for the Triathlon relative to the price of each comparison unit.[a] For example, at Willow Grove NAS, the Triathlon can be priced $5,700 higher than a system with a 10.2 SEER and 97 AFUE and still have a lower 15-year LCC. Table 20 shows price differentials at an annual maintenance cost $25 lower than the $175 assumed through most of the LCC analysis.

Tables 19 and 20 can be used to determine a price for the Triathlon such that it has a LCC lower than or equal to all three comparison systems. For example, using Table 19 ($175 annual maintenance) and the San Antonio prices (Table 9) for the comparison units, cost-effective prices for the GHP at Willow Grove NAS must be $9,718 (5,700 + 4,018), $8,985 (3,068 + 5,917), and $9,572 (6,072 + 3,500) to be competitive against Units A, B and C, respectively. The lowest of these, $8,985, is the price at which the GHP would be competitive against all three AC/furnace systems.

Table 21 shows the results of such calculations for each location using the comparison-system prices of Table 9. The two columns illustrate the sensitivity of the results to changes in the assumed annual maintenance costs for the GHP. Column 1 assumes $175 and column 2 assumes $150. The prices in Table 21 are listed in descending order.

York International has indicated that typical single-unit prices for the Triathlon in the United States will range from $6,000 to $8,000. In Table 21, both Willow Grove NAS and Fort Irwin are shown to be cost-effective locations for the Triathlon at prices above $8,000. At a $6,000 price, Fort Drum and Fort Dix are also shown to be cost-effective locations if the annual maintenance cost is assumed to be $150. However, both Fort Stewart and Fort Sam Houston require prices below $6,000 to have LCCs lower than systems A, B, and C.

Sites such as Fort Sam Houston and Fort Stewart can potentially achieve installed prices below $6,000 by consideration of a less efficient (in the heating season) two-pipe version of the Triathlon. This system is referred to as a two-pipe version because it has no boiler (gas-fired auxiliary heat), no water-glycol loop, and no secondary heat exchanger. The two-pipe system uses conventional electric-resistance back-up heat and, as a result, can be priced as much as $1,000 less than the standard four-pipe Triathlon system (two refrigerant lines and two glycol lines). In southern locations such as Fort Sam and Fort Stewart, the performance (and comfort) advantage offered by the four-pipe system was shown to be not cost-effective

(a) These price differentials are calculated as the amount the GHP present value of energy and maintenance costs is lower than the corresponding value for the comparison system. The present value components of LCC used in these calculations are presented in Appendix F.

Table 19. Cost-Effective Price Differential of Triathlon GHP (assuming $175 annual maintenance costs)

	10.2/97%	15.6/97%	12.2/80%
Willow Grove	5700	3068	6072
Irwin	5876	2391	5159
Dix	1801	636	3012
Drum	1864	1555	4344
Stewart	1279	-201	873
Sam Houston	688	-850	456

Table 20. Cost-Effective Price Differential of Triathlon GHP (assuming $150 annual maintenance costs)

	10.2/97%	15.6/97%	12.2/80%
Willow Grove	5998	3366	6370
Irwin	6174	2689	5457
Dix	2099	934	3310
Drum	2162	1853	4642
Stewart	1577	97	1171
Sam Houston	986	-552	754

within the $6,000 to $8,000 price range. However, if by use of the two-pipe version the $6,000 lower-price limit were reduced by $1,000, both Fort Sam Houston and Fort Stewart could potentially be cost-effective locations (see Table 21).[a]

(a) The two-pipe Triathlon was not considered in this economic analysis because the Triathlon tested at Fort Sam Houston used gas-fired auxiliary heating (four-pipe version).

Table 21. Cost-Effective Prices for the Triathlon GHP Under Two Assumptions for Annual Maintenance Costs

	175	150
Willow Grove	8985	9283
Irwin	8308	8606
Drum	5882	6180
Dix	5819	6117
Stewart	5297	5595
Sam Houston	4706	5004

Conclusions

The winter-heating test has demonstrated the Triathlon GHP to be a reliable system. Two significant downtimes resulting in less than 100% availability were the result of component failures identified as well known preproduction design deficiencies that have been corrected in all Triathlon production units.

Occupants concluded that the GHP provided good comfort with acceptable levels of operating noise. Monitoring of indoor temperatures during heating operation showed the variable speed GHP to provide better temperature control than the two existing AC/furnace systems.

The unit operated at performance levels anticipated by the manufacturer. The unit's overall COP during the winter-heating test was 1.28. Annual heating-energy cost savings by the Triathlon relative to the conventional furnace systems ranged from $32.9 (18.3% over Units 1 and 2; AFUE = 97.0%) to $100.8 (40.6% over Unit 3; AFUE = 69.2%) for a normal San Antonio winter.[a]

However, on a total operating cost basis, the Triathlon does not offer annual savings at Fort Sam Houston when compared with the most efficient of the systems in the field comparison. Lower than national-average electricity prices, $100 higher maintenance costs, and a mild winter climate all contribute to higher annual operating costs for the GHP when compared to the field Units 1 and 2 and 9.8% savings in annual operating costs over Unit 3, which was built in 1975 (EER = 7.5, AFUE = 69.2%).

The LCC of the Triathlon ($8,000 installed; $175 annual maintenance) was compared to the LCC of three commercially available AC/furnace systems at six federal bases. Of the six bases analyzed, the GHP was found cost-effective at two—Willow Grove Naval Air Station in Philadelphia and Fort Irwin near Barstow, California. Both sites had effective-electricity rates more than twice the national average and rates structured to include ratcheted-demand charges. Willow Grove NAS yielded the highest LCC savings ($984 over a 15.6 SEER air conditioner and a 97% AFUE furnace) for the GHP due to high racheted-demand charges coupled with a significant heating season and higher than national-average gas prices. At a lower price ($6000 installed) and lower annual maintenance cost ($150), Fort Drum and Fort Dix are also shown to be cost-effective locations.

(a) Based on internal commercial gas and electricity rates established at Fort Sam Houston.

Although the standard Triathlon evaluated in this analysis is generally not selling at single-unit prices below $6,000, a 2-pipe version (using electric-resistance back-up heat in substitution for the standard gas-boiler auxiliary heater) can offer as much as a $1,000 reduction in price. This version is potentially less efficient in the heating mode (no engine waste-heat recovery) but could be the cost effective choice in locations with mild heating seasons. This substitution potentially reduces LCC for the Triathlon to a level competitive at the remaining two bases, Fort Stewart and Fort Sam Houston.

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Appendix A

Triathlon GHP Background Information

Copyrighted information removed.

Appendix B

Part-Load Performance of Unit 2

Appendix B

Part-Load Performance of Unit 2

To characterize the part-load performance of Unit 2, a higher resolution data stream was taken beginning January 15, 1995. Data was recorded every 5 minutes. This allowed the data stream to be postprocessed in such a way as to yield cycle resolved data. Cycle events divided by logger intervals were recombined into complete cycles. This allowed for plotting of efficiency, input capacity, and output capacity by duty-cycle to illustrate variation in performance by under partial loading (Figures B.1 through B.4).

As was described in the body of this report, the part-load mapping approach presented in Volume 1 of this report and used in the cooling season analysis was not used in the furnace analysis. This was decided mainly because it appears that duty cycle is not an adequate part-load performance indicator for this furnace and house occupant. For example, in Figure B.1 a significant number of points have efficiency over 100%. Also there is a stronger drop in efficiency at low duty cycle than what is typically seen in furnace field data. This may be an indication that energy consumed within a cycle is not always completely delivered (as hot air) within that same cycle. This effect may be related to the unusually low airflow in Unit 2 that was described in Volume 1.

Outliers in the plots result partly from cycle events that could not be correctly re-assembled in the postprocessing. Another source of outliers appears to be sudden thermostat changes by the occupant. These outliers generally have relatively high run times (occupant turns up the thermostat in the morning), which is why the averages in the two capacity plots are significantly higher than a visual average of the scatter plots. As seen in Figure B.3, at higher run times, the furnace has a higher input capacity.

Because of the apparent lack of independence between cycles and the significant impact of the occupant, a simple average efficiency was used to represent the performance of the unit. The average efficiency is calculated as the total heat output during the test period (excluding electric fan heat) divided by the total gas energy input during the test period. The application of this average efficiency is described in the Comparative Energy Analysis section.

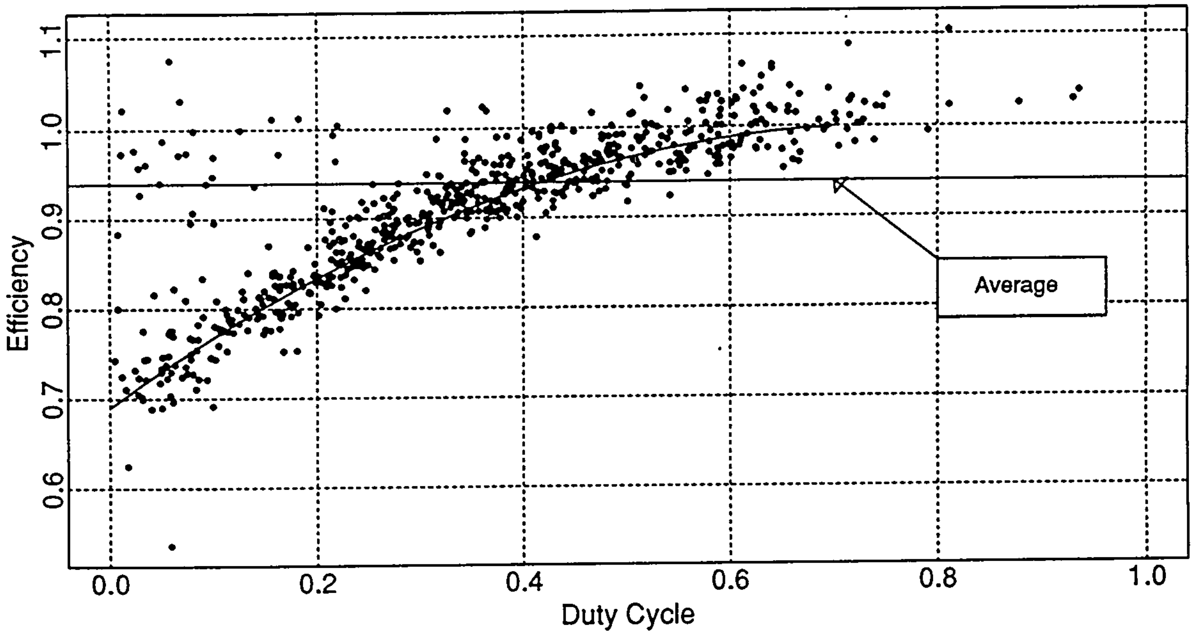


Figure B.1. Unit 2 Efficiency, 1/15/95-3/31/95

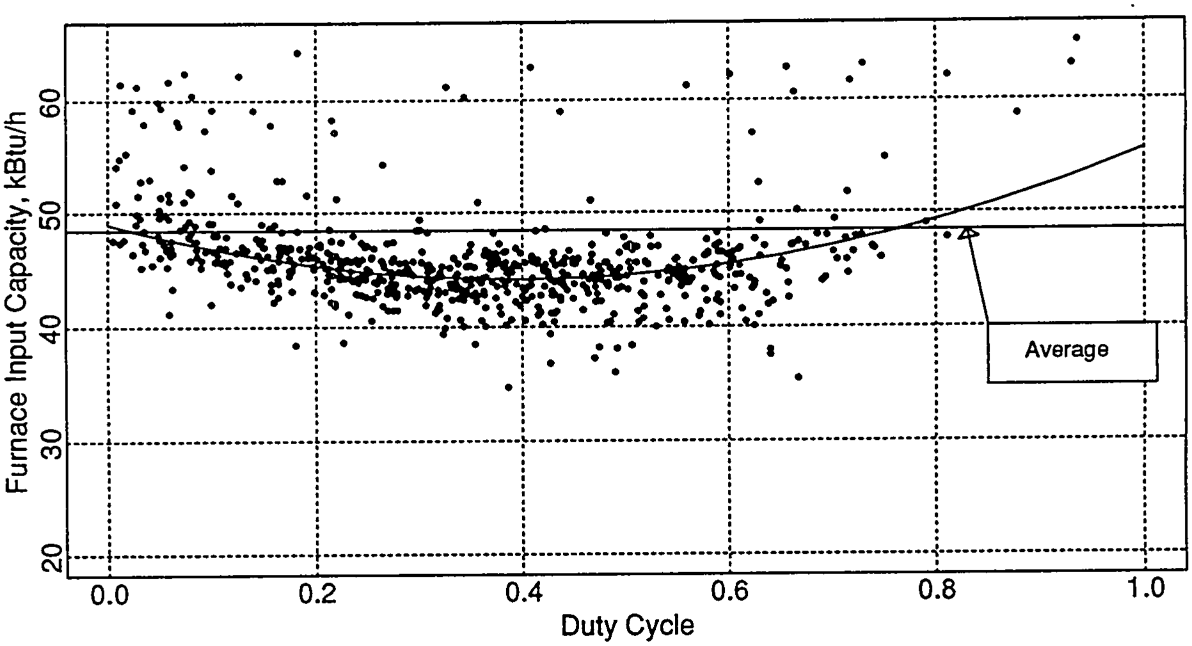


Figure B.2. Unit 2 Input Capacity, 1/15/95-3/31/95

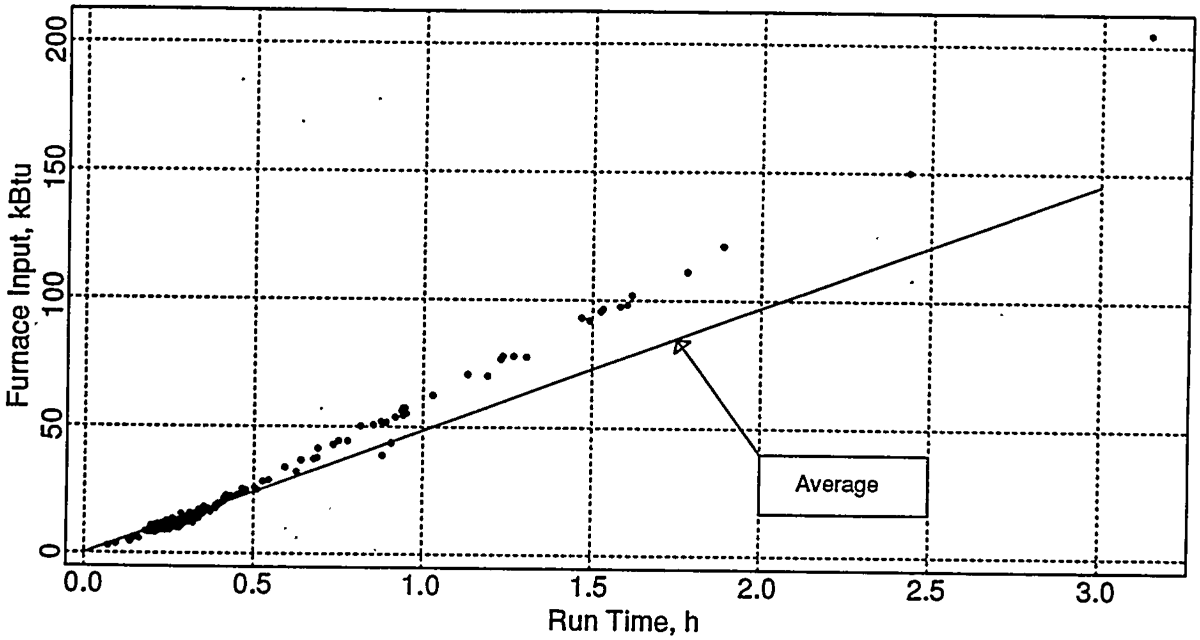


Figure B.3. Unit 2 Gas Input Versus Furnace-Fan Run Time, 1/15/95-3/31/95

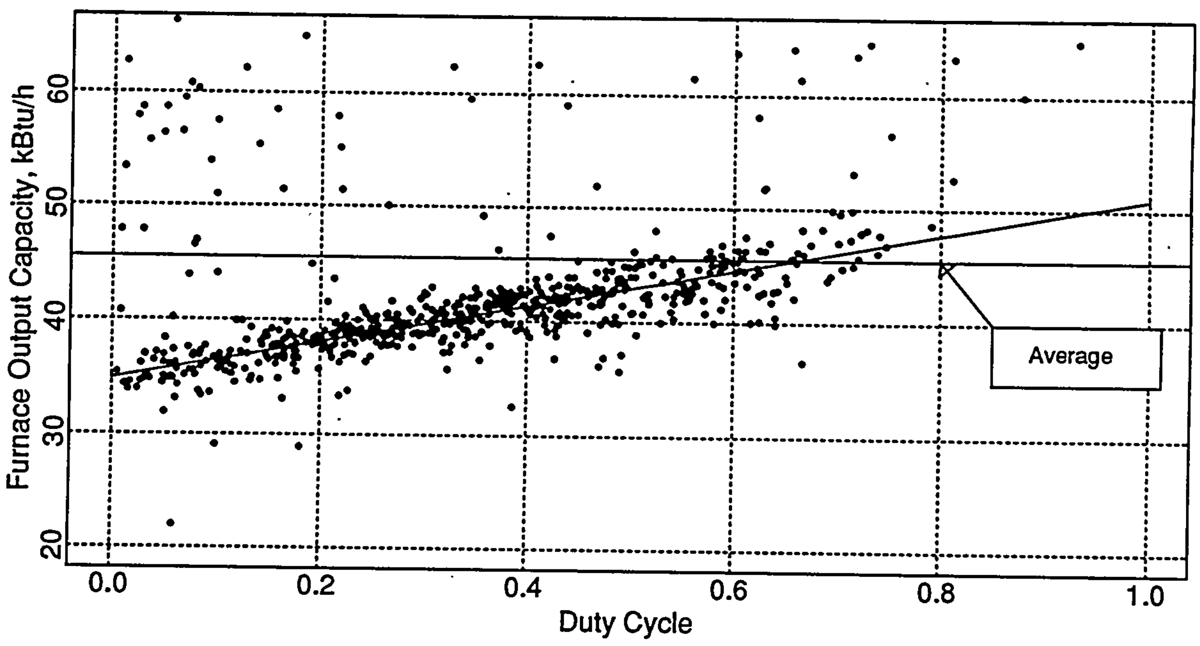


Figure B.4. Unit 2 Output Capacity, 1/15/95-3/31/95

Appendix C

Additional Heating-Season Field Data on the Triathlon GHP

Appendix C

Additional Heating-Season Field Data on the Triathlon GHP

The documentation in this appendix was provided to PNL by Battelle-Columbus. Battelle served on the project on behalf of and funded by the Gas Research Institute and had the role of installing the monitoring instrumentation on the GHP and collecting the data from that system. The following are pages from original documentation produced by Battelle.

1994 - 1995 Heating Season Summary Report for the San Antonio Triathlon Test GHP

Introduction

The San Antonio York Triathlon Gas Heat Pump (GHP) was installed in early June, 1994. Data collection began on June 17, 1994. Performance of the unit in the cooling mode is discussed in a previous report. The unit began heating operation on October 26, 1994 and continued through April 26, 1995.

GHP Operation

The Triathlon GHP under test in San Antonio demonstrated good overall heating performance during the 1994 -1995 heating season. The availability of the unit was less than 100% as a result of two outages:

Discharge Flange Gasket Leak

On February 9, the Triathlon unit shut down as a result of a loss of refrigerent charge condition which was caused by a leak at the discharge fitting gasket at the outlet of the compressor. The dealer replaced the gasket, recharged the unit, and placed it back online.

The discharge fitting gasket design on this pre-production Triathlon GHP was obsoleted by a design improvement made to all production Triathlon GHP's prior to the start of production. All production Triathlon GHP's use a brazed joint in place of the bolted flange and gasket assembly as on the test unit thereby eliminating any potential risk of a gasket leak.

Failed Starter Motor

On March 3, the Triathlon did not start as a result of an inoperative starter. The starter was returned to Briggs & Stratton for analysis. This starter accumulated approximately 4,320 starts at the current location. In addition, an unknown number of starts were accumulated during chamber testing in York's laboratories during the year prior to field installation. Briggs & Stratton determined that the starter drive yoke washer had broken free from the crimp and vibrated against the armature windings. The winding insulation eventually broke down, resulting in several open circuits. The drive used on this starter was an initial sample from the supplier. In addition, this starter exhibited excessive nose bushing wear. The bushing was an iron-graphite material that has been shown to provide superior life over earlier designs. However, the armature shaft in the bushing area was not polished after heat treatment. The resulting heat treat scale acted as an abrasive, leading to early excessive bushing wear.

The starter which was originally installed in the pre-production Triathlon GHP was a very early pre-production sample from the supplier. As such, very little testing of this configuration was accomplished before the CRADA test began. Design deficiencies identified from both of the problems experienced are well known and have been corrected in all Triathlon production starter assemblies.

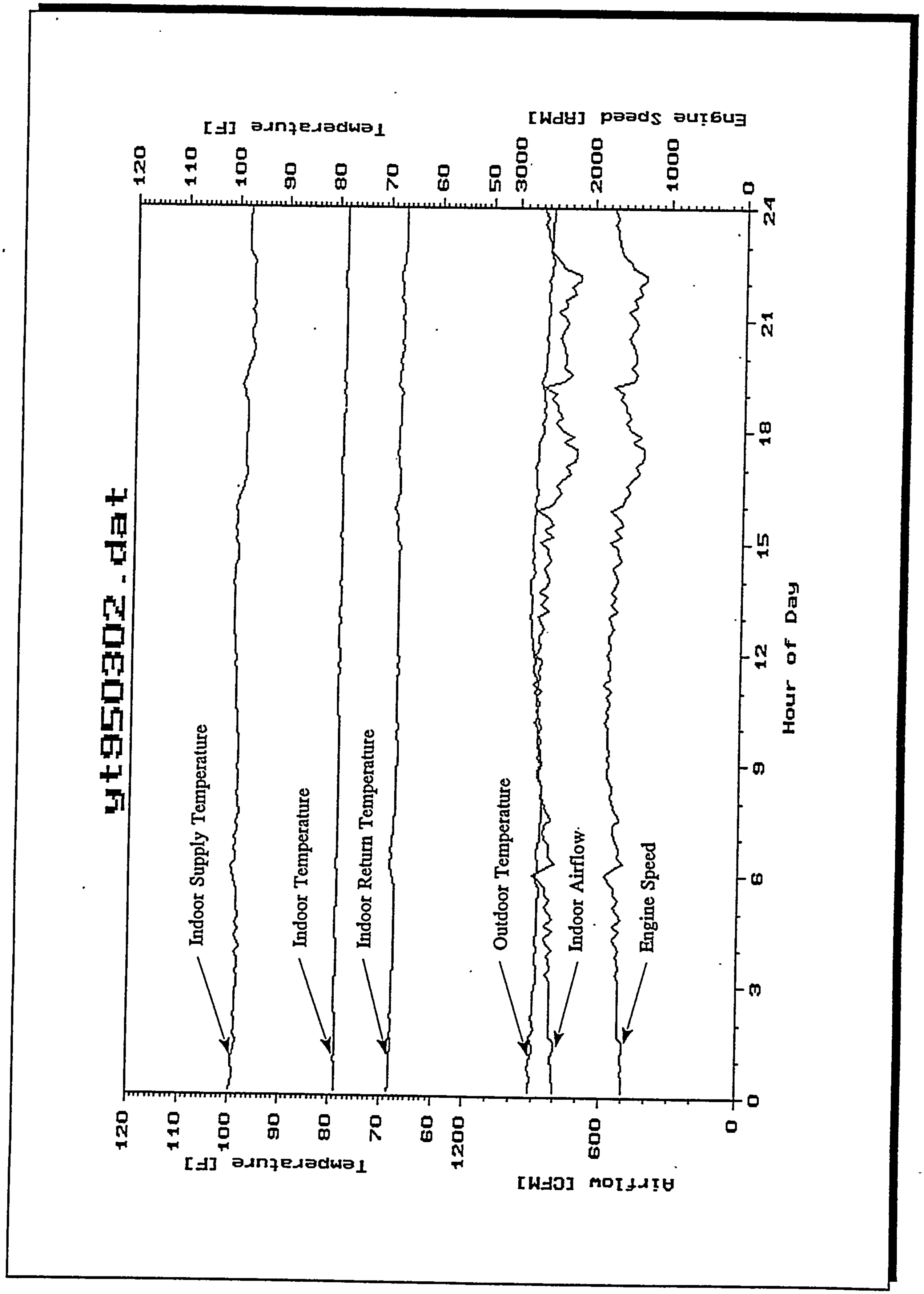
Results

The Triathlon GHP under test at this site has demonstrated seasonal performance levels slightly above the baseline established by the Phase I Field Test program in both heating and cooling modes. During the 1994 - 1995 heating season, this GHP operated at a heating gas COP of 1.35. The overall system gas COP including the auxiliary heater operation was 1.28. The system cost the homeowner $95.29 to operate in the heating mode using City Public Service Co. residential gas and electric rates. Using local gas and electric rates an electric heat pump would require an HSPF of 15.0 to achieve the same overall heating operating cost as the Triathlon GHP. An HSPF of 14.2 would be required using 1994 national average gas and electric rates.

The performance and cost information presented in this report are actual field measured data and should not be used to compare against chamber or manufacturer data. Field test experience with the GHP indicates that field measured performance levels do not match those expected from chamber results primarily due to the differences in operating conditions experienced in the field.

Details of the operation and performance of the Triathlon GHP are provided in the following data attached to this report:

1. Heating Season Summary Performance Report.
2. Daily Operation for the Peak Heating Day, March 2, 1995.
3. Thermostat Cycle Rate, Heating 94-95.
4. Daily Heating Operation History, 94-95 (by date).
5. Daily Heating Operation History, 94-95 (against OD Temp, 3 graphs).

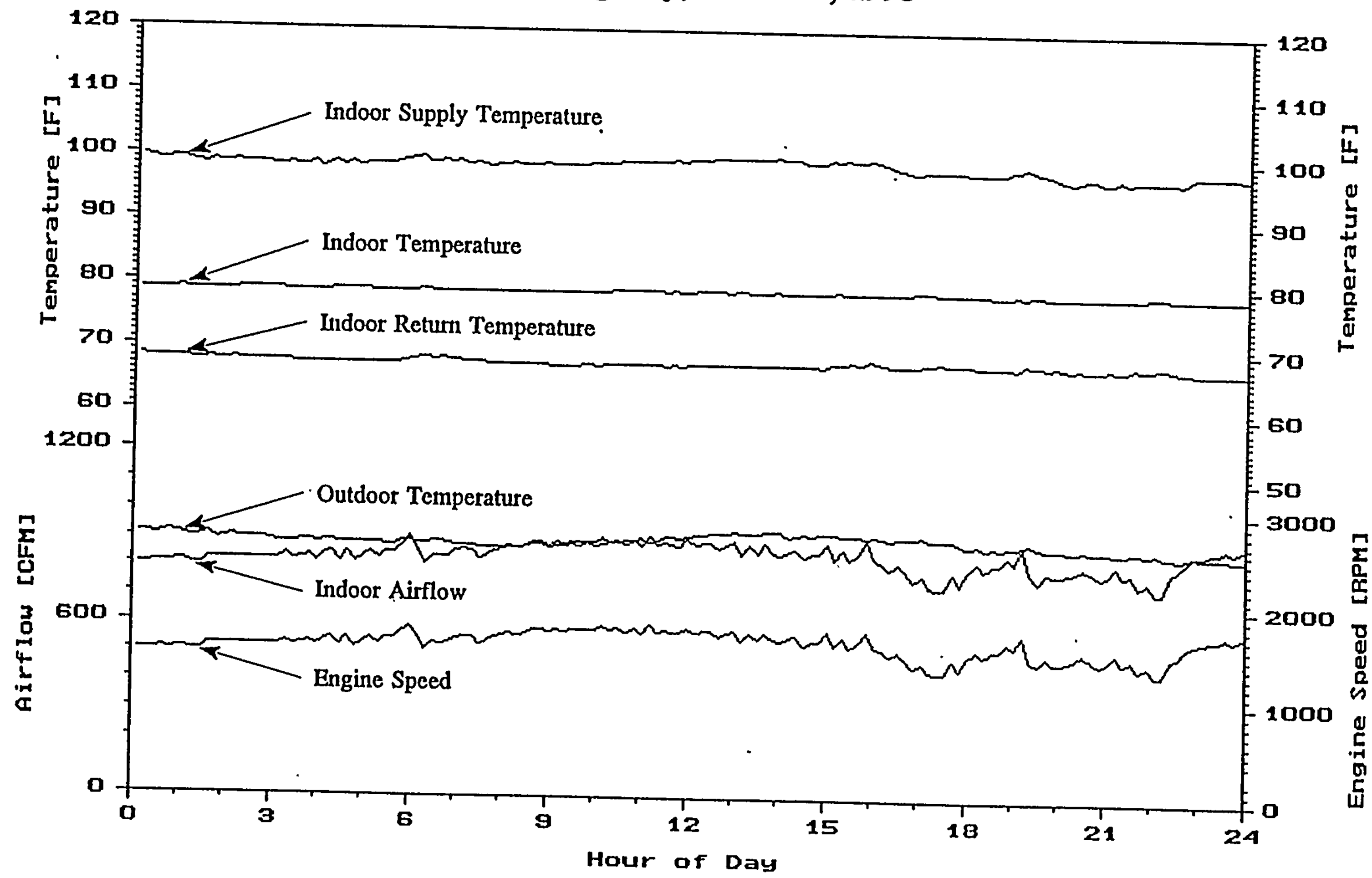

yt950302.dat
Indoor Supply Temperature
Indoor Temperature
Indoor Return Temperature
Outdoor Temperature
Indoor Airflow
Engine Speed
Temperature [F]
Airflow [CFM]
Engine Speed [RPM]
Hour of Day
120
110
100
90
80
70
60
50
1200
600
0
3000
2000
1000
3
6
9
12
15
18
21
24

Periodic Performance Report
1994 - 1995 Heating Season
San Antonio Crada Triathlon GHP

1994 - 1995 Heating Season
from 10/26/94
thru 04/30/95

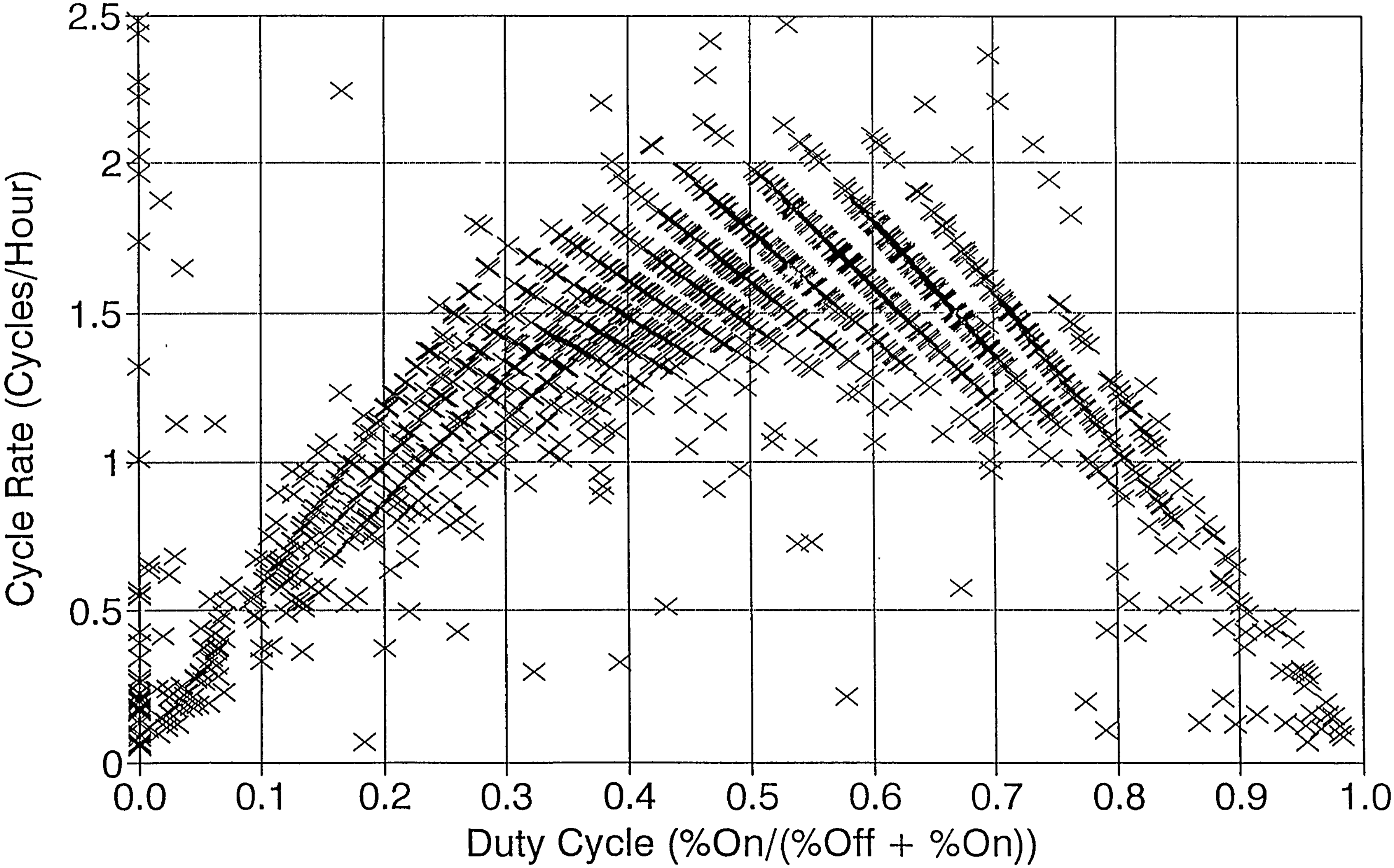
Total time [Hrs] =	4488.0	
Data time [Hrs] =	4406.1	(98.2 %)
Engine time [Hrs] =	1234.6	(28.0 %)
Availability =	97.0 %	
Engine Cycles =	2760	
Defrost Cycles =	1	
Auxiliary Heater Cycles =	272	
Average Outdoor Temp [F] =	60.1	
Minimum Outdoor Temp [F] =	32.3	(01/05/95)
Maximum Outdoor Temp [F] =	89.9	(04/21/95)
Peak Cooling Day [KBtu] =	-244.3	(04/22/95)
Peak Heating Day [KBtu] =	670.9	(03/02/95)
Cooling Performance (Modes 4,5):		
Cooling Engine Op. [Hrs] =	209.1	
Electricity Use [KWHr] =	68.9	
Sensible Capacity [KBtu] =	-2774.3	
Latent Capacity [KBtu] =	-1000.4	
Total Cooling Cap. [KBtu] =	-3774.7	
Gas Use [KBtu] =	3447.9	
Thermal COP =	1.095	(77.2 F)
EER Equiv. 1994 Natl Avg =	11.9	(77.2 F)
Cooling Operating Cost =	$ 17.12	
Heating Performance, Engine Only (Modes 1,4,6,7):		
Heating Engine Op. [Hrs] =	1020.0	
Electricity Use [KWHr] =	339.4	
Refrig. Capacity [KBtu] =	19071.4	
Coolant Capacity [KBtu] =	4969.8	
Total Heating Cap. [KBtu] =	24041.2	
Gas Use [KBtu] =	17857.8	
Thermal COP =	1.346	(49.6 F)
Heating Performance, Overall (Modes 1-4,6,7):		
Heating Eng+Aux Op. [Hrs] =	1044.7	
Electricity Use [KWHr] =	359.3	
Refrig. Capacity [KBtu] =	19202.4	
Coolant Capacity [KBtu] =	6137.3	
Total Heating Cap. [KBtu] =	25339.7	
Gas Use [KBtu] =	19834.7	
Thermal COP =	1.278	(49.5 F)
HPF Equiv. 1994 Natl Avg =	14.2	(49.5 F)
Heating Operating Cost =	$ 95.29	
City Public Service Average Rates:		
Natural Gas [$/MBtu] =	3.7957	
Electricity [$/KW-Hr] =	0.05615	
Total Operating Cost =	$112.42	

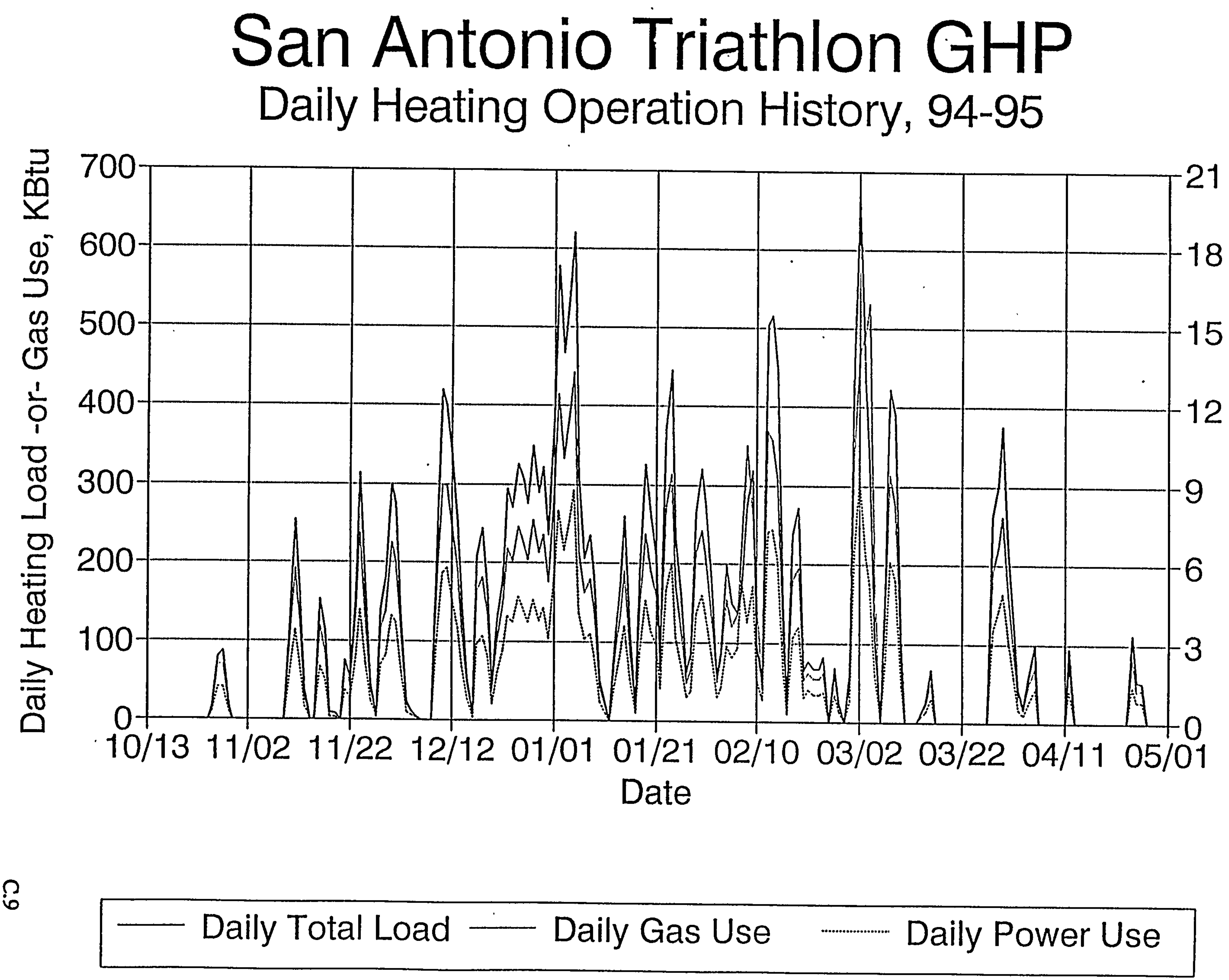
San Antonio Triathlon GHP
Peak Heating Day, March 2, 1995



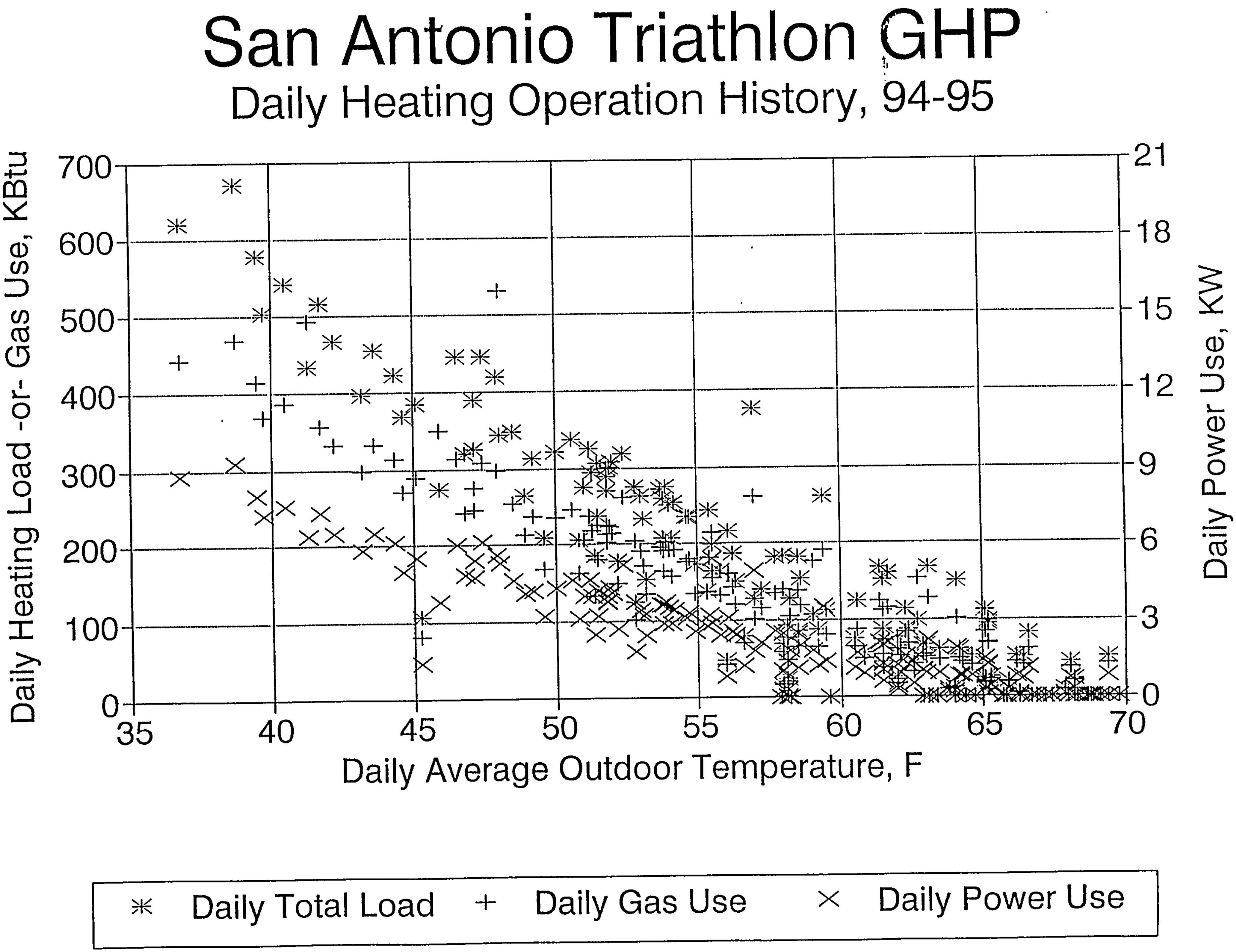
San Antonio Triathlon GHP

Thermostat Cycle Rate, Heating 94-95



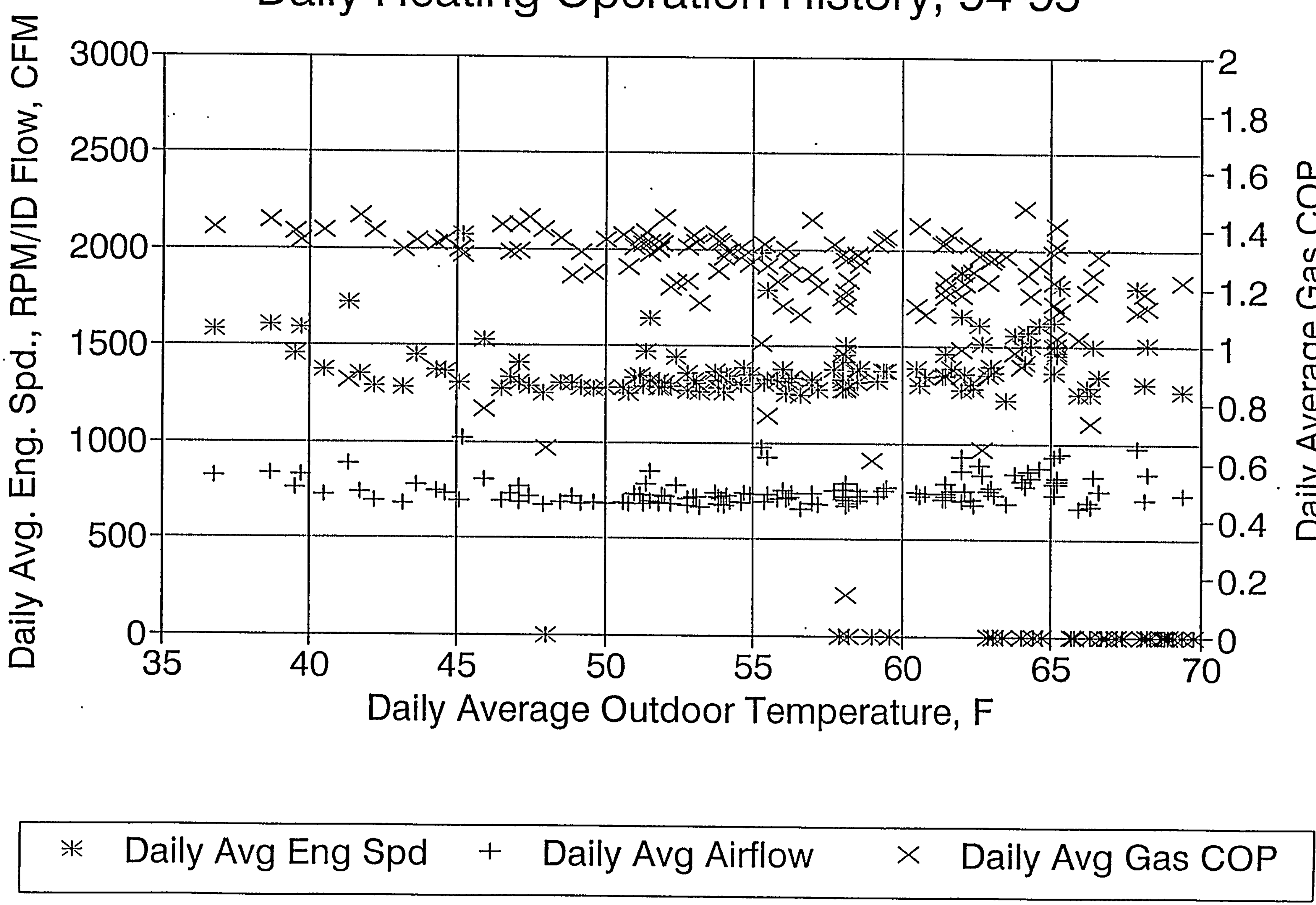


San Antonio Triathlon GHP
Daily Heating Operation History, 94-95
Daily Heating Load -or- Gas Use, KBtu
700
600
500
400
300
200
100
0
Daily Power Use, KW
21
18
15
12
9
6
3
0
10/13 11/02 11/22 12/12 01/01 01/21 02/10 03/02 03/22 04/11 05/01
Date
Daily Total Load
Daily Gas Use
Daily Power Use


San Antonio Triathlon GHP
Daily Heating Operation History, 94-95
Daily Heating Load -or- Gas Use, KBtu
0
100
200
300
400
500
600
700
Daily Power Use, KW
0
3
6
9
12
15
18
21
35
40
45
50
55
60
65
70
Daily Average Outdoor Temperature, F
Daily Total Load
Daily Gas Use
Daily Power Use

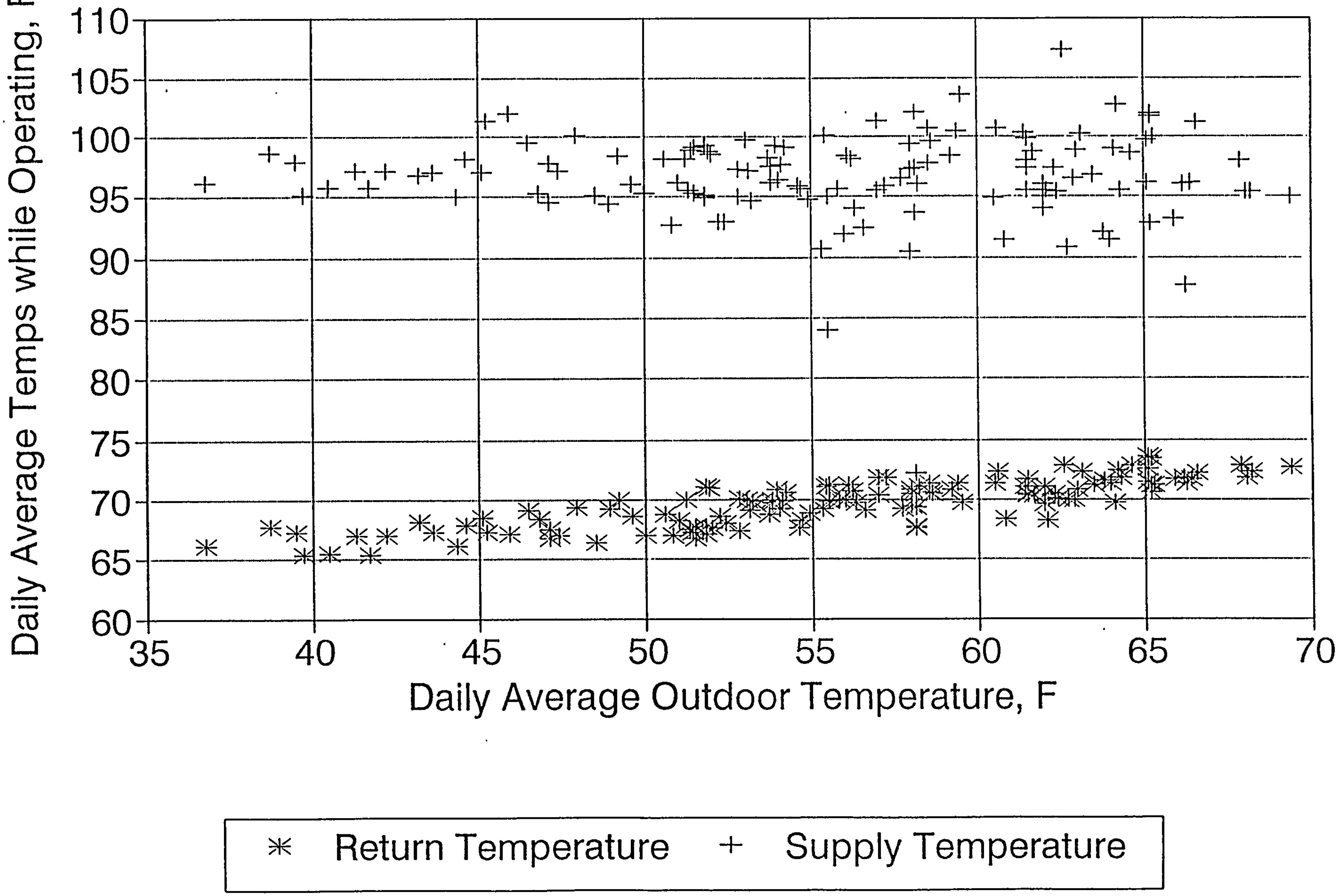
San Antonio Triathlon GHP

Daily Heating Operation History, 94-95



San Antonio Triathlon GHP

Daily Heating Operation History, 94-95



Appendix D

Performance Check by Computer Simulation

Appendix D

Performance Check by Computer Simulation

The documentation in this appendix was provided to PNL by Battelle-Columbus. Battelle served as a subcontractor to the Gas Research Institute and had the role of installing the monitoring instrumentation on the GHP and collecting the data from that system. The following are pages from original documentation produced by Battelle.

A computer model is used for periodically checking the performance of the field test GHP. By using the field test operating conditions reported by the data acquisition system as input to the model, the model can be used to obtain "expected" performance values. These results can then be compared to the actual data collected to assess the performance of the unit at that particular moment.

Attachment 3.

Performance Check of the San Antonio Triathlon GHP

	Measured Performance	Model Est. Performance	Difference
Date	1/3/95		
Time	4:12:30 - 4:22:37		
Unit operating at steady state conditions for 30 min prior to sample period			
Sample Period	10.04 min		
Outdoor Amb. Temp	46.8 °F	Input	
Outdoor Amb. RH	100 %	Input	
Indoor Return Temp	68.6 °F	Input	
Indoor Supply Temp	99.8 °F	93.1 °F	6.7 °F
Engine Speed	1209 RPM	Input	
Indoor Airflow	686 SCFM	Input	
Compressor Superheat	29 °F	Input	
Suction Temp	63 °F	55 °F	8 °F
Suction Pressure	60 psig	49 psig	11 psi
Discharge Temp	157 °F	196 °F	39 °F
Discharge Pressure	193 psig	185 psig	8 psi
Indoor Power	93 Watts		
Outdoor Power	194 Watts		
Capacity	23,044 Btu/Hr	18,320 Btu/Hr	26 %
Gas Use	15,789 Btu/Hr	14,200 Btu/Hr	11 %
Gas COP	1.46	1.29	13 %

Attachment 3.

Performance Check of the San Antonio Triathlon GHP

	Measured Performance	Model Est. Performance	Difference
Date	1/3/95		
Time	7:34:27 - 9:35:04		
Unit operating at steady state conditions for 4.5 hours prior to sample period			
Sample Period	120.64 min		
Outdoor Amb. Temp	40.0 °F	Input	
Outdoor Amb. RH	100 %	Input	
Indoor Return Temp	66.5 °F	Input	
Indoor Supply Temp	97.2 °F	90.5 °F	6.7 °F
Engine Speed	1209 RPM	Input	
Indoor Airflow	664 SCFM	Input	
Compressor Superheat	25 °F	Input	
Suction Temp	53 °F	48 °F	5 °F
Suction Pressure	53 psig	47 psig	6 psi
Discharge Temp	151 °F	189 °F	38 °F
Discharge Pressure	186 psig	178 psig	8 psi
Indoor Power	82 Watts		
Outdoor Power	228 Watts		
Capacity	21,927 Btu/Hr	17,490 Btu/Hr	21 %
Gas Use	15,430 Btu/Hr	13,770 Btu/Hr	12 %
Gas COP	1.42	1.27	12 %

Attachment 3.

Performance Check of the San Antonio Triathlon GHP, cont'd

	Measured Performance	Model Est. Performance	Difference
Date	1/5/95		
Time	4:00:52 - 6:01:18		
Unit operating at steady state conditions for 8 hours prior to sample period			
Sample Period	120.46 min		
Outdoor Amb. Temp	33.6 °F	Input	
Outdoor Amb. RH	100 %	Input	
Indoor Return Temp	67.4 °F	Input	
Indoor Supply Temp	97.2 °F	90.4 °F	6.2 °F
Engine Speed	2130 RPM	Input	
Indoor Airflow	1034 SCFM	Input	
Compressor Superheat	29 °F	Input	
Suction Temp	46 °F	40 °F	6 °F
Suction Pressure	40 psig	34 psig	6 psi
Discharge Temp	161 °F	205 °F	44 °F
Discharge Pressure	187 psig	178 psig	9 psi
Indoor Power	262 Watts		
Outdoor Power	229 Watts		
Capacity	33,147 Btu/Hr	26,060 Btu/Hr	27 %
Gas Use	24,695 Btu/Hr	21,310 Btu/Hr	16 %
Gas COP	1.34	1.22	10 %

Attachment 3.

Performance Check of the San Antonio Triathlon GHP

	Triathlon Measured Performance	CP5B/C Model Est. Performance	Difference
Date	3/1/95		
Time	5:52:42 - 6:52:55		
Unit operating at steady state conditions for 5 hrs prior to sample period			
Sample Period	60.23 min		
Outdoor Amb. Temp	44.9 °F	Input	
Outdoor Amb. RH	100 %	Input	
Indoor Return Temp	68.8 °F	Input	
Indoor Supply Temp	100.5 °F	93 °F	7.5 °F
Engine Speed	1209 RPM	Input	
Indoor Airflow	684 SCFM	Input	
Compressor Superheat	28 °F	Input	
Suction Temp	62 °F	53 °F	9 °F
Suction Pressure	60 psig	48 psig	12 psi
Discharge Temp	156 °F	195 °F	39 °F
Discharge Pressure	194 psig	184 psig	10 psi
Indoor Power	92 Watts		
Outdoor Power	226 Watts		
Capacity	23,334 Btu/Hr	18,020 Btu/Hr	29 %
Gas Use	15,790 Btu/Hr	14,130 Btu/Hr	12 %
Gas COP	1.48	1.28	16 %

Attachment 4., cont'd

Performance Check of the San Antonio Triathlon GHP

	Triathlon Measured Performance	CP5B/C Model Est. Performance	Difference
Date	4/24/95		
Time	7:28:56 - 7:59:03		
Mode	Heating		
Unit operating at steady state conditions for 140 min prior to sample period			
Sample Period	30.12 min		
Outdoor Amb. Temp	57.9 °F	Input	
Indoor Return Temp	69.1 °F	Input	
Indoor Supply Temp	106.5 °F	95.9 °F	10.6 °F
Engine Speed	1208 RPM	Input	
Indoor Airflow	702 SCFM	Input	
Compressor Superheat	33 °F	Input	
Suction Temp	73.5 °F	64 °F	9.5 °F
Suction Pressure	69 psig	56.8 psig	12.2 psi
Discharge Temp	166 °F	197 °F	31 °F
Discharge Pressure	208 psig	194 psig	14 psi
Indoor Power	102 Watts		
Outdoor Power	193 Watts		
Capacity, Total	28,246 Btu/Hr	20,160 Btu/Hr	37.0 %
Gas Use	16,789 Btu/Hr	14,830 Btu/Hr	13.2 %
Gas COP	1.68	1.40	21.1 %

Appendix E

Triathlon Performance Data Based on Chamber Test Measurements

Appendix E

Triathlon Performance Data Based on Chamber Test Measurements

The following plots and tables of data are the result of runs of the BINHEAT and BINCOOL program supplied to PNL by York International. This program presents the results of chamber testing done by York on the Triathlon. The data is given here to support any future temperature-bin-based performance analysis of the GHP in various climates.

The table lists the temperature and loading assumptions supplied to the programs. The remaining terms in the table are program outputs. Return temperatures are assumed to be 70°F for heating and 80°F for cooling. For heating, the term TOTCAP refers to the total heating capacity of the system including the auxiliary heat; HPCAP is engine-based heating capacity (excluding auxiliary). For cooling, TOTCAP refers to the total of the sensible and latent cooling capacity. COP is calculated as the ratio of the load to gas consumption rate. Part-load factor is the ratio of load to capacity. This data includes the degradation effects of part-load cycling.

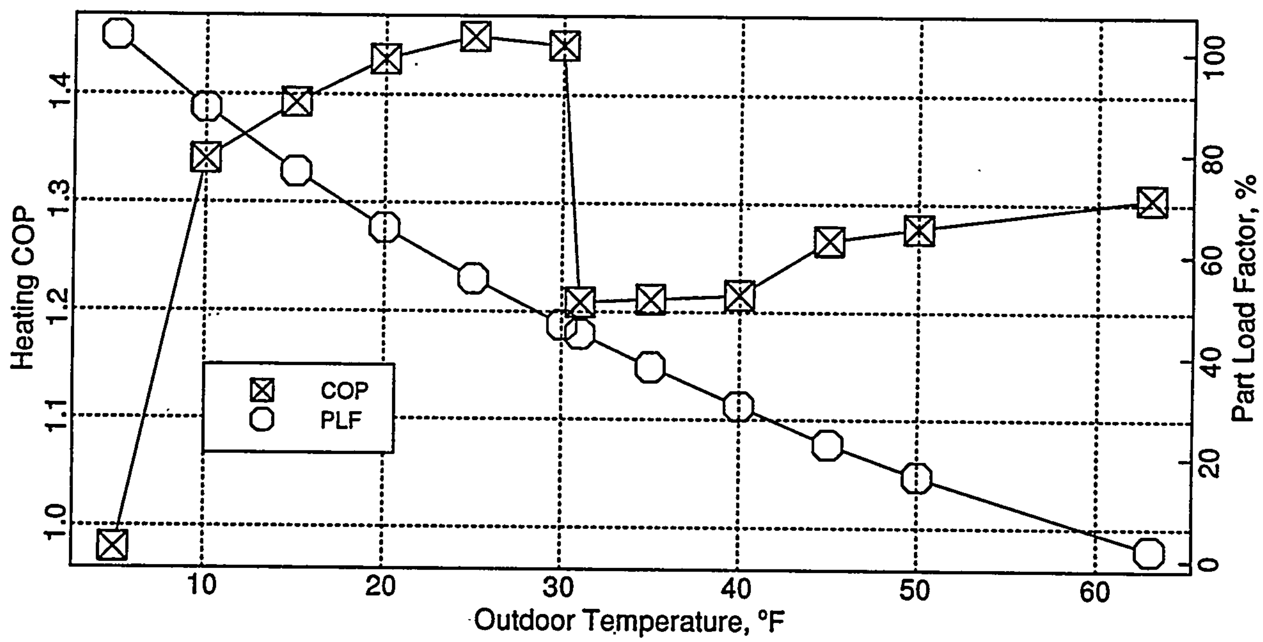


Figure E.1. Triathlon Heating COP as Determined Under Chamber Testing

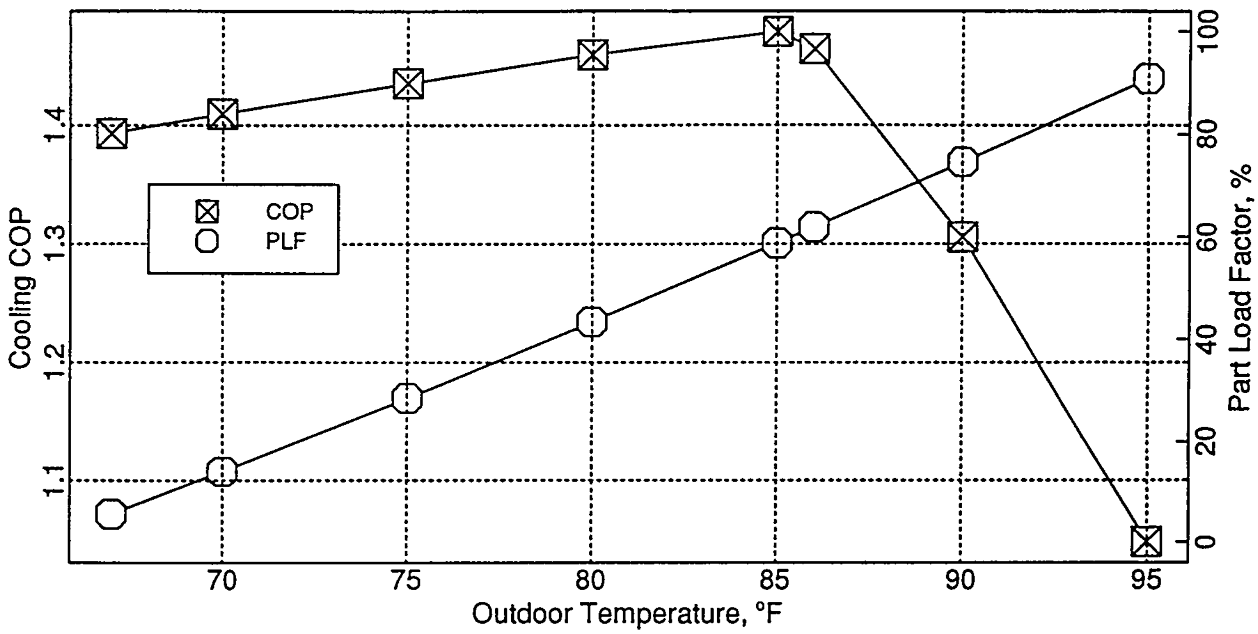


Figure E.2. Triathlon Cooling COP as Determined Under Chamber Testing

Cooling Performance

	ODB,F	Load,kBtu/h	Gas,kBtu/h	Fan,W	Speed,rpm	TOTCAP,kBtu/h
[1,]	67	2.35	1.69	36.22	1200	42.25
[2,]	70	5.88	4.17	87.64	1200	41.88
[3,]	75	11.76	8.19	166.15	1200	41.26
[4,]	80	17.64	12.09	236.88	1200	40.65
[5,]	85	23.52	15.91	299.90	NA	40.03
[6,]	86	24.69	16.86	312.17	NA	39.91
[7,]	90	29.39	22.52	372.50	NA	39.42
[8,]	95	35.27	33.68	473.37	NA	38.80

Heating Performance

	ODB,F	Load,kBtu/h	Gas,kBtu/h	Fan,W	Speed,rpm	HPCAP,kBtu/h	TOTCAP,kBtu/h
[1,]	5	30.80	31.43	648.00	3000	29.84	93.84
[2,]	10	28.23	21.07	425.61	NA	31.74	95.74
[3,]	15	25.67	18.43	358.62	NA	33.64	97.64
[4,]	20	23.10	16.12	317.76	NA	35.41	99.41
[5,]	25	20.53	14.11	303.03	NA	37.11	101.11
[6,]	30	17.97	12.43	314.43	NA	38.80	102.80
[7,]	31	17.45	14.44	283.14	1200	39.14	103.14
[8,]	35	15.40	12.71	237.24	1200	40.50	104.50
[9,]	40	12.83	10.56	185.11	1200	42.19	106.19
[10,]	45	10.27	8.11	152.72	1200	45.04	109.04
[11,]	50	7.70	6.03	109.25	1200	46.94	110.94
[12,]	63	1.03	0.79	12.92	1200	51.88	115.88

Appendix F

Intermediate Results in the Life-Cycle Cost Analysis

Appendix F

Intermediate Results in the Life-Cycle Cost Analysis

This appendix presents in spreadsheet form a single sheet of intermediate results (annual gas and electric energy consumption and demand charge calculations) that serve as input to the BLCC4 LCC software. Additional results appearing in the body of the report such as energy costs and savings are also shown here. Column labels used in the sheet are defined below.

GcMBtu	Gas consumed in cooling, MBtu
GhMBtu	Gas consumed in heating, MBtu
GtMBtu	Total gas consumed, MBtu
Eckwh	Electricity consumed in cooling, kWh
Ehkwh	Electricity consumed in heating, kWh
Etkwh	Total electricity consumed, kWh
Gc$	Cost of gas consumed in cooling, $
Gh$	Cost of gas consumed in heating, $
Ec$	Cost of electricity consumed in cooling, $
Eh$	Cost of electricity consumed in heating, $
C$	Total cost of fuels consumed in cooling including demand charges, $
H$	Total cost of fuels consumed in heating, $
Dem$	Annual demand charges, $
OpCost$	Total annual operating cost including maintenance costs, $
Erateckwh	Effective electricity rate calculated total annual cost of electricity (including demand charges) divided by the total annual electric energy, cents/kwh
CE_Sav$	Cooling energy savings including demand, $
HE_Sav$	Heating energy savings, $
OC_Sav$	Savings in total operating cost, $

Following the spreadsheet is a printed file (LCC.example) showing the step-by-step calculations made to determine the LCC of the Triathlon and comparison system C at Fort Stewart. This file illustrates many of the calculations that are made in the spreadsheet.

Each BLCC4 run has been summarized with two sheets printed from the BLCC4 program. The first sheet lists the inputs used for each alternative including annual energy use, demand charges, base rates for gas and electricity, initial cost for each alternative, and annual maintenance cost. Study life and equipment life are assumed to be 15 years. The second sheet summarizes the present-value costs of each alternative. Total life-cycle cost is composed of three present-value costs: investment cost, maintenance costs, and energy costs.

[1] "Fort Sam (using their internal rates)"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	42.31	29.60	71.91	863.50	531.35	1394.85	181.69	127.09	42.14	25.93	223.83	153.02						
10.2/97%	0.00	40.07	40.07	5642.37	309.43	5951.80	0.00	172.09	275.35	15.10	275.35	187.19	0	551.84	4.88	0.00	0.00	0.00
15.6/97%	0.00	40.07	40.07	3689.24	309.43	3998.68	0.00	172.09	180.04	15.10	180.04	187.19	0	537.53	4.88	51.52	34.17	-14.31
12.2/80%	0.00	48.59	48.59	4717.39	375.19	5092.58	0.00	208.66	230.21	18.31	230.21	226.96	0	442.22	4.88	-43.79	34.17	-109.62
[1] ""													0	532.17	4.88	6.38	73.95	-19.67

[1] "Fort Sam (using their exteral rates)"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	42.31	29.60	71.91	863.50	531.35	1394.85	180.88	126.52	16.04	9.87	235.93	136.40	39.00	547.32				
10.2/97%	0.00	40.07	40.07	5642.37	309.43	5951.80	0.00	171.32	104.84	5.75	344.57	177.07	239.74	596.64	4.65	0.00	0.00	0.00
15.6/97%	0.00	40.07	40.07	3689.24	309.43	3998.68	0.00	171.32	68.55	5.75	225.30	177.07	156.75	477.37	5.89	108.64	40.68	49.32
12.2/80%	0.00	48.59	48.59	4717.39	375.19	5092.58	0.00	207.73	87.65	6.97	288.08	214.70	200.43	577.79	5.78	-10.63	40.68	-69.95
[1] ""															5.79	52.16	78.31	30.46

[1] "Fort Sam (using San Antonio retail rates for summer months)"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	42.31	29.60	71.91	863.50	531.35	1394.85	176.58	123.52	50.17	30.87	226.75	154.39	0	556.14	5.81	0.00	0.00	0.00
10.2/97%	0.00	40.07	40.07	5642.37	309.43	5951.80	0.00	167.25	356.32	17.98	356.32	185.23	0	616.55	6.29	129.56	30.84	60.40
15.6/97%	0.00	40.07	40.07	3689.24	309.43	3998.68	0.00	167.25	232.98	17.98	232.98	185.23	0	493.21	6.28	6.22	30.84	-62.94
12.2/80%	0.00	48.59	48.59	4717.39	375.19	5092.58	0.00	202.80	297.90	21.80	297.90	224.59	0	597.50	6.28	71.15	70.20	41.35

[1] ""

[1] "Willow Grove"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	16.27	73.20	89.47	332.00	1314.20	1646.21	89.31	401.88	9.93	39.29	191.67	441.17	92.43	807.84	8.60	0.00	0.00	0.00
10.2/97%	0.00	99.12	99.12	2169.41	765.32	2934.73	0.00	544.18	64.87	22.88	633.04	567.06	568.17	1275.10	22.35	441.37	125.89	467.26
15.6/97%	0.00	99.12	99.12	1418.46	765.32	2183.78	0.00	544.18	42.41	22.88	413.91	567.06	371.50	1055.97	20.00	222.24	125.89	248.13
12.2/80%	0.00	120.18	120.18	1813.77	927.96	2741.73	0.00	659.81	54.23	27.75	529.26	687.56	475.03	1291.82	20.32	337.59	246.39	483.98

[1] ""

[1] "Fort Dicks"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	16.27	73.20	89.47	332.00	1314.20	1646.21	91.1	409.91	29.02	114.86	134.88	524.78	14.76	834.65	9.64	0.00	0.00	0.00
10.2/97%	0.00	99.12	99.12	2169.41	765.32	2934.73	0.0	555.06	189.61	66.89	280.34	621.95	90.73	977.29	11.83	145.46	97.17	142.63
15.6/97%	0.00	99.12	99.12	1418.46	765.32	2183.78	0.0	555.06	123.97	66.89	183.30	621.95	59.32	880.25	11.46	48.42	97.17	45.59
12.2/80%	0.00	120.18	120.18	1813.77	927.96	2741.73	0.0	673.01	158.52	81.10	234.38	754.11	75.86	1063.49	11.51	99.50	229.34	228.84

[1] ""

[1] "Fort Stewart"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	34.84	23.94	58.78	710.98	429.86	1140.84	104.51	71.83	17.77	10.75	160.78	82.57	38.50	418.36	5.87	0.00	0.00	0.00
10.2/97%	0.00	32.42	32.42	4645.74	250.33	4896.07	0.00	97.26	116.14	6.26	352.79	103.52	236.65	531.31	7.33	192.01	20.95	112.95
15.6/97%	0.00	32.42	32.42	3037.60	250.33	3287.93	0.00	97.26	75.94	6.26	230.67	103.52	154.73	409.19	7.21	69.89	20.95	-9.17
12.2/80%	0.00	39.31	39.31	3884.14	303.53	4187.66	0.00	117.93	97.10	7.59	294.96	125.52	197.85	495.47	7.22	134.17	42.94	77.12

[1] ""

[1] "Fort Drum"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	3.63	105.14	108.77	74.09	1887.69	1961.78	22.14	641.36	3.58	91.25	33.99	732.61	8.26	941.60	5.26	0.00	0.00	0.00
10.2/97%	0.00	142.37	142.37	484.12	1099.29	1583.41	0.00	868.46	23.40	53.14	74.21	921.60	50.81	1070.81	8.04	40.22	188.99	129.20
15.6/97%	0.00	142.37	142.37	316.54	1099.29	1415.83	0.00	868.46	15.30	53.14	48.52	921.60	33.22	1045.12	7.18	14.53	188.99	103.52
12.2/80%	0.00	172.62	172.62	404.76	1332.89	1737.65	0.00	1053.01	19.57	64.43	62.04	1117.44	42.48	1254.48	7.28	28.05	384.83	312.88

[1] ""

[1] "Fort Irwin"

	GcMBtu	GhMBtu	GtMBtu	Eckwh	Ehkwh	Etkwh	Gc$	Gh$	Ec$	Eh$	C$	H$	Dem$	OpCost$	Erateckwh	CE_Sav$	HE_Sav$	OC_Sav$
Triathlon	28.97	40.77	69.75	591.32	732.02	1323.34	144.26	203.00	59.92	74.18	267.93	277.18	63.75	720.11	14.95	0.00	0.00	0.00
10.2/97%	0.00	55.21	55.21	3863.83	426.29	4290.13	0.00	274.88	391.54	43.20	783.42	318.08	391.88	1176.50	19.27	515.49	40.90	456.39
15.6/97%	0.00	55.21	55.21	2526.35	426.29	2952.64	0.00	274.88	256.01	43.20	512.23	318.08	256.23	905.32	18.81	244.30	40.90	185.20
12.2/80%	0.00	66.94	66.94	3230.42	516.88	3747.30	0.00	333.30	327.35	52.38	654.99	385.68	327.63	1115.66	18.88	387.06	108.49	395.55

```
This file contains step by step calculations that lead to the LCC estimate
for the Triathlon and one comparison system at Fort Stewart.

///////////// Field Monitoring Basis ///////////////

The following normal-year energy-usage numbers are from the San Antonio field
test.  Triathlon and comparison units energy projections (to different
climates) are based on these numbers.

Heating
-------
                 kcf      kwh
Triathlon 27.90008 510.9322
   Unit 2 37.77914 297.5405

Cooling
-------
                         kwh     kcf
   Triathlon          863.50   41.48
 Unit 1 (pp)         5663.41    0.00
Unit 1 (map)         5351.36    0.00

Average of Unit1 (SEER = 10.45) cooling energy (pp and map) = 5507.385 kwh

Demand summer power draws
-------------------------
               kw
Triathlon     0.5
Unit 1        3.0

Demand diversity factor = 0.75

Note: MBtu = 1.02 * kcf  assuming a heating value of 1020 btu/cf

These numbers above correspond to the following normal year weather
characteristics at San Antonio: HDD = 2251.67, CDD = 2470.83

//////  CALCULATIONS for FORT STEWART  ////////////////////

Inputs for Fort Stewart:

HDD = 1894.4
CDD = 2034.4
Cost of gas ($/Mbtu) = 3.0
Cost of elec ($/kwh) = 0.025
Demand ($/kw) = 8.85
Demand months = 4
Ratchet months = 8
Ratchet percent = 95

Triathlon predicted energy use:
------------------------------
Gas cooling = 1.02 * 41.48  * (2034.4/2470.83) = 34.83633 (MBtu)
Elec cooling =       863.50 * (2034.4/2470.83) = 710.9774 (kwh)
Gas heating = 1.02 * 27.9   * (1894.4/2251.67) = 23.9426 (MBtu)
elec heating =       510.9  * (1894.4/2251.67) = 429.8361 (kwh)

So,
Annual Gas use = 34.83633 + 23.9426 = 58.77893 (MBtu)
Annual Elec use = 710.9774 + 429.8361 = 1140.813 (kwh)

Annual Demand charges = 8.85 * 0.5 * 0.75 * (4 + 8*0.95) = 38.4975 ($)

Comparison Unit C predicted energy use:
---------------------------------------
Unit characteristics: AFUE = 80%
                      SEER = 12.2.
Gas cooling = 0
Elec cooling = 5507.385 * (10.45/12.2) * (2034.4/2470.83) = 3884.145 (kwh)
Gas heating = 1.02 * 37.77914 * (97/80) * (1894.4/2251.67) = 39.30981 (MBtu)
Elec heating =       297.5405 * (97/80) * (1894.4/2251.67) = 303.5252 (kwh)

So,
```



```
Annual Gas use = 39.30981 (MBtu)
Annual elec use = 3884.145 + 303.5252 = 4187.67 (kwh)

Annual demand charge = 8.85 * 3.0 * (10.45/12.2) * 0.75 * (4 + 8*0.95)
                     = 197.8519 ($)

Inputs needed by the LCC analysis program:
-----------------------------------------
                          Triathlon  Unit C
                          ---------  --------
Annual Elec (kwh)          1140.8    4187.6
Annual Gas (MBtu)          58.7      39.3
Annual Demand ($)          38.4      197.8
Maintenance ($)            175       75
Initial Cost ($)           8000      3500

Energy rates
Elec ($/kWh) = 0.025
Gas  ($/MBtu) = 3.000

/////////   Output from LCC program /////////

                Triathlon Unit C
LCC ($)         13281     9655
```

QI filename = FORTSAM1.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.049	$4.386		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 1
State Abbreviation = TX

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.0920	2005	1.2068						
1996	1.0596	2006	1.4034						
1997	0.2559	2007	1.7042						
1998	0.4248	2008	1.2313						
1999	1.1825	2009	0.7231						
2000	1.5914								
2001	0.8265								
2002	0.2043								
2003	0.4277								
2004	1.1542								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.1771	2005	1.5673						
1996	1.4580	2006	1.0508						
1997	1.3090	2007	3.1312						
1998	0.8395	2008	2.4415						
1999	0.5122	2009	1.2108						
2000	0.7624								
2001	1.7009								
2002	1.1243								
2003	0.5513								
2004	2.3075								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80.0	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1395	72	0
2	10.2/90+%	HVC	5951	40	0
3	15.6/96.6	HVC	3998	40	0
4	12.2/80.0	HVC	5092	49	0

BLCC Quick Input Program (QI2.1-95) 08-11-1995/11:24:45

QI filename = FORTSAM1.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	Present-Value Costs			
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80.0	$3500	$895	$6021	$10416<--MIN LCC
10.2/90+%	$4018	$895	$6067	$10980
15.6/96.6	$5917	$895	$4839	$11651
Triathlon	$8000	$2089	$5047	$15136

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Can't compute comparative economic measures for an alternative against itself.

* Investment costs include capital replacements and residual values (if any).
Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = FORTSAM2.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.019	$4.270		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 1
State Abbreviation = TX

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.0920	2005	1.2068						
1996	1.0596	2006	1.4034						
1997	0.2559	2007	1.7042						
1998	0.4248	2008	1.2313						
1999	1.1825	2009	0.7231						
2000	1.5914								
2001	0.8265								
2002	0.2043								
2003	0.4277								
2004	1.1542								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.1771	2005	1.5673						
1996	1.4580	2006	1.0508						
1997	1.3090	2007	3.1312						
1998	0.8395	2008	2.4415						
1999	0.5122	2009	1.2108						
2000	0.7624								
2001	1.7009								
2002	1.1243								
2003	0.5513								
2004	2.3075								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80.0	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1395	72	39
2	10.2/90+%	HVC	5951	40	240
3	15.6/96.6	HVC	3998	40	157
4	12.2/80.0	HVC	5092	49	200

BLCC Quick Input Program (QI2.1-95)   08-11-1995/11:13:38

QI filename = FORTSAM2.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	Present-Value Costs				
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs	
12.2/80.0	$3500	$895	$6547	$10943	<--MIN LCC
10.2/90+%	$4018	$895	$6779	$11693	
15.6/96.6	$5917	$895	$5241	$12054	
Triathlon	$8000	$2089	$4897	$14986	

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Can't compute comparative economic measures for an alternative against itself.

* Investment costs include capital replacements and residual values (if any).
Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = FORTSAM3.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Other	Nat.Gas	
Units:	(kWh)	(kWh)	(MBtu)	
Price per unit:	$0.058	$0.063	$4.174	
Escalation type code:	2	2	2	

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 1
State Abbreviation = TX

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.0920	2005	1.2068						
1996	1.0596	2006	1.4034						
1997	0.2559	2007	1.7042						
1998	0.4248	2008	1.2313						
1999	1.1825	2009	0.7231						
2000	1.5914								
2001	0.8265								
2002	0.2043								
2003	0.4277								
2004	1.1542								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.1771	2005	1.5673						
1996	1.4580	2006	1.0508						
1997	1.3090	2007	3.1312						
1998	0.8395	2008	2.4415						
1999	0.5122	2009	1.2108						
2000	0.7624								
2001	1.7009								
2002	1.1243								
2003	0.5513								
2004	2.3075								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80.0	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Other (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1395	0	72	0
2	10.2/90+%	HVC	309	5642	40	0
3	15.6/96.6	HVC	309	3689	40	0
4	12.2/80.0	HVC	375	4717	49	0

BLCC Quick Input Program (QI2.1-95)   08-11-1995/11:41:31

QI filename = FORTSAM3.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Sam Houston
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	------------------Present-Value Costs------------------				
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs	
12.2/80.0	$3500	$895	$6805	$11200	<--MIN LCC
10.2/90+%	$4018	$895	$7039	$11953	
15.6/96.6	$5917	$895	$5448	$12260	
Triathlon	$8000	$2089	$5013	$15102	

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Can't compute comparative economic measures for an alternative against itself.

* Investment costs include capital replacements and residual values (if any).
Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = WILLOW.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Willow Grove
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.030	$5.490		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 2
State Abbreviation = PA

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	-0.6659	2005	0.1886						
1996	-0.4394	2006	0.4128						
1997	0.1344	2007	1.4752						
1998	0.4413	2008	0.6136						
1999	0.1723	2009	-0.6231						
2000	0.3805								
2001	0.6473								
2002	0.4342								
2003	-0.0754								
2004	-0.1314								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.5262	2005	1.8496						
1996	1.5574	2006	1.2707						
1997	1.5369	2007	3.7844						
1998	1.0811	2008	2.9490						
1999	0.7128	2009	1.5395						
2000	0.9178								
2001	2.0937								
2002	1.5205								
2003	0.7415								
2004	2.7987								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80%	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1646	89	92
2	10.2/90+%	HVC	2935	99	568
3	15.6/96.6	HVC	2184	99	371
4	12.2/80%	HVC	2742	120	475

BLCC Quick Input Program (QI2.1-95) 08-09-1995/17:48:10

QI filename = WILLOW.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Willow Grove
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	-----------------Present-Value Costs----------------			
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80%	$3500	$895	$15597	$19993
10.2/90+%	$4018	$895	$15225	$20139
15.6/96.6	$5917	$895	$12593	$19405
Triathlon	$8000	$2089	$8331	$18421<--MIN LCC

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Comparative economic measures for Triathlon relative to 12.2/80%:
NET SAVINGS = $1572; SIR = 1.35; AIRR = 5.08%
Ratio of present-value energy savings to total savings = 1.00

* Investment costs include capital replacements and residual values (if any).
Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = DICKS.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Dicks
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.087	$5.600		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 2
State Abbreviation = NJ

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	-0.6659	2005	0.1886						
1996	-0.4394	2006	0.4128						
1997	0.1344	2007	1.4752						
1998	0.4413	2008	0.6136						
1999	0.1723	2009	-0.6231						
2000	0.3805								
2001	0.6473								
2002	0.4342								
2003	-0.0754								
2004	-0.1314								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.5262	2005	1.8496						
1996	1.5574	2006	1.2707						
1997	1.5369	2007	3.7844						
1998	1.0811	2008	2.9490						
1999	0.7128	2009	1.5395						
2000	0.9178								
2001	2.0937								
2002	1.5205								
2003	0.7415								
2004	2.7987								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80%	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1646	89	15
2	10.2/90+%	HVC	2935	99	91
3	15.6/96.6	HVC	2184	99	59
4	12.2/80%	HVC	2742	120	76

BLCC Quick Input Program (QI2.1-95)   08-09-1995/17:47:08

QI filename = DICKS.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Dicks
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	------------------Present-Value Costs-----------------			
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80%	$3500	$895	$12874	$17269
10.2/90+%	$4018	$895	$11663	$16577<--MIN LCC
15.6/96.6	$5917	$895	$10498	$17310
Triathlon	$8000	$2089	$8668	$18758

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Comparative economic measures for 10.2/90+% relative to 12.2/80%:
NET SAVINGS = $692; SIR = 2.34; AIRR = 9.00%
Ratio of present-value energy savings to total savings = 1.00

* Investment costs include capital replacements and residual values (if any). Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = FORTSTEW.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Stewart
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.025	$3.000		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 2
State Abbreviation = GA

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	0.7457	2005	-0.7232						
1996	0.0238	2006	-0.7766						
1997	-0.4530	2007	0.0000						
1998	-0.2383	2008	0.6171						
1999	0.7652	2009	0.1650						
2000	1.2122								
2001	0.6832								
2002	0.0700								
2003	0.1631								
2004	-0.2801								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.6066	2005	1.8911						
1996	1.7931	2006	1.3311						
1997	1.6052	2007	3.6123						
1998	1.0265	2008	2.7774						
1999	0.6250	2009	1.4389						
2000	0.8517								
2001	1.9925								
2002	1.4422								
2003	0.6674								
2004	2.6398								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80.0	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1141	59	39
2	10.2/90+%	HVC	4896	32	237
3	15.6/96.6	HVC	3288	32	155
4	12.2/80.0	HVC	4187	39	198

BLCC Quick Input Program (QI2.1-95)   08-14-1995/10:00:36

QI filename = FORTSTEW.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Stewart
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	Present-Value Costs			
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80.0	$3500	$895	$5259	$9655<--MIN LCC
10.2/90+%	$4018	$895	$5665	$10579
15.6/96.6	$5917	$895	$4185	$10997
Triathlon	$8000	$2089	$3192	$13281

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Can't compute comparative economic measures for an alternative against itself.

* Investment costs include capital replacements and residual values (if any).
  Residual values for initial capital investment are calculated when life extends beyond end of study period.
  Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = DRUM.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Drum
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.048	$6.100		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 2
State Abbreviation = NY

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	-0.6659	2005	0.1886						
1996	-0.4394	2006	0.4128						
1997	0.1344	2007	1.4752						
1998	0.4413	2008	0.6136						
1999	0.1723	2009	-0.6231						
2000	0.3805								
2001	0.6473								
2002	0.4342								
2003	-0.0754								
2004	-0.1314								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	2.5262	2005	1.8496						
1996	1.5574	2006	1.2707						
1997	1.5369	2007	3.7844						
1998	1.0811	2008	2.9490						
1999	0.7128	2009	1.5395						
2000	0.9178								
2001	2.0937								
2002	1.5205								
2003	0.7415								
2004	2.7987								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80%	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1962	109	8
2	10.2/90+%	HVC	1583	142	51
3	15.6/96.6	HVC	1416	142	33
4	12.2/80%	HVC	1738	173	42

BLCC Quick Input Program (QI2.1-95)   08-13-1995/12:06:38

QI filename = DRUM.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Drum
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	-----------------Present-Value Costs-----------------			
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80%	$3500	$895	$15731	$20126
10.2/90+%	$4018	$895	$13251	$18164<--MIN LCC
15.6/96.6	$5917	$895	$12942	$19754
Triathlon	$8000	$2089	$10193	$20282

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Comparative economic measures for 10.2/90+% relative to 12.2/80%:
NET SAVINGS = $1962; SIR = 4.79; AIRR = 14.33%
Ratio of present-value energy savings to total savings = 1.00

* Investment costs include capital replacements and residual values (if any).
Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

BLCC Quick Input Program (QI2.1-95)   08-13-1995/12:53:29

QI filename = IRWIN.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Irwin
Base date of study = 1995
Service date = 1995
Study Period = 15 years
Discount rate = 3.0%
Annually recurring costs and energy costs discounted from end of year.
DOE energy price escalation rate file = ENCOST95

Number of alternatives in file = 4
Number of groups in file = 1

Note: Project alternatives displayed in increasing order of investment cost

Group code: HVC	-----------------	Present-Value Costs	----------------	
Alternative Name	Investment Costs*	OM&R Costs	Energy Costs	Total Life-Cycle Costs
12.2/80%	$3500	$895	$13742	$18137
10.2/90+%	$4018	$895	$14459	$19373
15.6/96.6	$5917	$895	$10974	$17787
Triathlon	$8000	$2089	$7389	$17478<--MIN LCC

Comparative measures are only calculated for the alternative with lowest LCC relative to alternative with the lowest present-value investment cost.

Comparative economic measures for Triathlon relative to 12.2/80%:
NET SAVINGS = $659; SIR = 1.15; AIRR = 3.94%
Ratio of present-value energy savings to total savings = 1.00

* Investment costs include capital replacements and residual values (if any). Residual values for initial capital investment are calculated when life extends beyond end of study period.
Residual values for capital replacements are calculated when life extends beyond end of study period.

QI filename = IRWIN.QI
Analysis type = Federal Analysis--Energy Conservation Projects
Project name = Fort Irwin
Base Date of Study = 1995
Service Date = 1995
Study Period = 15 years
Discount rate = 3.0%
Inflation rate = 0.00%
Cap replacements and residual values (if any) included as investment costs.
Residual values automatically calculated for capital components.
Residual values automatically calculated for capital replacements.

Common energy data	#1	#2	#3	#4
Energy type:	Electric	Nat.Gas		
Units:	(kWh)	(MBtu)		
Price per unit:	$0.101	$4.970		
Escalation type code:	2	2		

Data for DOE escalation rates:
DOE Escalation Rate File = ENCOST95
Rate Schedule Type = 2
State Abbreviation = CA

DOE Price escalation rates for Electric

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	0.6306	2005	1.2684						
1996	0.4572	2006	1.9207						
1997	1.1230	2007	0.8334						
1998	1.3296	2008	0.6555						
1999	1.2376	2009	0.8616						
2000	1.0651								
2001	0.7992								
2002	1.6500								
2003	1.2557								
2004	0.0441								

DOE Price escalation rates for Nat.Gas

Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)	Year	Rate(%)
1995	3.0838	2005	1.7990						
1996	3.7970	2006	2.3306						
1997	2.1629	2007	2.2050						
1998	0.9166	2008	1.2346						
1999	0.9969	2009	1.2874						
2000	1.2579								
2001	1.5065								
2002	2.0081								
2003	2.4822								
2004	2.0967								

Number of alternatives in file = 4
Number of groups in file = 1

ALT #	ALTERNATIVE NAME	GROUP CODE	LIFE (Y/M)	INITIAL COST($)	CAPITAL REPLACEMENTS FREQ*	CAPITAL REPLACEMENTS COST($)	ANNUAL OM&R COST($)	NON-ANNUAL OM&R FREQ*	NON-ANNUAL OM&R COST($)
1	Triathlon	HVC	15/0	8000	0/0	0	175	0/0	0
2	10.2/90+%	HVC	15/0	4018	0/0	0	75	0/0	0
3	15.6/96.6	HVC	15/0	5917	0/0	0	75	0/0	0
4	12.2/80%	HVC	15/0	3500	0/0	0	75	0/0	0

*FREQ = Frequency of occurrence (in years/months)

ALT #	ALTERNATIVE NAME	GROUP CODE	ANNUAL ENERGY USE Electric (kWh)	ANNUAL ENERGY USE Nat.Gas (MBtu)	AN. ELEC. DEMAND CHARGE($)
1	Triathlon	HVC	1323	70	64
2	10.2/90+%	HVC	4290	55	392
3	15.6/96.6	HVC	2952	55	256
4	12.2/80%	HVC	3747	67	328

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