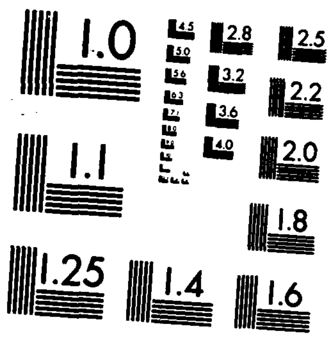
AD-A173 399 FAN ELECTRICITY CONSUMPTION FOR VARIABLE-AIR-VOLUME 1/2
SYSTEMS(U) ILLINOIS UNIV AT URBANA J D SPITLER ET AL.
SEP 86 CERL-TR-E-86/06 DACW88-84-D-0031

UNCLASSIFIED F/G 13/1 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

US Army Corps of Engineers
Construction Engineering Research Laboratory

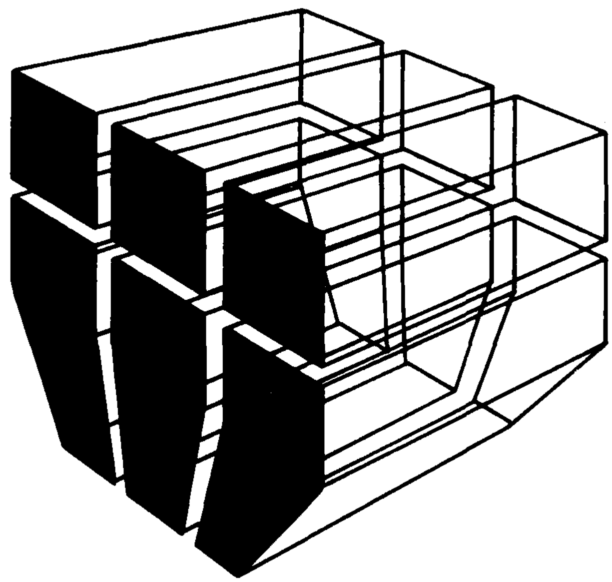
USA-CERL

TECHNICAL REPORT E-86/06
September 1986
Retrofit Control Systems for Energy Conservation

AD-A173 399

Fan Electricity Consumption for Variable-Air-Volume Systems

by
Jeffrey D. Spitler
Douglas C. Hittle



This report documents the results of a study conducted to quantify potential energy savings provided by different flow modulation methods and fan control strategies.

Results showed that variable-air-volume (VAV) systems have substantial amounts of energy in buildings with large internal loads and considered to be core-dominated. Trends noted were shifting of fractional flows downward for warmer climates and envelope-dominated buildings. Thus, the greatest savings for VAV systems occur in envelope-dominated buildings in cooler climates.

The economics decision to install frequency converters or inlet vanes should be based on individual building and climate characteristics. However, noise levels and maintenance factors should also be considered.

Approved for public release; distribution unlimited.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CERL TR E-86/06	5 MONITORING ORGANIZATION REPORT NUMBER(S) CERL TR E-86/06
6a. NAME OF PERFORMING ORGANIZATION University of Illinois 6b. OFFICE SYMBOL *(If applicable)*	7a NAME OF MONITORING ORGANIZATION U.S. Army Construction Engr Research Laboratory
6c. ADDRESS *(City, State, and ZIP Code)* Urbana, IL 61801	7b. ADDRESS *(City, State, and ZIP Code)* P.O. Box 4005 Champaign, IL 61820-1305
8a. NAME OF FUNDING / SPONSORING ORGANIZATION HQ USACE 8b. OFFICE SYMBOL *(If applicable)* DAEN-ZCF-U	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DACW-88-84-D-003-18
8c. ADDRESS *(City, State, and ZIP Code)* The Pentagon Washington, D.C. 20310-2600	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 62781 · PROJECT NO. T45 · TASK NO B · WORK UNIT ACCESSION NO 002

11. TITLE *(Include Security Classification)*
Fan Electricity Consumption for Variable-Air-Volume Systems (Unclassified)

12. PERSONAL AUTHOR(S)
Spitler, Jeffrey D.; Hittle, Douglas C.

13a. TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT *(Year, Month, Day)*	15 PAGE COUNT
Final	FROM ______ TO ______	86-09	101

16. SUPPLEMENTARY NOTATION
Copies are available from the National Technical Information Service
Springfield, VA 22161

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
13	01	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
energy consumption
control systems
fans
variable-air-volume systems

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This report documents the results of a study conducted to quantify potential energy savings provided by different flow modulation methods and fan control strategies.

Results showed that variable-air-volume (VAV) systems save substantial amounts of energy in buildings with large internal loads and considered to be core-dominated. Trends noted were shifting of fractional flows downward for warmer climates and envelope-dominated buildings. Thus, the greatest savings for VAV systems occur in envelope-dominated buildings in cooler climates.

The economics decision to install frequency converters or inlet vanes should be based on individual building and climate characteristics. However, noise levels and maintenance factors should also be considered.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a NAME OF RESPONSIBLE INDIVIDUAL D. P. Mann	22b TELEPHONE *(Include Area Code)* 217-373-7223	22c OFFICE SYMBOL CERL-IMT

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

FOREWORD

This research was conducted for the Office of the Assistant Chief of Engineers (OACE) under Project 4A162781AT45, "Basic Research in Military Construction"; Task B, "Energy Systems"; Work Unit 002, "Retrofit Control Systems for Energy Conservation." The work was performed by the University of Illinois at Urbana-Champaign under contract DACW-88-84-D-003-18 to the Energy Systems Division (ES), U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. Douglas C. Hittle was the USA-CERL Principal Investigator. Mr. B. Wasserman, DAEN-ZCF-U, was the OACE Technical Monitor.

Dr. G. R. Williamson is Acting Chief of USA-CERL-ES. COL Norman C. Hintz is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

A-1

CONTENTS

FIGURES

FIGURES (Cont'd)

FIGURES (Cont'd)

FIGURES (Cont'd)

TABLES

FAN ELECTRICITY CONSUMPTION FOR VARIABLE-AIR-VOLUME SYSTEMS

1 INTRODUCTION

Background

The use of variable-air-volume (VAV) systems in heating, ventilating, and air-conditioning (HVAC applications) is an excellent means of saving energy, either in new construction or as a retrofit. The electricity consumed by the supply fan is a large part of the total VAV system energy consumption. For a given building in a given climate, the amount of electricity consumed depends on several factors: the type of fan, the method of flow modulation, the type of controls used, and the type of VAV box. The different types of fans typically used in VAV systems include backward-inclined and forward-curved centrifugal fans, and vaneaxial fans.

There are many ways to modulate flow. One would be to do nothing--just let the static pressure across the fan increase as the VAV boxes close down. This is essentially the performance characteristic of discharge dampers. In increasing order of efficiency, other methods are use of inlet guide vanes and speed control for centrifugal fans and varying the pitch of the fan blades for vaneaxial fans. Either proportional or proportional-integral controls can be used to control the flow modulation.

Several publications have explained the advantages of various fan control strategies for VAV systems. Janisse[1] gave performance data for different fan control strategies. Several other reports estimated energy savings based on different flow reductions[2] or an assumed load profile.[3] Two reports[4] gave estimates of the flow fractions at which the most operating hours occur, based on experience.

A more quantitative estimate is desirable for getting an accurate energy analysis. The Building Loads Analysis and System Thermodynamic (BLAST) system[5]--a comprehensive set of subprograms for predicting energy consumption in buildings--is ideal for this type of calculation since it can compute zone loads, required supply air volumes, fan fractions, and fan electricity consumption. The developmental version of BLAST used for this study can output the fraction of full flow for each hour so load profiles can be developed.

---

[1]N. Janisse, "How to Control Air Systems," *Heating - Piping - Air Conditioning* (April 1969).

[2]R. Kazar and J. Lynch, "Centrifugal Fan Design for Energy Conservation," *TAPPI Journal*, Vol 61, No. 9 (September 1978).

[3]W. Ballard, "Comparative Energy Savings in Fan Systems," *Proceedings, International Conference on Fan Design & Applications* (Guilford, England, 1982).

[4]S. Sessler and W. Shiver, "Energy Use Can Be Reduced in Air Handling Systems," *Specifying Engineer* (March 1981); R. Haines, "Fan Energy - P vs. PI Control," *Heating - Piping - Air Conditioning* (August 1984).

[5]D. C. Hittle, *The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0: Users Manual*, Vols I and II, Technical Report E-153/ADA072272 and ADA072273 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1979).

Objective

The objective of this study was to quantify potential energy savings for different flow modulation methods and fan control strategies.

Approach

Three prototypical buildings were developed, and five sites were chosen to represent different climates in the United States. Three VAV options were simulated for each building and location to provide load profiles and quantitative energy savings for each building and location. Several simulations were also performed to compare proportional control to proportional-integral control for control of static pressure using electronic variable speed drives (alternating current [AC] inverters). Several additional simulations were done to compare the energy performance of different types of VAV terminal units. Economic calculations were made to examine the benefits of choosing frequency inverters instead of inlet vanes.

Mode of Technology Transfer

The information in this report has been incorporated into draft Design Instructions and Technical Specifications prepared by the U.S. Army Construction Engineering Research Laboratory (USA-CERL). The results will also be included in a new Technical Manual and Guide Specification on HVAC controls being prepared by the Corps of Engineers, Huntsville Division.

2 DESCRIPTION OF PROTOTYPE BUILDINGS

Three buildings--a dental clinic, a battalion headquarters, and a large office building--were chosen as prototypes for testing the fan control strategies.

Figure 1 shows the floor plan of the dental clinic. The clinic is a single-story building of about 9000 sq ft.* The exterior walls consist of 4-in. face brick, 2-in. mortar, 4-in. concrete block, an air space, and 1/2-in. gypsum board. The exterior wall area is 4050 sq ft, with about 340 sq ft of windows or glass doors. The floor is an 8-in. concrete slab with 1 in. of rigid insulation over a crawlspace. The roof consists of 1/2-in. stone, felt building membrane, metal deck, an airspace, 3 in. of insulation, and acoustical tile. The building occupancy, lighting, and electric loads are typical of office buildings. Appendix A, which is a sample input file, provides further details. The VAV system serves zones 1 through 10. Zone 11--the mechanical room--was not simulated.

The battalion headquarters was typical of the type that the Army is currently building. Figure 2 shows a floor plan. The battalion headquarters--a single-story building with office and classroom areas--contains about 12,000 sq ft of floor space. The exterior walls are constructed of 6-in. brick, 2-in. expanded polyurethane insulation, and 6- or 12-in. concrete block. The exterior walls are about 4000 sq ft in area, with about 400 sq ft of windows or glass doors. The floor is a 4-in. concrete, slab-on-grade floor. The roof is constructed from asphalt shingles, 3/4-in. plywood, 6 in. of mineral fiber insulation, an attic space, and acoustical tile. Appendix B gives further details in the sample input file. The VAV system serves zones 3, 4, 5, and 6.

Only one floor of the large office building was simulated; the results were multiplied by 20 to get the current order of magnitude for a 20-story building. Each floor has 22,500 sq ft of floor area of which 4900 sq ft are unoccupied (elevators, equipment rooms, electrical and telephone service, etc.). Figure 3 shows a floor plan. Zones 1 through 4 are on the perimeter and used as offices. Zone 5 is an interior zone. All zones have high-occupancy densities and high lighting and equipment loading. This building was intended to represent a more core-dominated building, as opposed to the more envelope-dominated battalion headquarters and dental clinic. The exterior walls are constructed with 4 in. of face brick, an airspace, 8-in. concrete block, and a layer of drywall. Each floor has a total exterior wall area of 6000 sq ft, which includes 2740 sq ft of double-pane windows. The wall mass may be a little heavier than is typical, but since the building is essentially core-dominated, the additional thermal mass should be insignificant. The floor and ceiling are identical, consisting of 4 in. of concrete, an airspace, and acoustical tile. Appendix C provides further details in a sample input file.

---

*Metric conversion factors: 1 in. = 25.4 mm; 1 sq ft = 0.092 m^2; °C = (°F-32)(5/9).

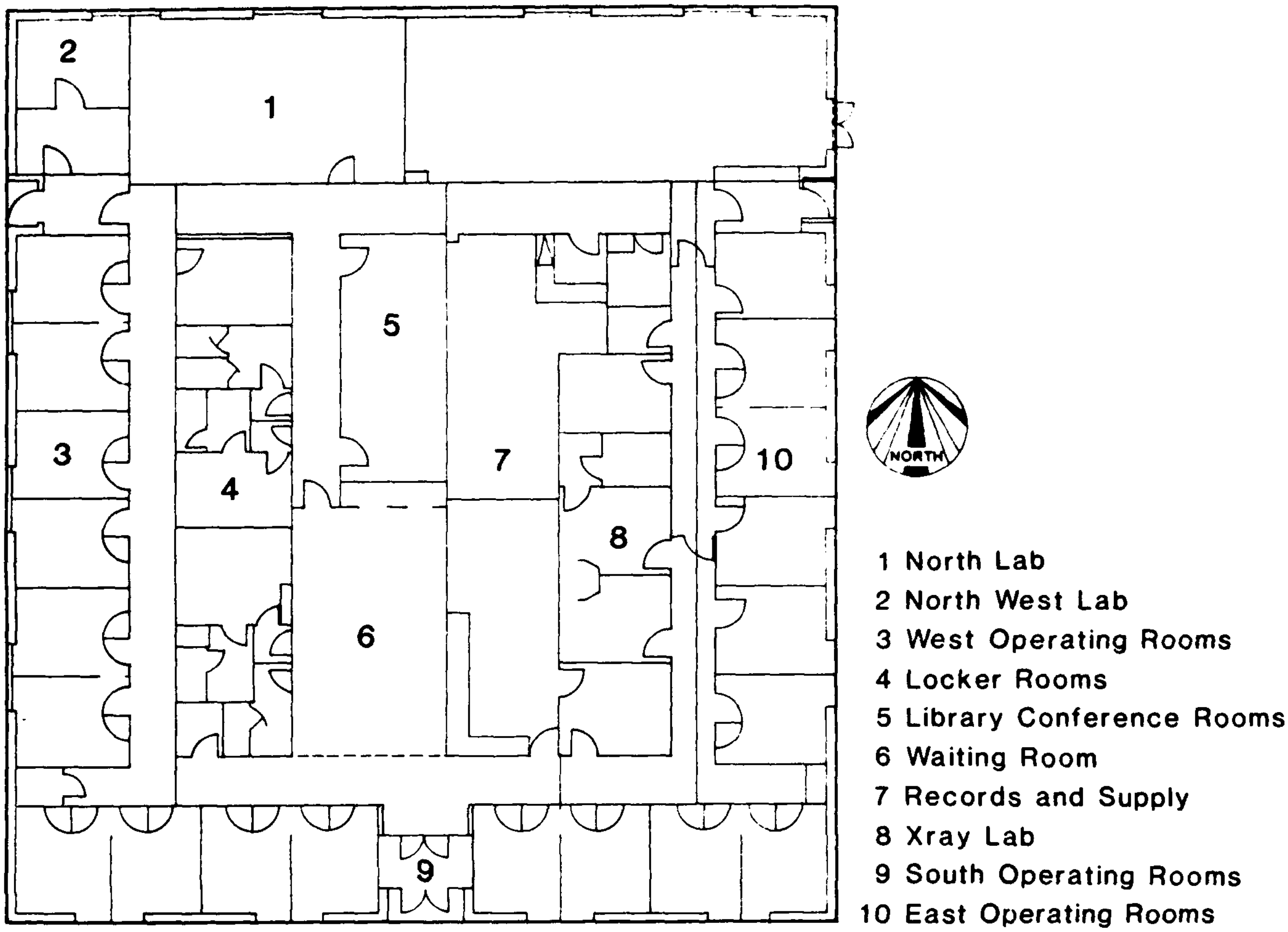


Figure 1. Dental clinic.

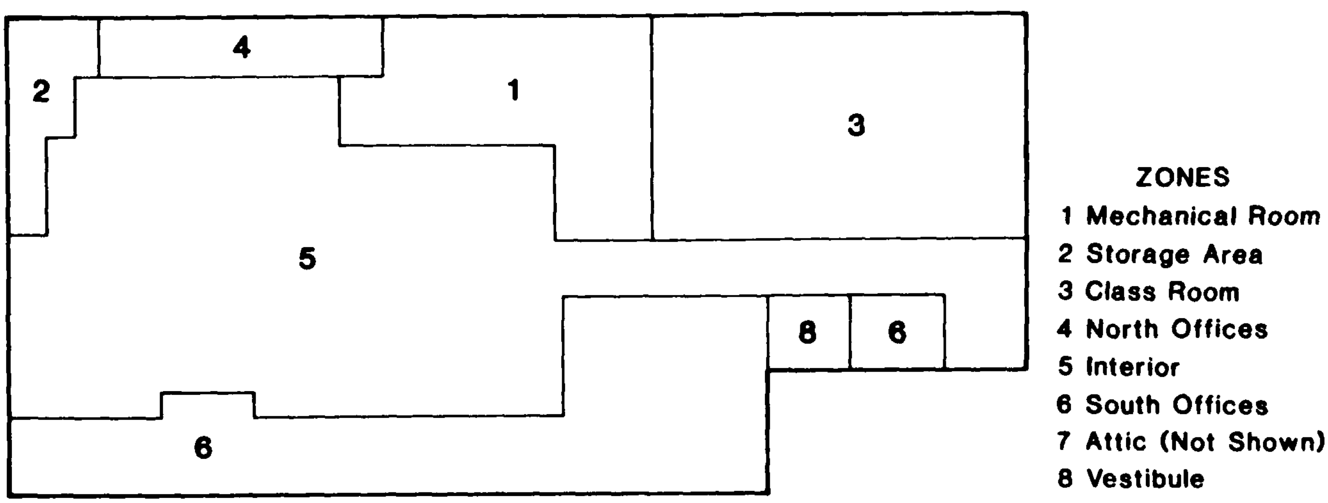
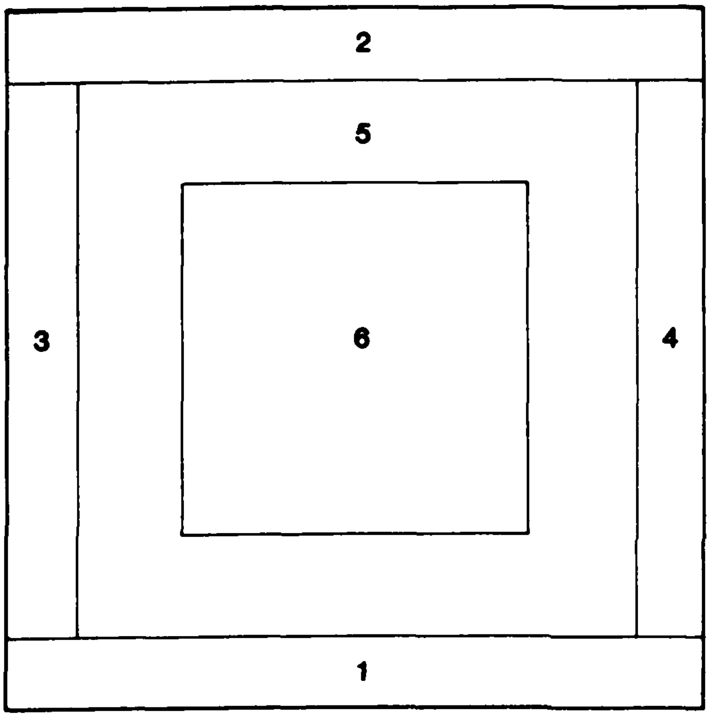


Figure 2. Battalion headquarters.



1 South-facing Offices
2 North-facing Offices
3 West-facing Offices
4 East-facing Offices
5 Interior Offices
6 Elevators and Service Areas
(Not simulated)

Figure 3. Large office building.

3 DESCRIPTION OF PROTOTYPE SYSTEMS AND WEATHER SITES

Prototype Systems

The baseline system for each building was a constant-volume terminal reheat system with cold-deck temperature of 55°F. The supply fan efficiency was 50 percent--a typical value for centrifugal blowers. This type of system tends to waste energy for several reasons: modulation of capacity is affected by reheating air that has just been cooled, the fan runs at full power whenever it is on, and the fan must come on if heating is needed at night.

The VAV systems simulated all had cold-deck temperatures of 59°F. The supply fan efficiency was 50 percent at full flow. The pressure difference (DP) across the supply fan was 3.0 in. of water. All the VAV boxes had minimum fractions of 0.3. Hence, if all the boxes were pinched down to their minimum fraction, the flow would be 30 percent of the maximum. During occupied periods, the percentage of outside air was 20 percent. This percentage was based on typical occupancy densities and a compromise between ventilation requirements for smoking and nonsmoking areas. During unoccupied periods, the percentage of outside air was set to 10 percent to account for leakage through the outside air dampers.

The ventilation percentage would be quite high if it were based on meeting American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) requirements[6] for smoking areas at the VAV minimum fraction. Ideally, a minimum ventilation volume strategy would be implemented; however, this strategy is more difficult to implement and therefore not used very often.

A uniform sizing method must be used to make a fair comparison between different control strategies, systems, and system components. The method used was intended to be as close as reasonably possible to the "official" ASHRAE method, as described in the ASHRAE *Cooling and Heating Load Calculation Manual.* (Appendix D describes the sizing method used.) The terminal reheat systems were sized smaller than the VAV systems because of their lower cold-deck temperature.

The three fan modulation methods simulated were discharge dampers, inlet vanes, and motor speed control (AC inverter). The performance data used for the first part of the study were taken from Janisse. Figure 4 is a plot of fraction of full power vs. fraction of full flow, but the origin of these curves is undocumented. (Similar data are often presented in manufacturers' advertisements; however, a comprehensive on-line literature search revealed no documented data on the effect of different modulation methods on fan performance. Other data are also available from manufacturers in the form of modifying factors that are read from graphs and applied to fan tables to get part-load performance.)

Another simulation was run using curves that model a particular fan with both proportional and proportional-integral control of an AC inverter. This model was developed from manufacturers' data and an estimation of the offset of the proportional controller. Although it was not intended to be a general model, it can give an idea of the

[6]"Ventilation for Acceptable Indoor Air Quality," American Society of Heating, Refrigerating and Air-Conditioning Engineers, Standard 62-1981 (1981).

potential savings of a proportional-integral controller. Figure 5 is a plot of these two curves.

Weather Sites

Sites were chosen that would have weather representative of different climates in the United States. The following sites were chosen:

Site	Heating Degree Days	Cooling Degree Days
Colorado Springs, CO	6423	531
Columbia, MO	5046	1205
Phoenix, AZ	1765	3334
Houston, TX	1396	2745
Minneapolis, MN	8382	894

Climates can be partially characterized by their heating and cooling degree days. Other factors that are important, but not as easy to quantify, are humidity, clearness, and diurnal temperature swing. Two types of weather tapes were used to choose the sites: Test Reference Year (TRY) and Typical Meteorological Year (TMY).

Colorado Springs is a sunny climate with high heating degree days. Columbia is somewhat moderate with significant heating and cooling degree days, and Phoenix is a hot, desert climate. Houston is also hot, but has much higher humidity. Minneapolis has the highest heating requirements of all sites studied.

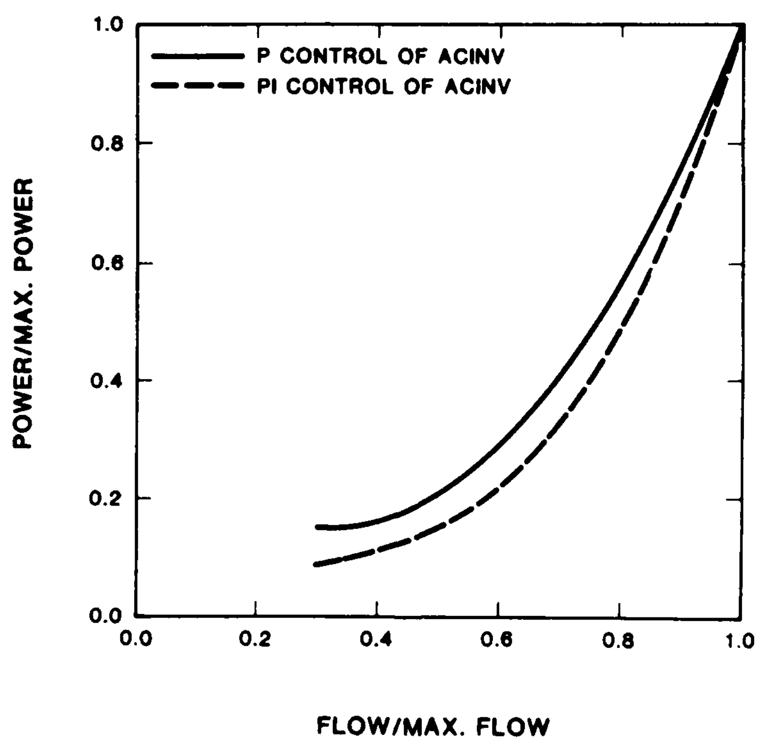


Figure 4. Fan part-load performance data.

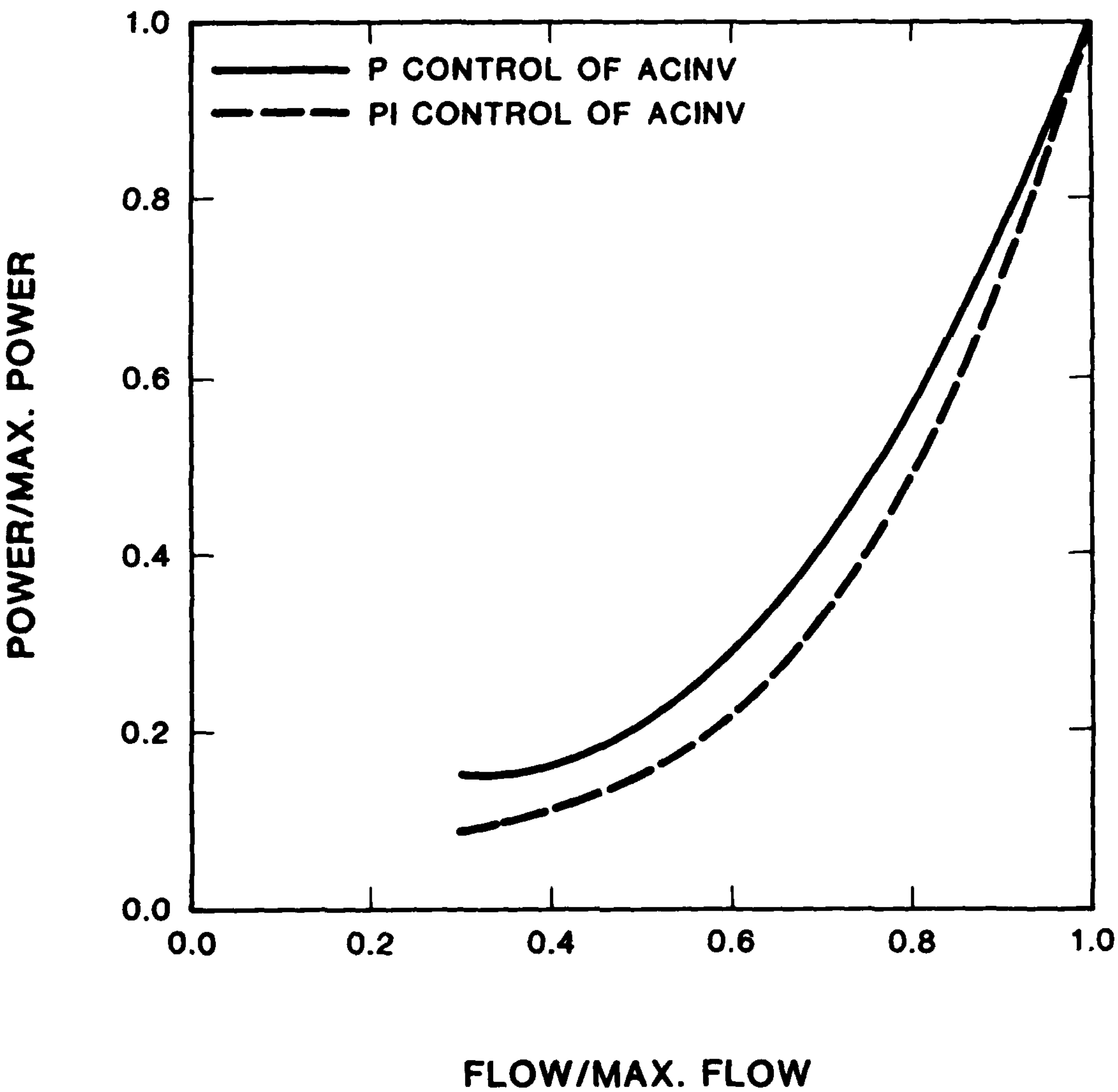


Figure 5. **Fraction of full power vs. fraction of full flow for proportional and proportional-integral control of an AC inverter.**

4 BASEBOARD VS. REHEAT CONSIDERATIONS

The type of heating methods used by VAV systems can greatly affect the fan's electricity consumption. VAV systems with reheat coils require that the fan be turned on (at the minimum fraction) to provide heat during unoccupied periods. VAV systems that have thermostatically controlled baseboard heat can provide heat without the fan being turned on. Buildings that require very many hours of heating during unoccupied periods could benefit from having baseboard heat. For example, the dental clinic in Colorado Springs has 2463 unoccupied hours when at least one zone requires heating. For the VAV system with reheat coils, the fan must run all these hours at minimum fraction; however, for the VAV system with baseboard heat, the fan can be shut off.

Figure 6 is an example of the impact the heating system can have on fan electricity consumption. System 1 is a standard terminal reheat system, and systems 2 and 3 are VAV systems with reheat; systems 4 and 5 have the same type of fan control as systems 2 and 3, respectively, but have baseboard heat. It is clear that the VAV system with baseboard heat and AC inverter fan speed control uses less than 10 percent of the fan electricity consumed by the standard terminal reheat system. Also, for each type of fan control, the VAV system with baseboard heat uses about 55 percent as much fan electricity as the system with reheat coils.

Figure 7 compares the energy consumption of the systems shown in Figure 6. It appears that the baseboard systems have a significant advantage over the reheat systems; however, this may be misleading, since the effects of infiltration and ventilation are not meticulously accounted for in these simulations. Generally, when a forced-air system is keeping the building pressurized, infiltration is negligible, while energy is used to condition the air that is brought in by the air-handling system and exfiltrated or exhausted. Thus, there is no problem comparing the two systems during the hours when both systems are running. The difficulty is during the unoccupied periods when heating is required. The VAV system with reheat will come on and bring in some outside air that will need conditioning. However, the VAV system with baseboard heat will turn on just the baseboard convectors, and no infiltration will be accounted for. This difference will make the baseboard system look as if it performs better than the reheat system. It may actually perform slightly better, since it is likely that more unconditioned air would be brought in by the fan system coming on than through infiltration.

Generally, it would seem to be good design practice to use baseboard convectors instead of reheat, at least for perimeter zones, where heat will be needed at night. In fact, if the setpoint of the perimeter zones were slightly higher than that of the interior zones, it would not be necessary for reheat to come on at night, if reheat is used for the interior zones.

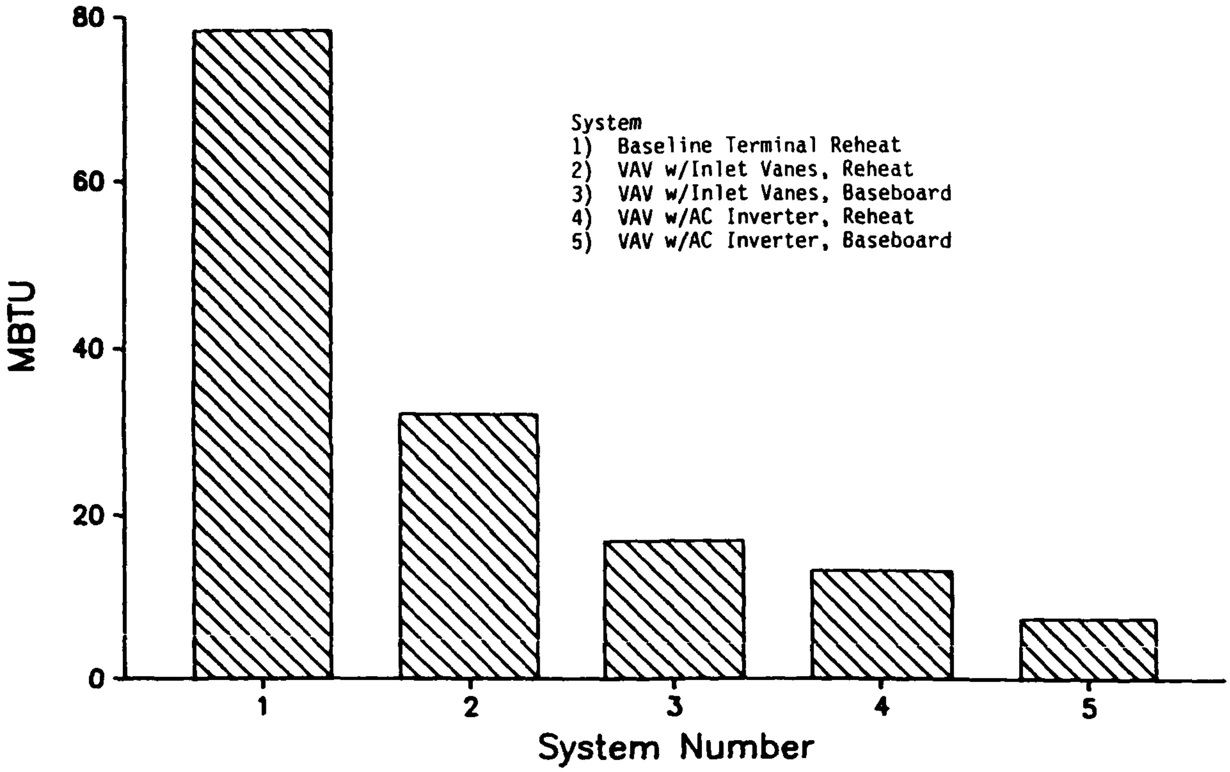


Figure 6. **Comparison of annual fan electricity consumption for VAV systems with reheat and VAV systems with baseboard heat (dental clinic, Colorado Springs, CO).**

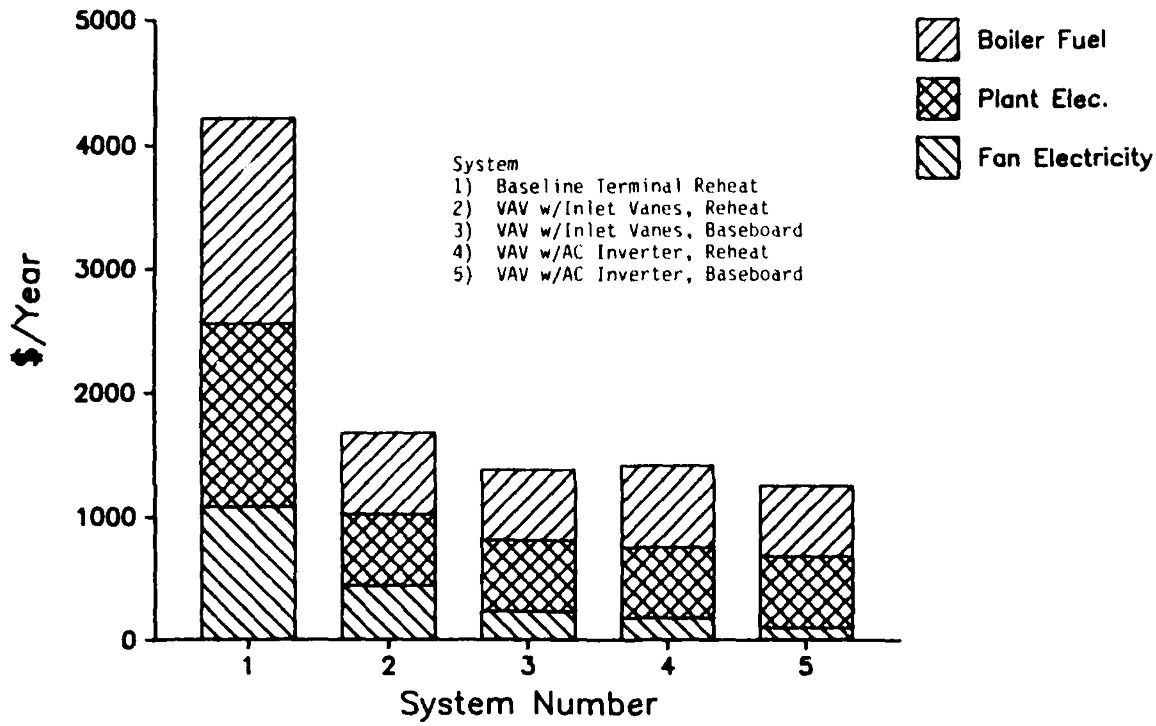


Figure 7. **Comparison of system energy cost for VAV systems with reheat and VAV systems with baseboard heat (dental clinic, Colorado Springs, CO).**

5 FAN HISTOGRAMS

Two major factors contribute to a VAV system's annual fan electricity consumption. The first factor is the annual distribution of heating and cooling loads during occupied periods (for a VAV system with baseboard heat). The variations in heating and cooling load can be related more directly to fan electricity consumption by examining the distribution of fractional fan flows between the minimum fraction and 100 percent.

The second factor is the fan system's partload performance. At least for a simple model, the fan system partload performance can be represented adequately by curves such as those shown in Figure 4. However, the load profile is somewhat unique for each situation, since it is very dependent on the building, its use, and the climate. In practice, the distribution of fractional flows is also affected by the system sizing, since an oversized system will tend to have lower flow fractions and an undersized system will tend to have higher flow fractions.

With this in mind, a report was added to BLAST to allow the fraction of full power to be printed for every hour of the simulation. The fraction of full flow is desired for purposes of generality, so a fan was "invented" that had a one-to-one ratio between fraction of full flow and fraction of full power. Then, when the report was turned on and the one-to-one fan was used, values of the fraction of full flow were reported. The fraction of full flow is equal to the sum of the zone cooling loads divided by the system design capacity and is set to the minimum fraction if it would otherwise be lower.

A FORTRAN program, HISTANL, was used to determine the frequency distribution. Appendix E provides the source code and a sample output. For convenience, the fractions of full flow were divided into increments of 0.05. They were then plotted as a type of histogram, or frequency distribution, with the fraction of full flow as the abscissa and the number of hours at each increment as the ordinate. For the histograms plotted in this report, bin 1 corresponds to zero flow, bin 6 corresponds to minimum fraction, and the remaining bins correspond to:

$$\frac{(i - 1)}{0} + 0.00001 \quad \text{to} \quad \frac{i}{20} + 0.00001$$

where i is the bin number.

Figures 8* through 10 are a series of histograms for the battalion headquarters with various degrees of system oversizing. Figure 8 shows the load profile for the standard 20 percent oversized system. Figures 9 and 10 show 10 percent and 0 percent oversizing.

Three features are readily observed from these histograms. The first is the large numbers of hours spent at the minimum fraction. Of a total of 2520 hours for the 20 percent oversized system, 1212 were spent at the minimum fraction. From Figure 4, one can see that the fan with inlet vanes consumed more than twice as much electricity as the fan with an AC inverter at the minimum flow fraction. Obviously, having a high number of hours at or near the minimum fraction will greatly affect annual fan electricity consumption.

*Figures follow the chapter.

The second feature is a gradual decrease in the number of hours at the minimum fraction and an increase in the average fan fraction as the amount of oversizing is decreased. This observation was expected.

The third feature is somewhat curious. A sort of bimodal distribution was observed in most of the histograms done for this study. The reason for this is not yet clear. It is hoped that the reason can be determined through a more detailed frequency analysis (on a monthly or hour-of-the-day basis).

The histograms were very useful for visualizing trends and finding errors in the input file. In one case, the wrong cold-deck temperature was being used; as a result, the air-handling system was grossly oversized. This showed up on the histogram as no occurrence of fraction of full flow above 65 percent. The capability of producing bin reports and line-printer histograms such as these could possibly be added to BLAST and made available to the general user public, which could benefit from this feature.

Figures 11 through 24 show the fractional flow distributions for the battalion headquarters in four of the five climates and the dental clinic and large office building in each of the five climates. Two general trends can be seen that have important implications for VAV flow control. The first is related to climate and the second to the building internal loads.

As the climate gets colder, the fractional flow distribution shifts to lower flow fractions. For the battalion headquarters and the dental clinic, this can result in large numbers of hours spent at the minimum flow fraction. For the large office building, this effect can still be seen, but is not quite as noticeable. This effect is intuitively expected, but its quantitative confirmation here helps explain some of the fan electricity consumption results reported later.

Perhaps more interesting are the differences among buildings in a given climate. If the fractional flow distributions of the three buildings are compared for any of the climates, the battalion headquarters has the most hours at or near the minimum fraction, the dental clinic has the second most, and the large office building has the fewest. Another way of looking at it in a qualitative sense is to see that the fractional flow distribution is being shifted to higher fractional flows from the battalion headquarters to the dental clinic and then to the large office building.

The most probable cause of these differences is the level of internal loads relative to the level of external loads. While all three buildings have roughly similar exterior construction, the degree of internal loading increases in observing the battalion headquarters, then the dental clinic, and finally the large office building. Hence, the large office building would probably be thought of as "core-dominated," while the battalion headquarters might be thought of as "envelope-dominated." The dental clinic is somewhere between these two.

"Core-dominated" and "envelope-dominated" are very qualitative terms; there is no simple core domination factor that can be calculated to determine if a building is core-dominated or envelope-dominated. However, one index that might be considered is the peak internal heat generation (lighting, equipment, and people) divided by the building's exterior surface area. Since all buildings in this study use the same schedules, this index seems to be a reasonably fair way to compare the buildings. The calculated values of this index are 3 Btu/hr/sq ft for the battalion headquarters, 6 Btu/hr/sq ft for the dental clinic, and 90 Btu/hr/sq ft for the large office building. The large office building's index is an order of magnitude higher than that of the other two buildings. This is due to several factors: the higher internal loading, the ceiling not being exposed to the outside environment, and the comparatively large floor area. (The internal load is about proportional to the floor area, while the external surface area, when there is no ceiling, is proportional to the square root of the floor area.) Although this is a simple idea, it does give a rough idea of the differences among the three buildings.

A result of these trends is that there are fewer and fewer hours at the minimum fraction as the progression is made from envelope-dominated buildings to core-dominated buildings and from colder climates to warmer climates. Since difficulties and first costs increase with decreasing minimum fraction, there is a point of diminishing return past which it is not worthwhile to decrease the minimum fraction of the system further. For the battalion headquarters in the colder climates, it might be worthwhile to reduce the minimum fraction below 0.3. While the large office building fan seldom drops below 0.5 of full flow, it would be wise to check the individual zone fractions.

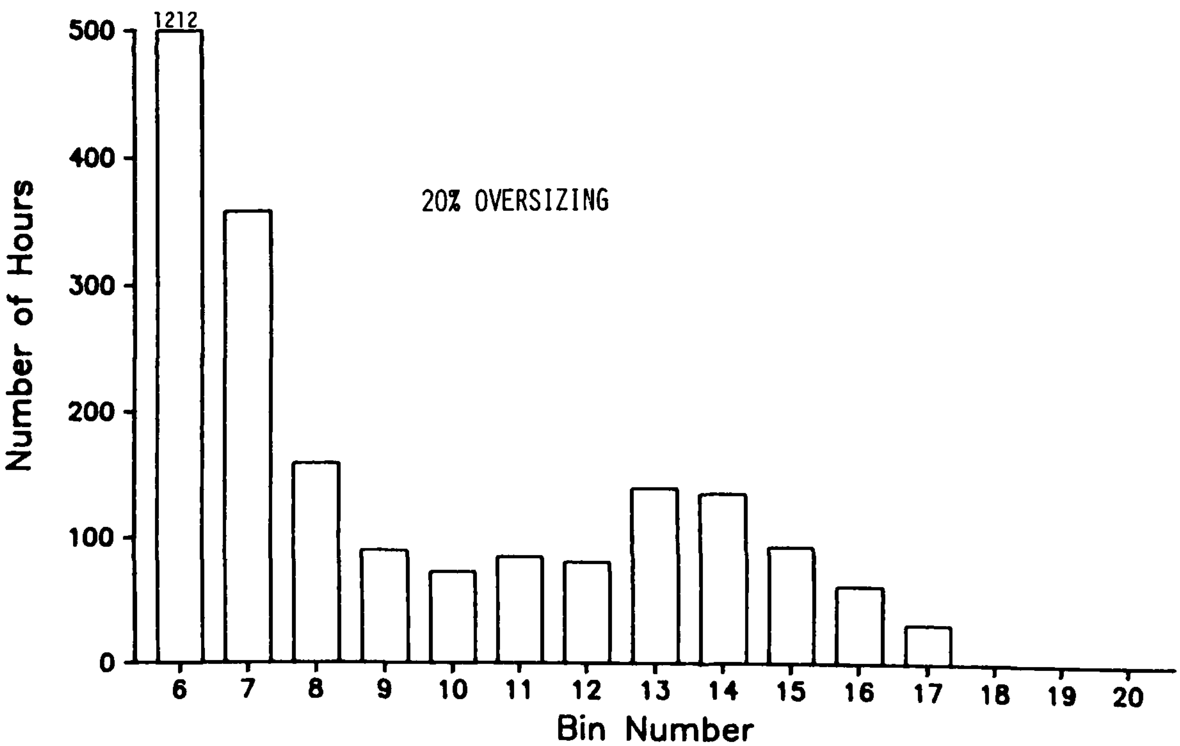


Figure 8. Annual distribution of the fraction of full flow, 20 percent oversizing (battalion headquarters, Colorado Springs, CO).

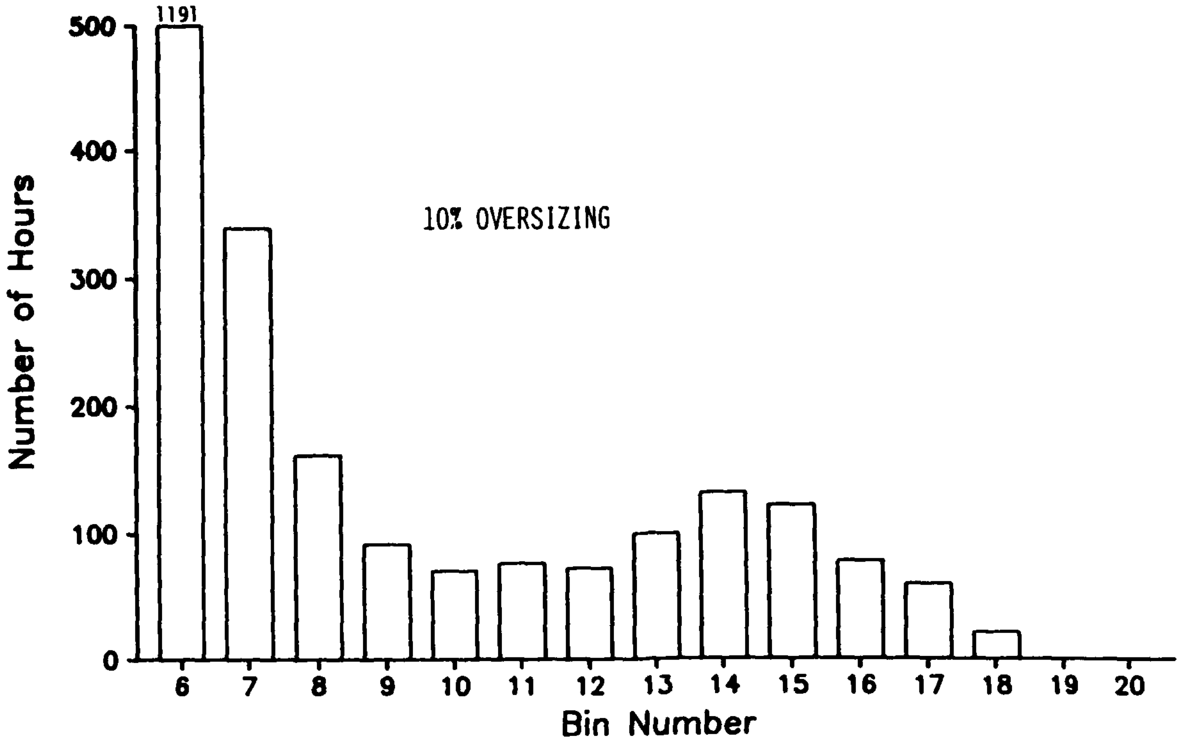


Figure 9. Annual distribution of the fraction of full flow, 10 percent oversizing (battalion headquarters, Colorado Springs, CO).

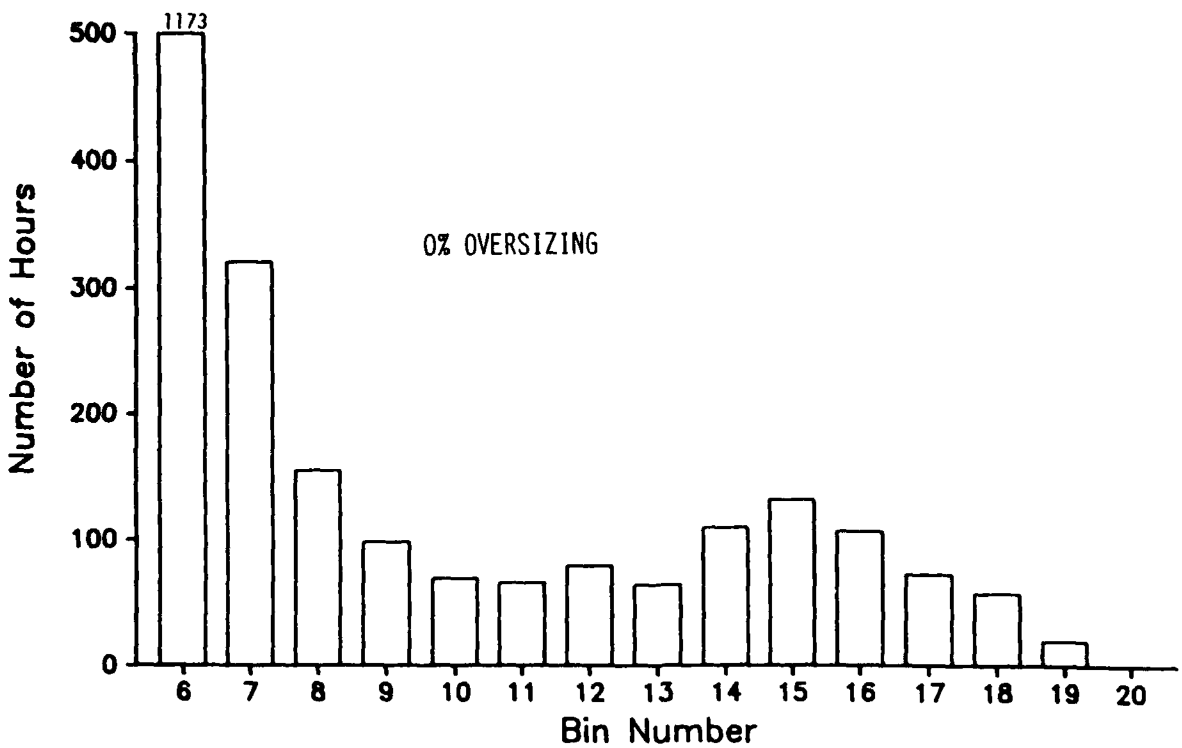


Figure 10. Annual distribution of the fraction of full flow, 0 percent oversizing (battalion headquarters, Colorado Springs, CO).

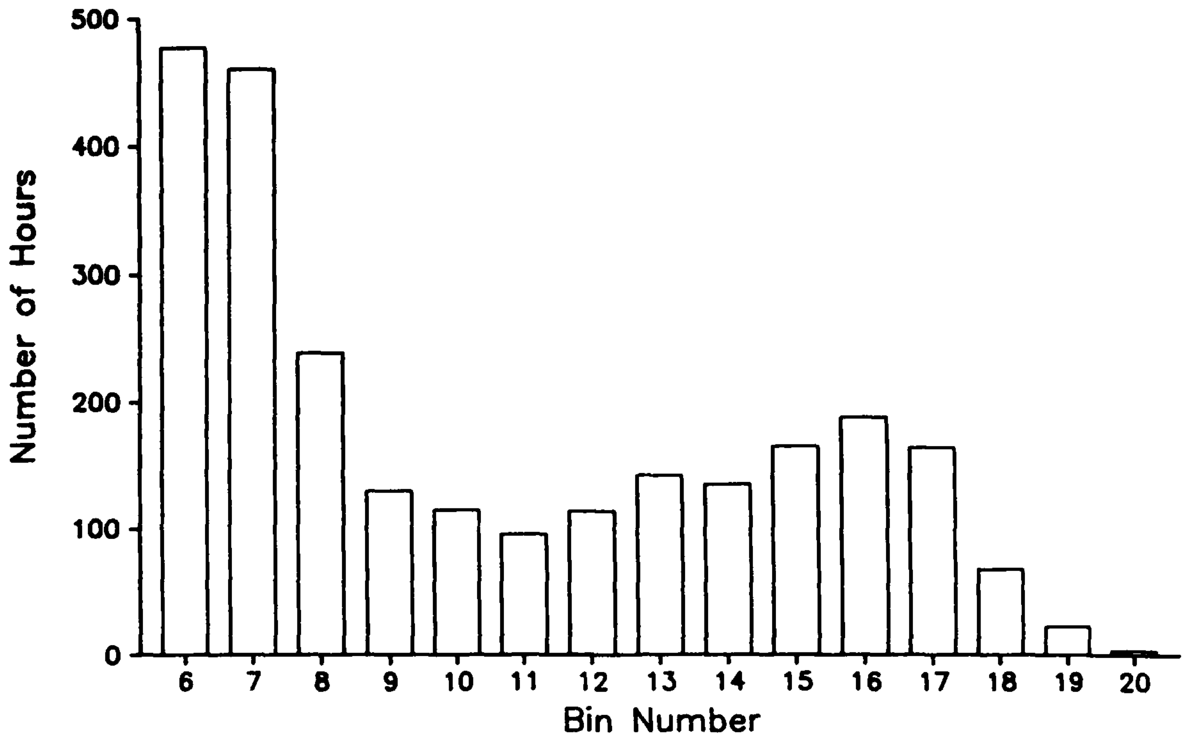


Figure 11. **Annual distribution of the fraction of full flow (battalion headquarters, Phoenix, AZ).**

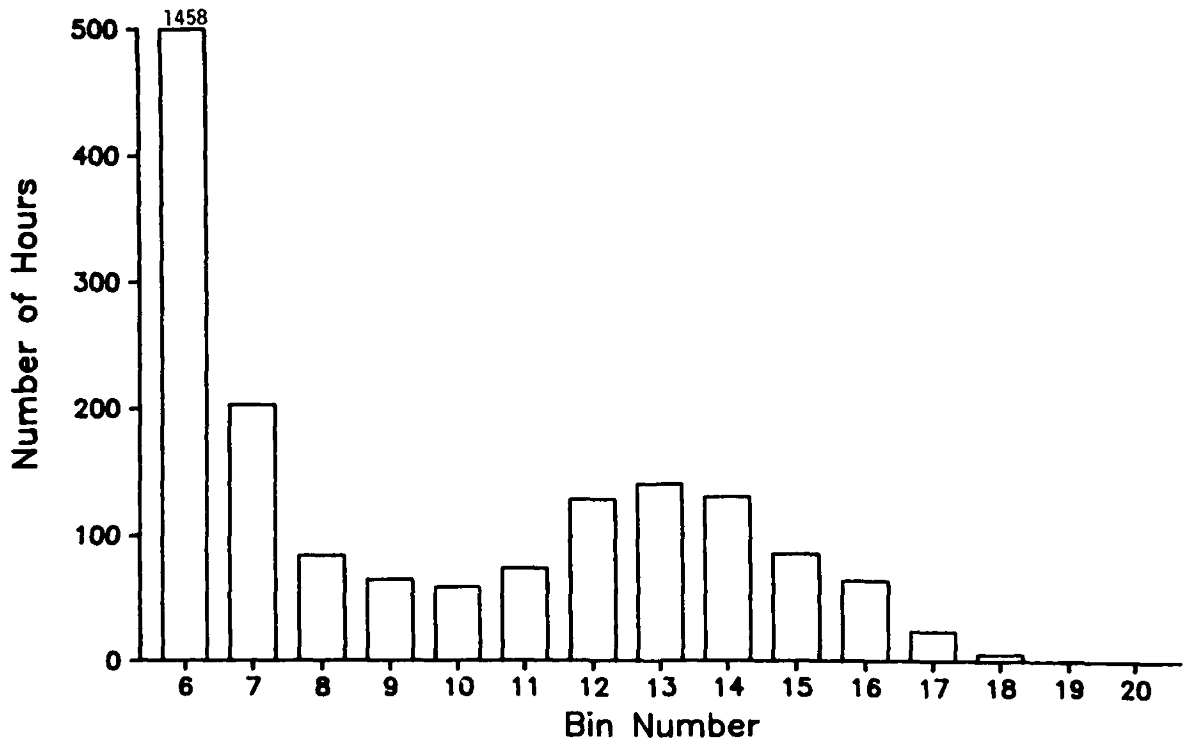


Figure 12. **Annual distribution of the fraction of full flow (battalion headquarters, Minneapolis, MN).**

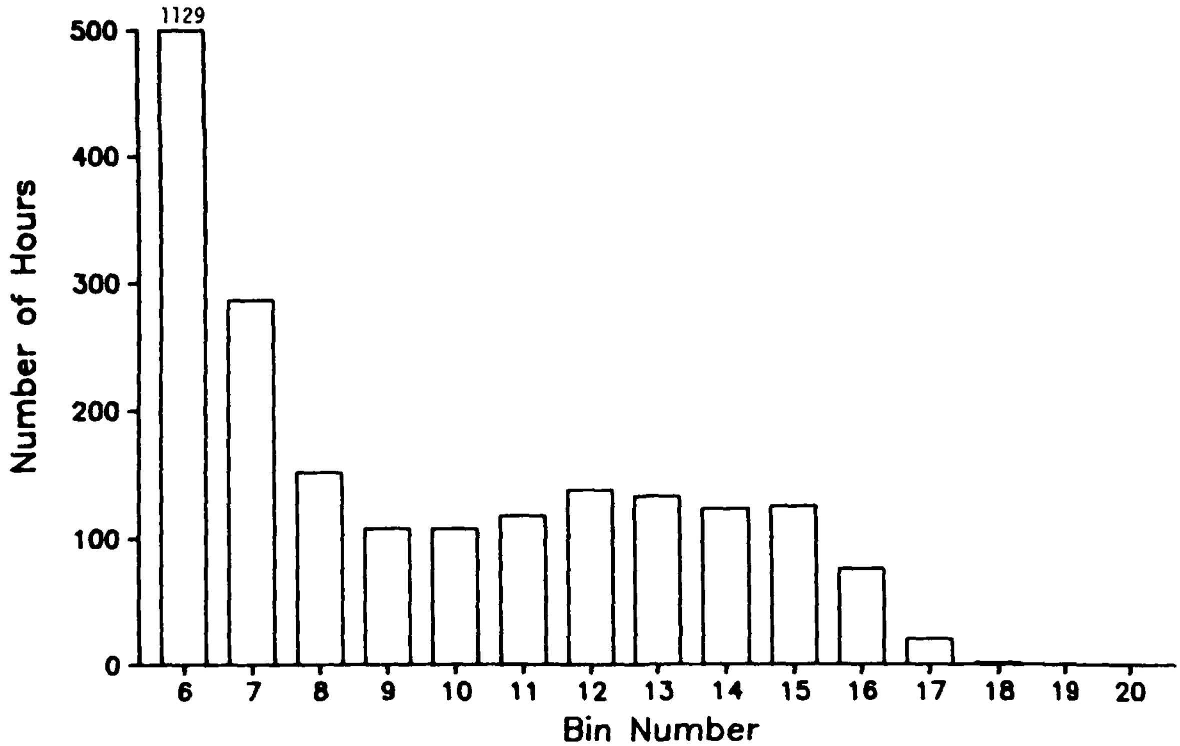


Figure 13. Annual distribution of the fraction of full flow (battalion headquarters, Columbia, MO).

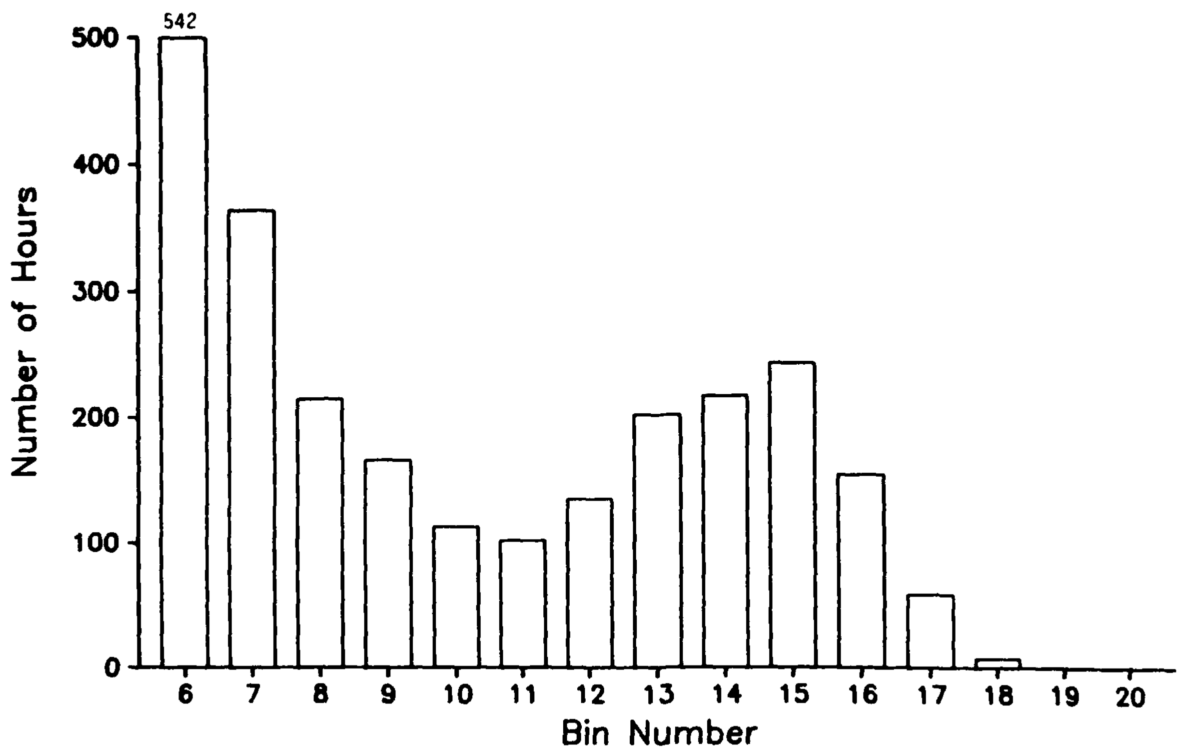


Figure 14. Annual distribution of the fraction of full flow (battalion headquarters, Houston, TX).

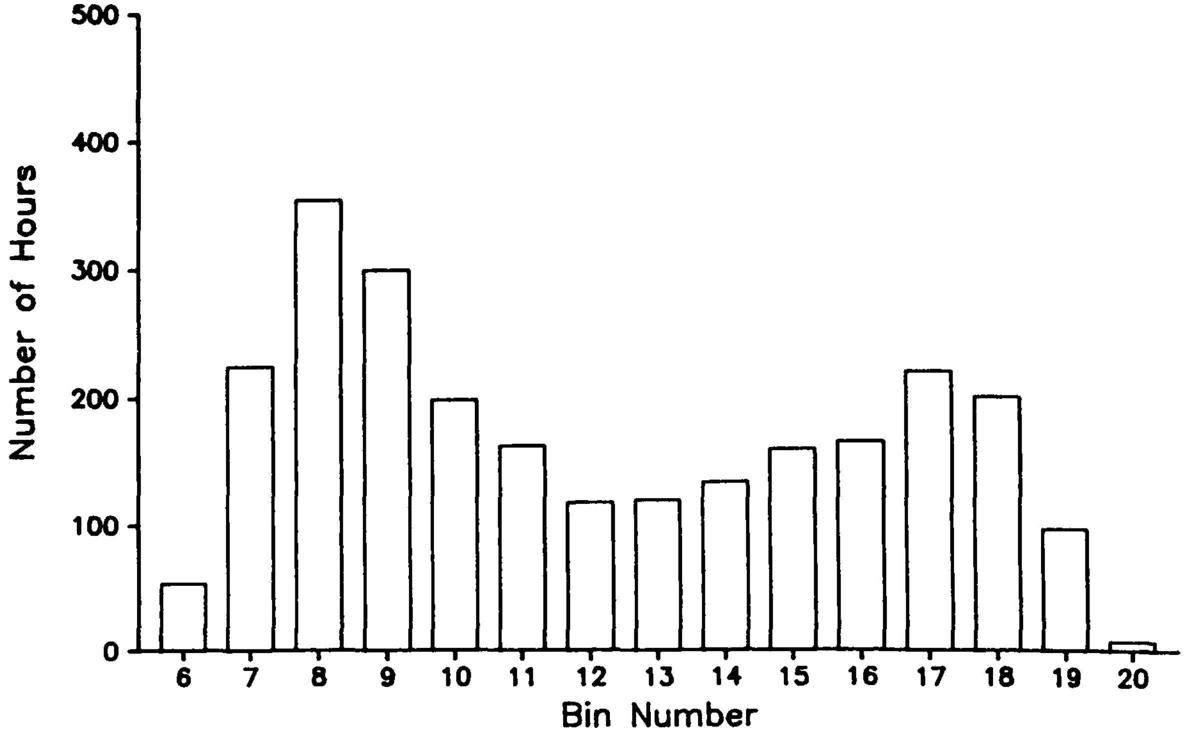


Figure 15. **Annual distribution of the fraction of full flow (dental clinic, Phoenix, AZ).**

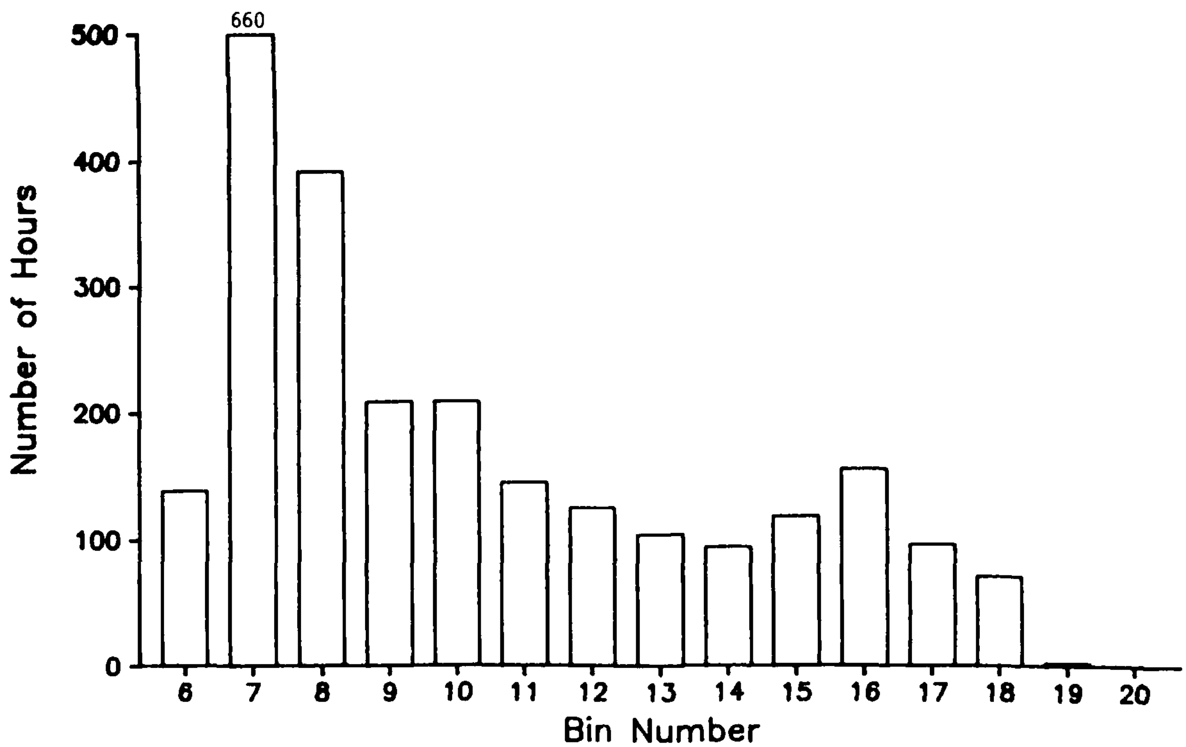


Figure 16. **Annual distribution of the fraction of full flow (dental clinic, Colorado Springs, CO).**

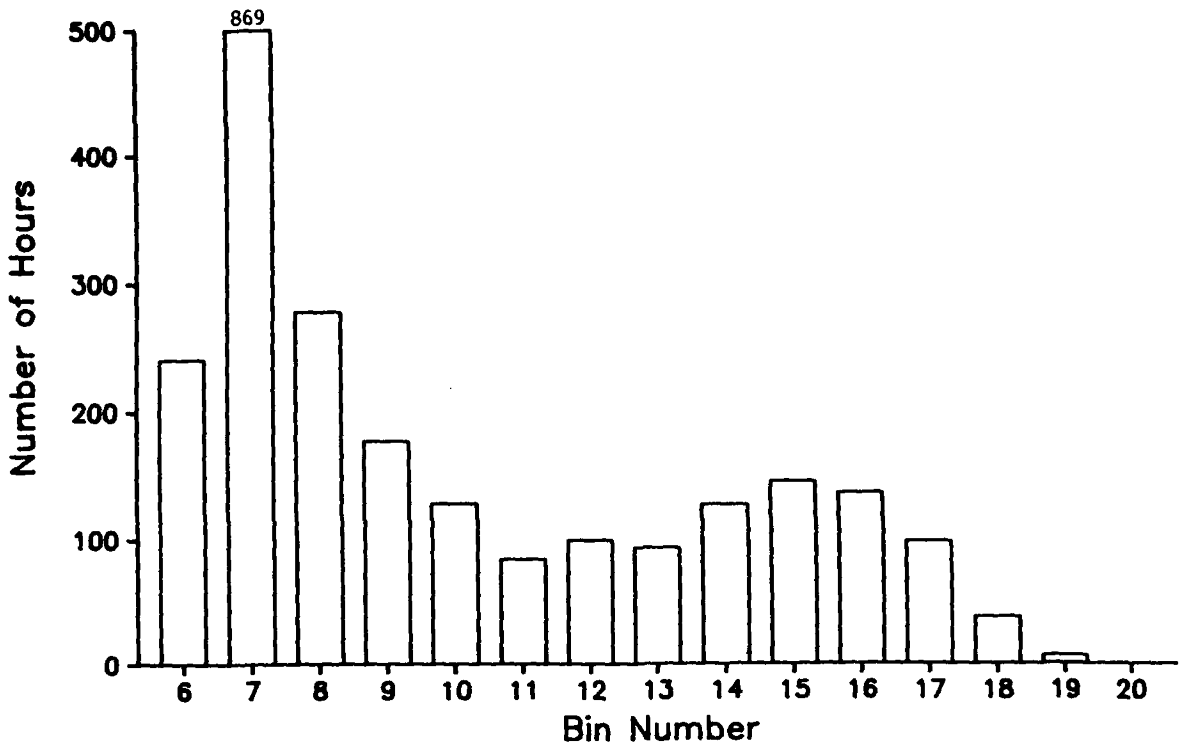


Figure 17. Annual distribution of the fraction of full flow (dental clinic, Minneapolis, MN).

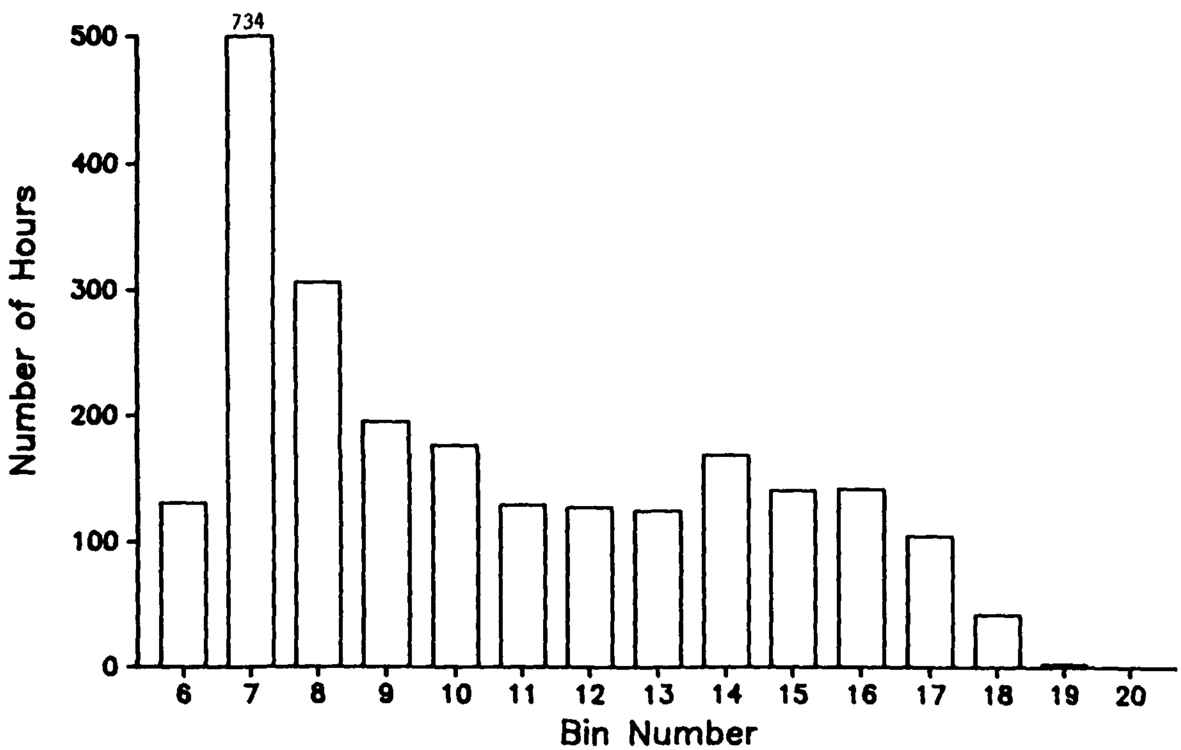


Figure 18. Annual distribution of the fraction of full flow (dental clinic, Columbia, MO).

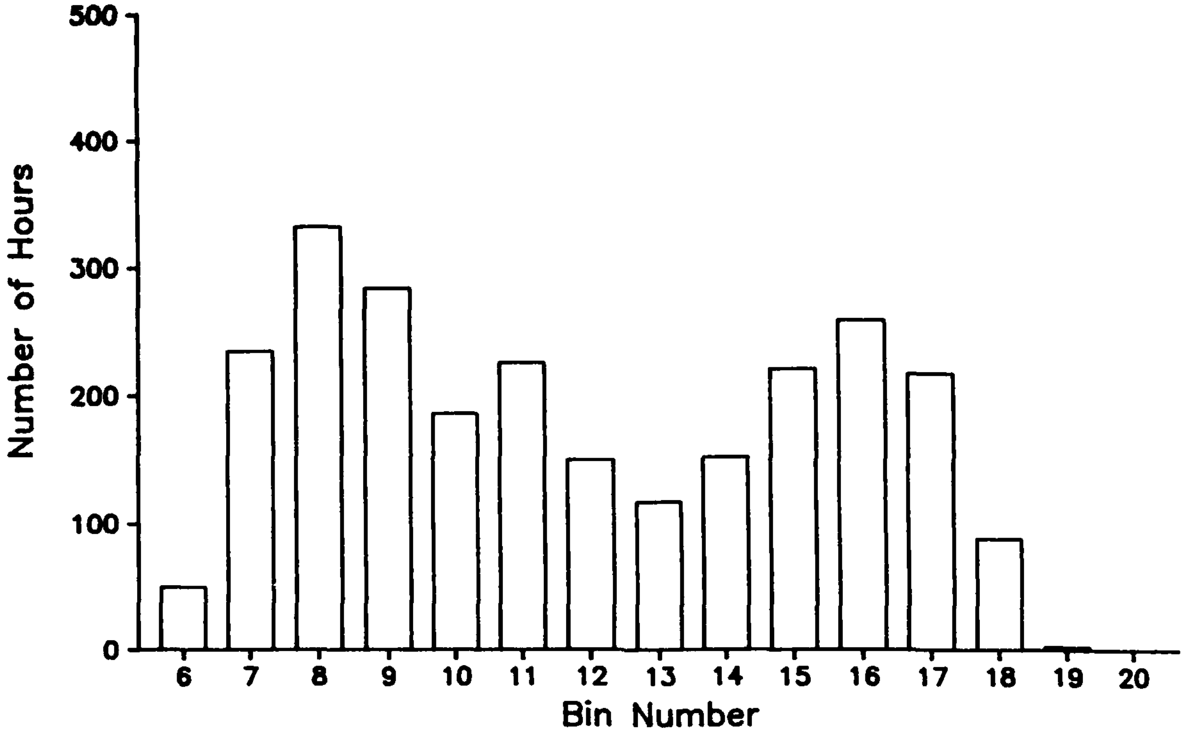


Figure 19. Annual distribution of the fraction of full flow (dental clinic, Houston, TX).

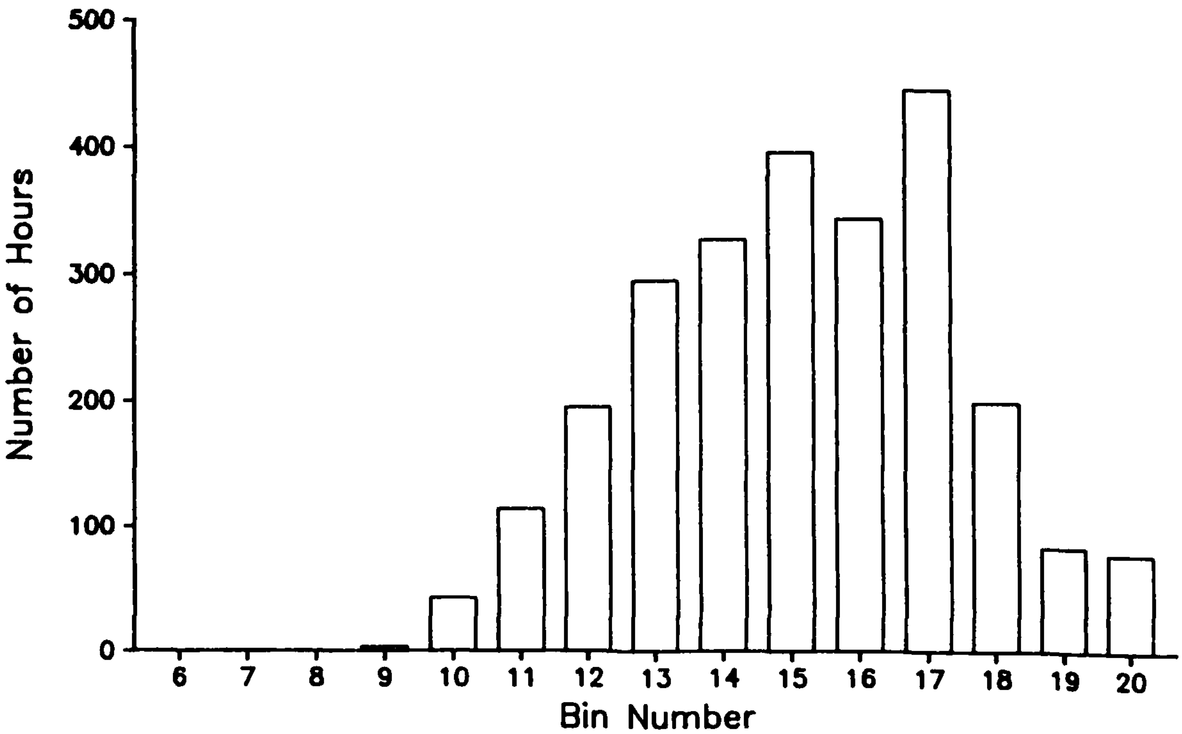


Figure 20. Annual distribution of the fraction of full flow (large office building, Phoenix, AZ).

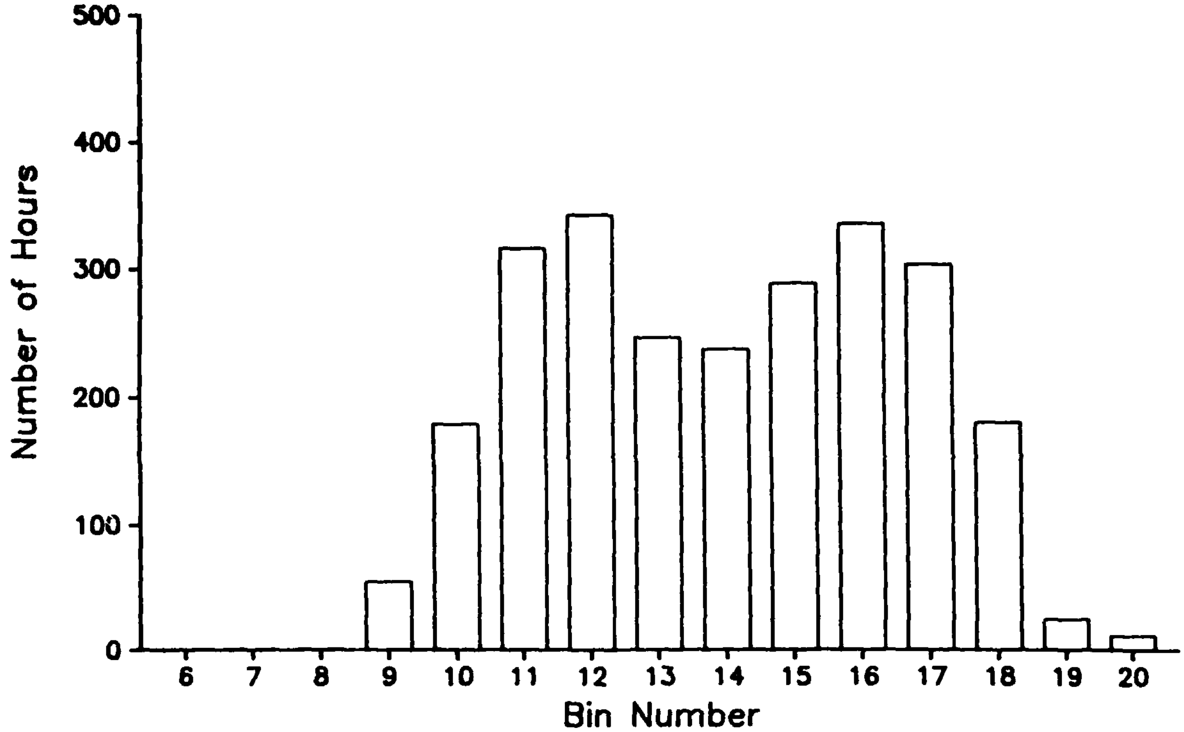


Figure 21. Annual distribution of the fraction of full flow (large office building, Colorado Springs, CO).

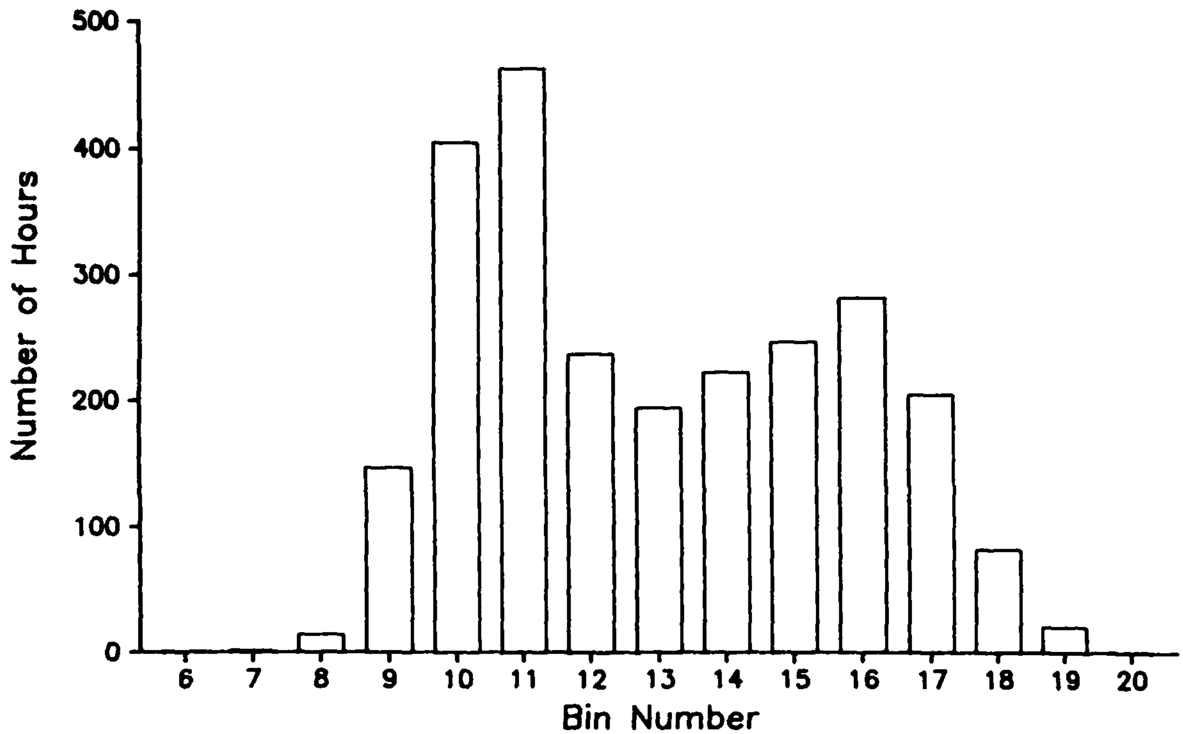


Figure 22. Annual distribution of the fraction of full flow (large office building, Minneapolis, MN).

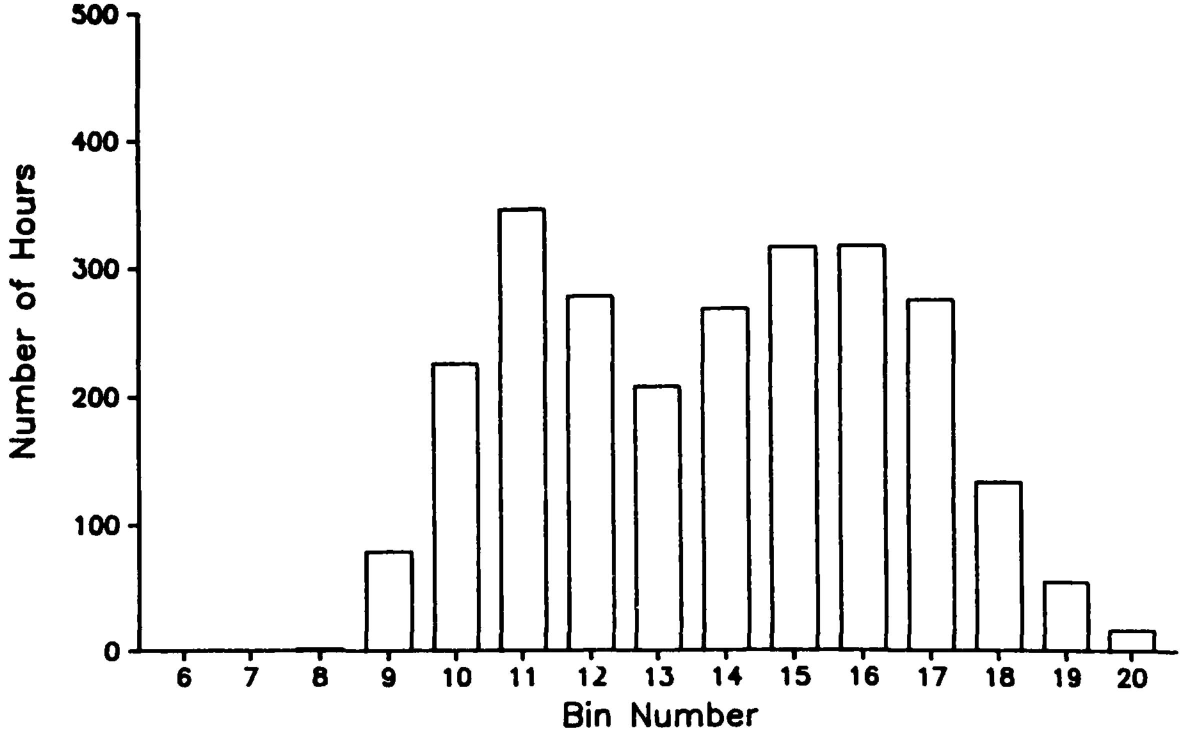


Figure 23. Annual distribution of the fraction of full flow (large office building, Columbia, MO).

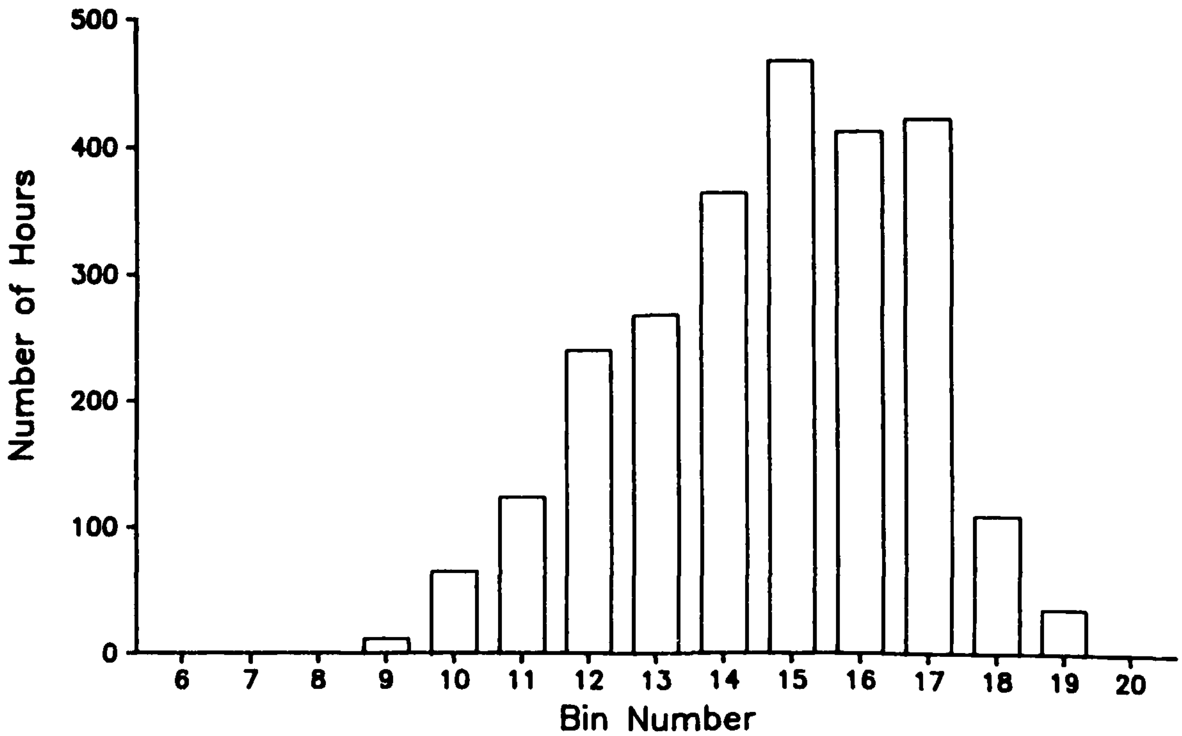


Figure 24. Annual distribution of the fraction of full flow (large office building, Houston, TX).

6 FAN ELECTRICITY AND SYSTEM ENERGY CONSUMPTION

Figures 25 through 39 compare annual fan electricity consumption for each of the three buildings in the five locations studied. As one would expect from looking at the fractional flow distributions, AC inverters offered the greatest savings over inlet vanes when the climate was cold or the building was envelope-dominated, or both. For each building/climate, Table 1 gives the fraction of fan electricity consumed by the VAV systems as compared to the baseline terminal reheat system. The greatest savings for a VAV system occurred for the battalion headquarters (the most envelope-dominated building) for Colorado Springs (87 percent savings) and Minneapolis (86.3 percent savings). Of course, these figures are for the VAV system with an AC inverter. The least savings were for the large office buildings (the most core-dominated building) in Phoenix and Houston. Here, the VAV system with discharge dampers actually consumed more fan electricity than the baseline terminal reheat system. This happened because the VAV system had a higher cold-deck temperature and therefore required substantially more cubic feet per minute (CFM). Combined with the low performance of the discharge dampers, this explains the high fan electricity consumption. However, the VAV system still performed much better overall than the terminal reheat system, as described below.

When compared to inlet vanes, AC inverters gave savings that ranged between 37 and 49 percent for the battalion headquarters, 29 and 42 percent for the dental clinic, and 16 and 27 percent for the large office building. As expected, the largest savings occurred for the battalion headquarters in the colder climates. The dental clinic, which is essentially envelope-dominated but not to the same degree as the battalion headquarters, had similar savings.

Figures 40 through 54 show the total system energy cost for each option/building / climate. System energy costs were obtained by making the following assumptions:

Boiler efficiency	0.9
Chiller COP	3.5
Fuel cost	$5.40/MBtu
Electricity cost	$13.74/MBtu

These costs were obtained by averaging typical energy costs in different parts of the country. These costs are intended to reflect typical ratios of fuel cost to electricity cost. These figures clearly show VAV's high potential to reduce energy costs. In addition, using more efficient fan controls means adding less heat to the air; hence, less system cooling is needed.

The HVAC industry has used the following "conventional wisdom": "Use constant volume systems for buildings with constant loads, and use VAV systems for buildings with varying loads." This is probably good advice, as long as one can identify a building with constant loads. The large office building in this study might be thought to have constant loads, since it had such high internal loads and relatively little exterior area. Indeed, it used cooling throughout the year, and in no climate simulated was any heating required during occupied hours. However, the amount of cooling required varied seasonally (Figures 20 through 24). The seasonal variation of cooling requirements allowed the VAV systems to provide large energy savings. For the large office building, this savings varied between 39 percent (Phoenix) and 62 percent (Minneapolis).

*Coefficient of performance.

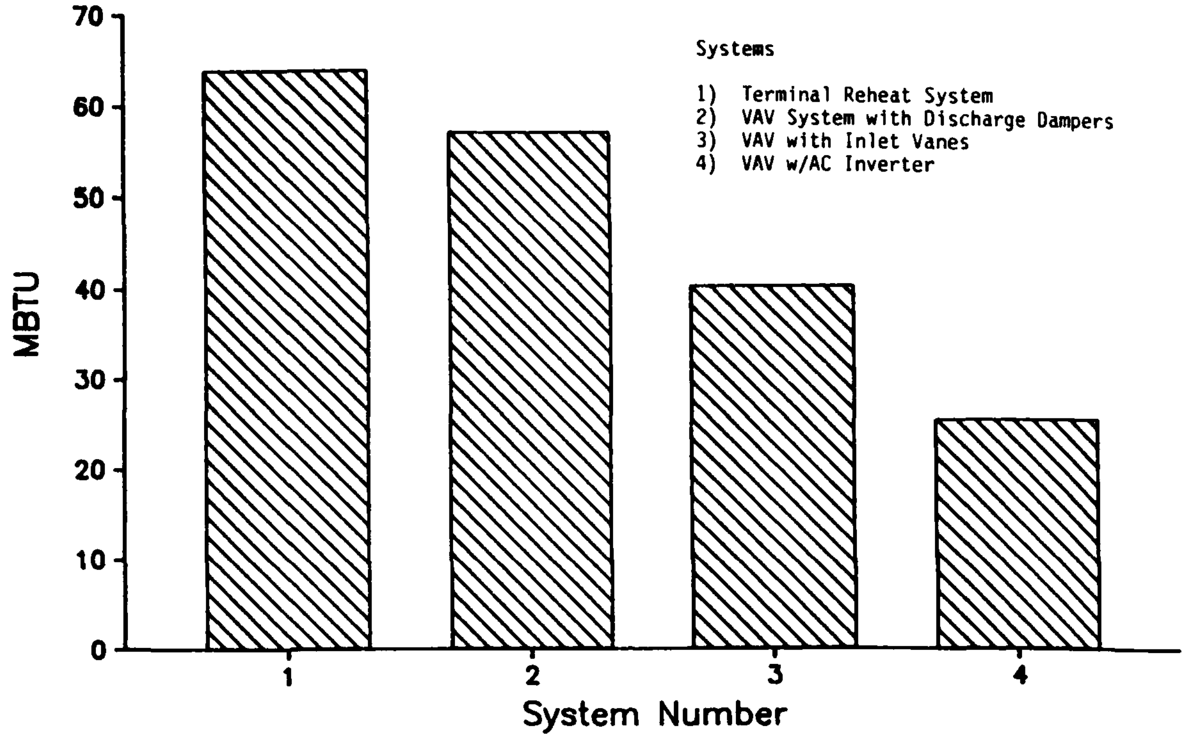


Figure 25. Annual fan electricity consumption (battalion headquarters, Phoenix, AZ).

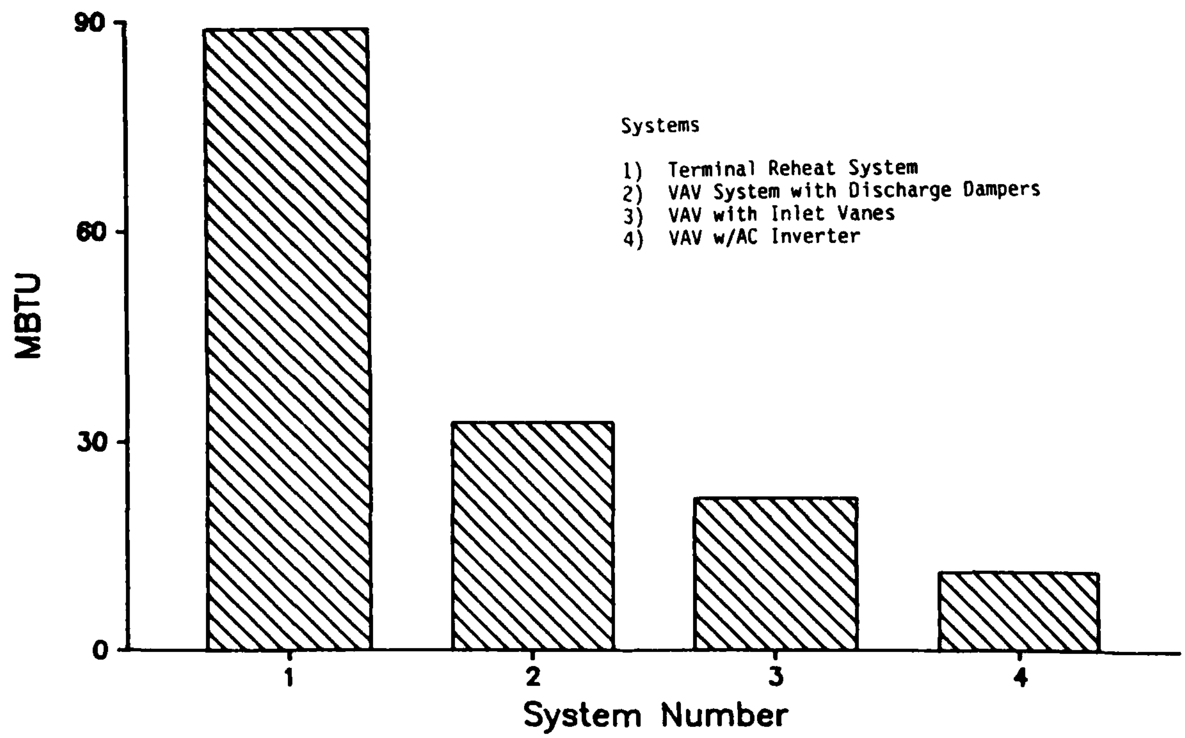


Figure 26. Annual fan electricity consumption (battalion headquarters, Colorado Springs, CO).

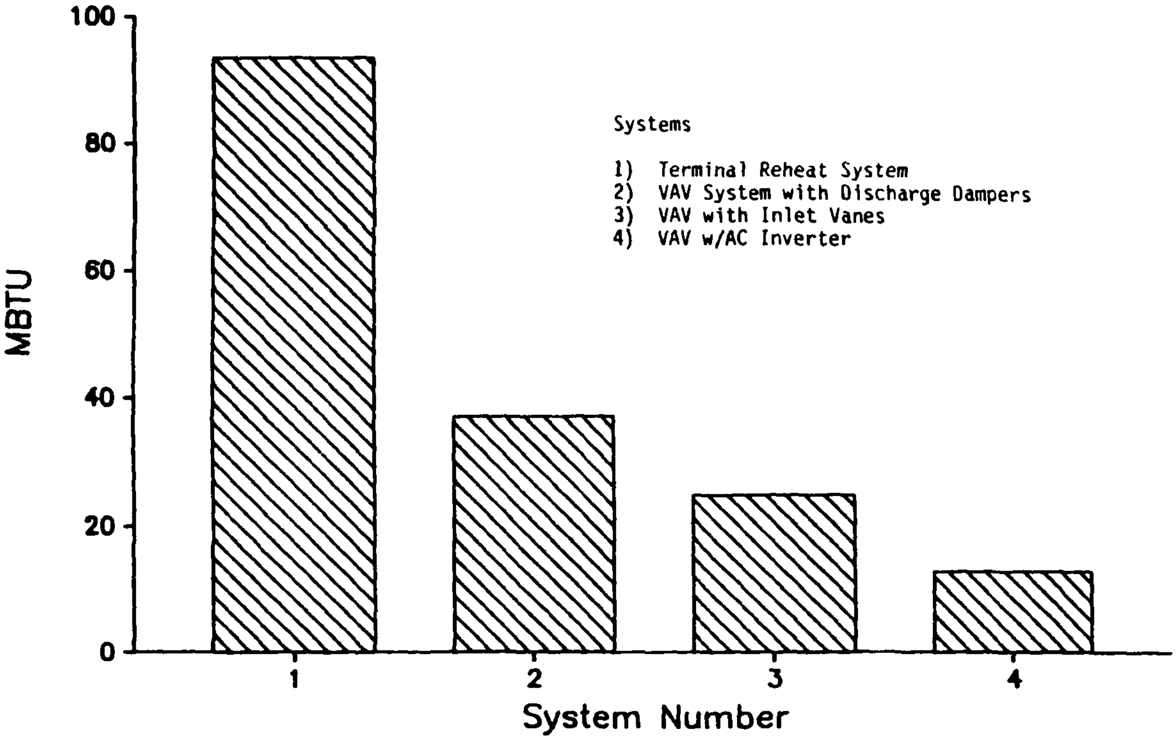


Figure 27. **Annual fan electricity consumption (battalion headquarters, Minneapolis, MN).**

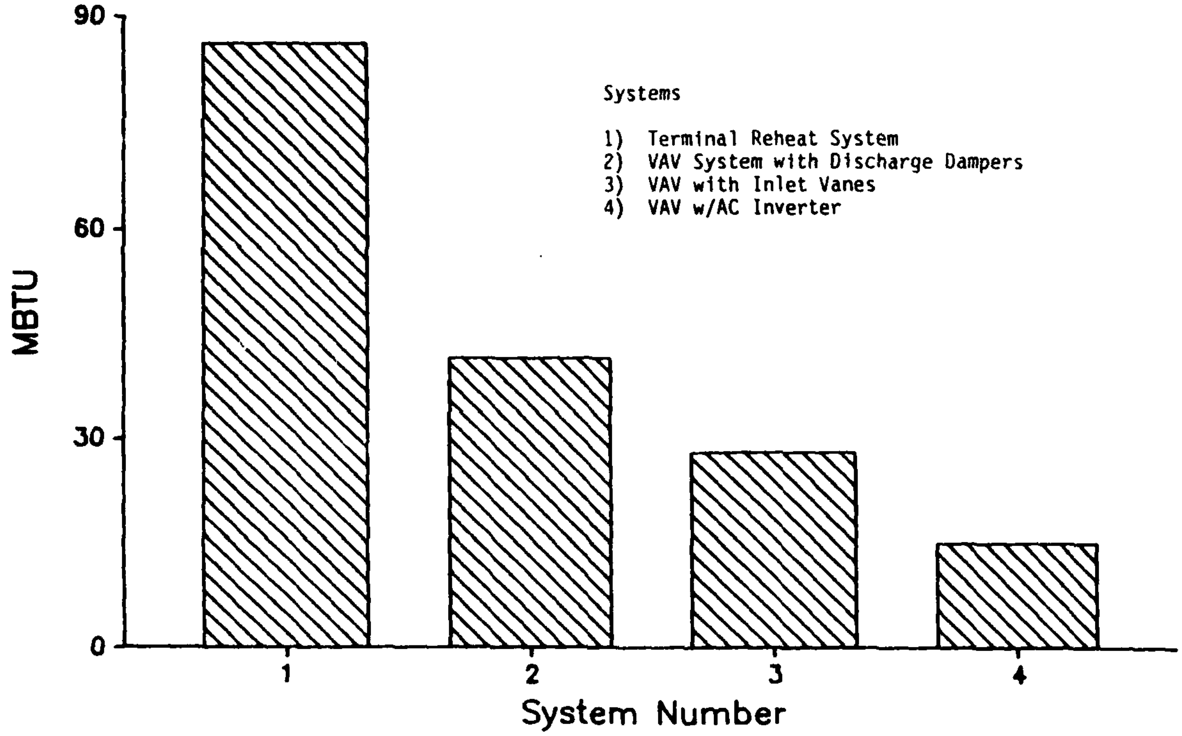


Figure 28. **Annual fan electricity consumption (battalion headquarters, Columbia, MO).**

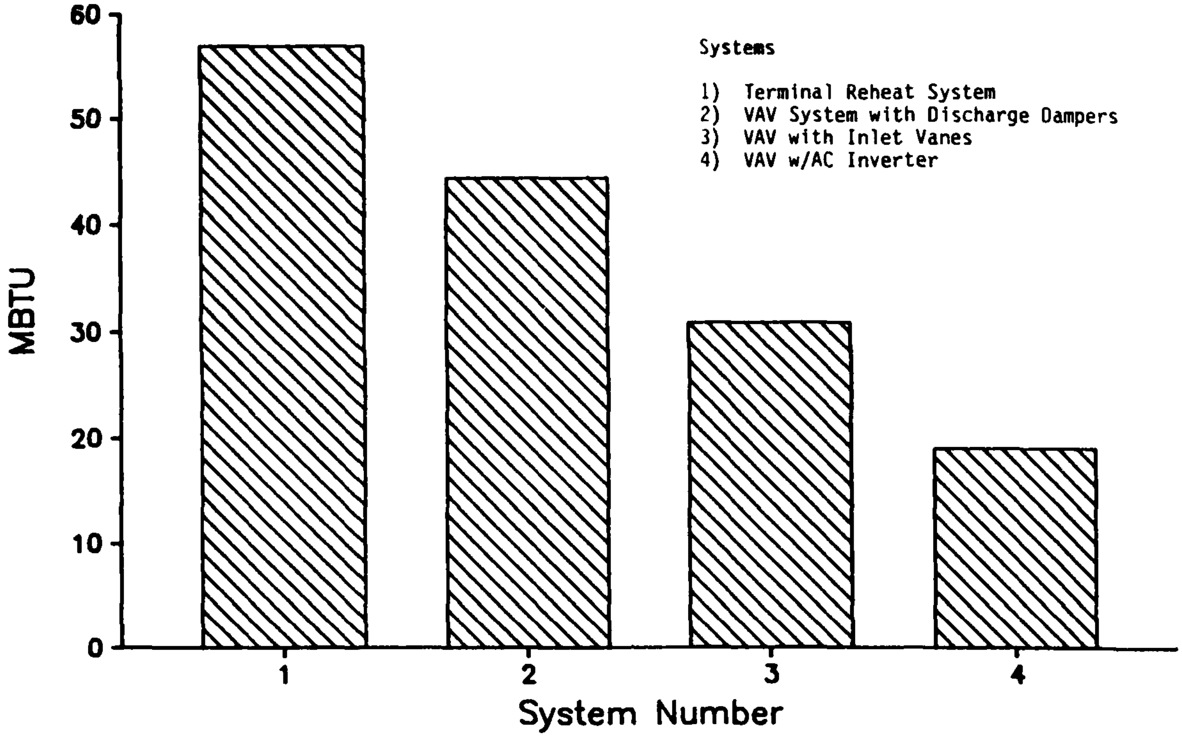


Figure 29. **Annual fan electricity consumption (battalion headquarters, Houston, TX).**

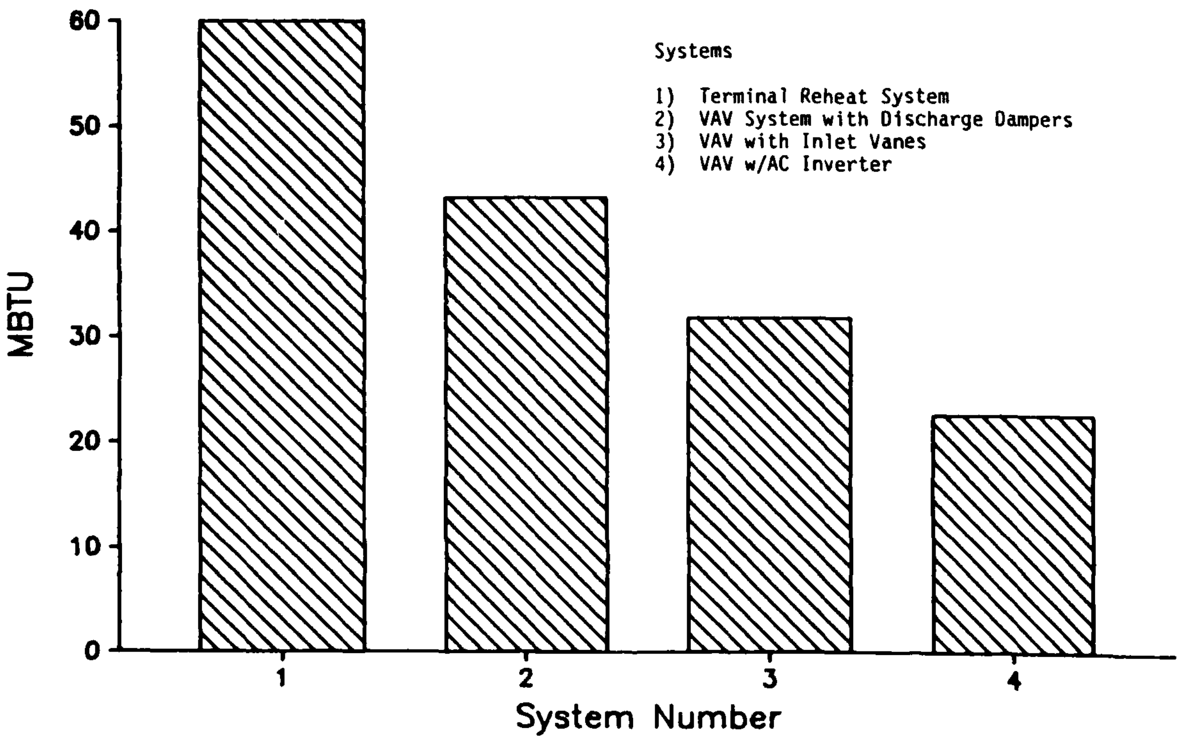


Figure 30. **Annual fan electricity consumption (dental clinic, Phoenix, AZ).**

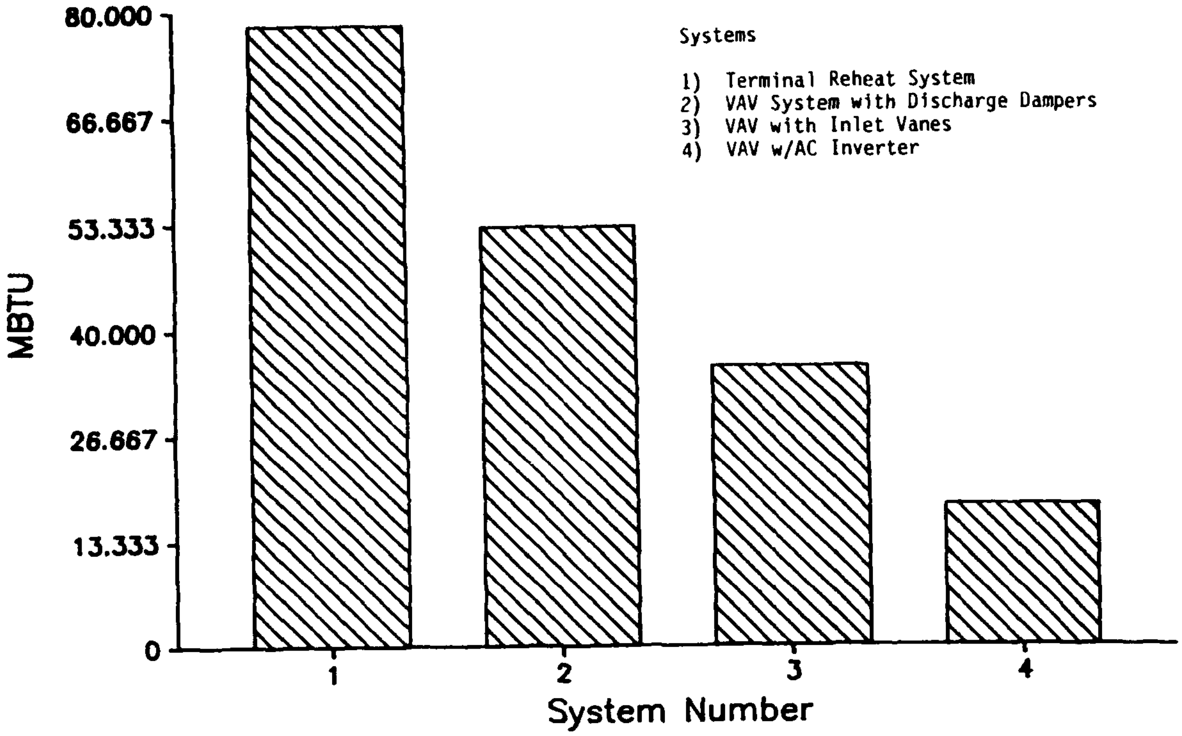


Figure 31. Annual fan electricity consumption (dental clinic, Colorado Springs, CO).

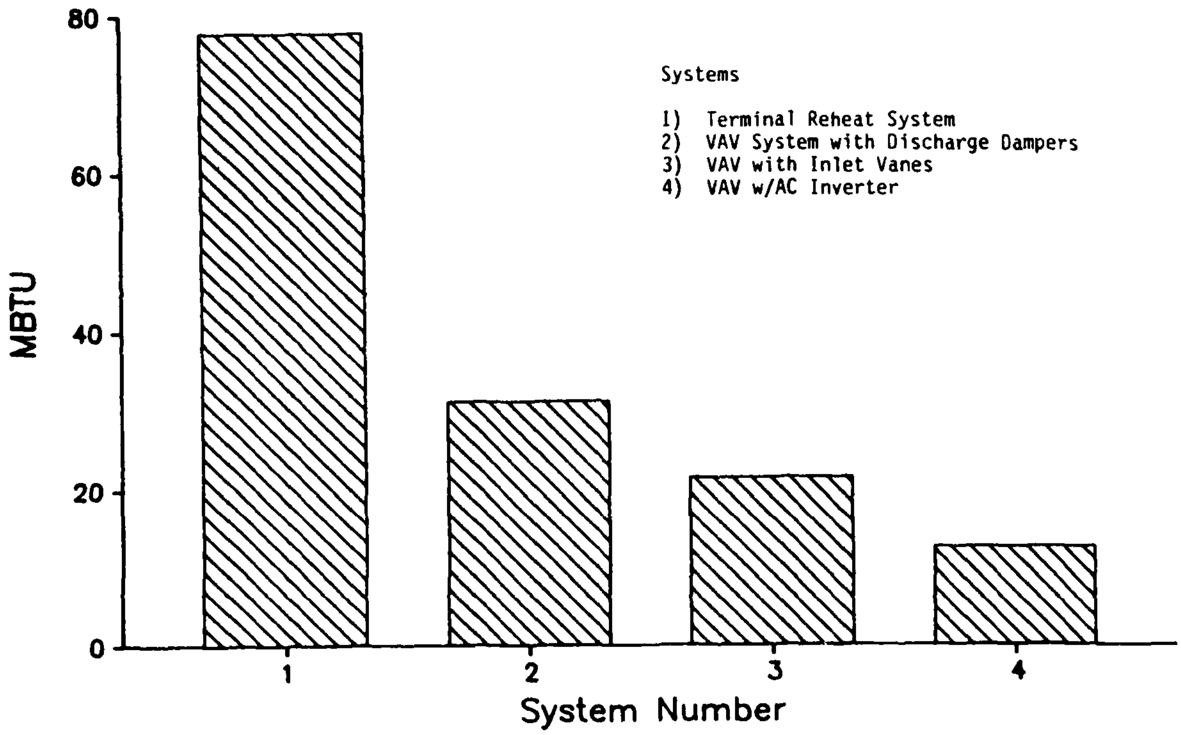


Figure 32. Annual fan electricity consumption (dental clinic, Minneapolis, MN).

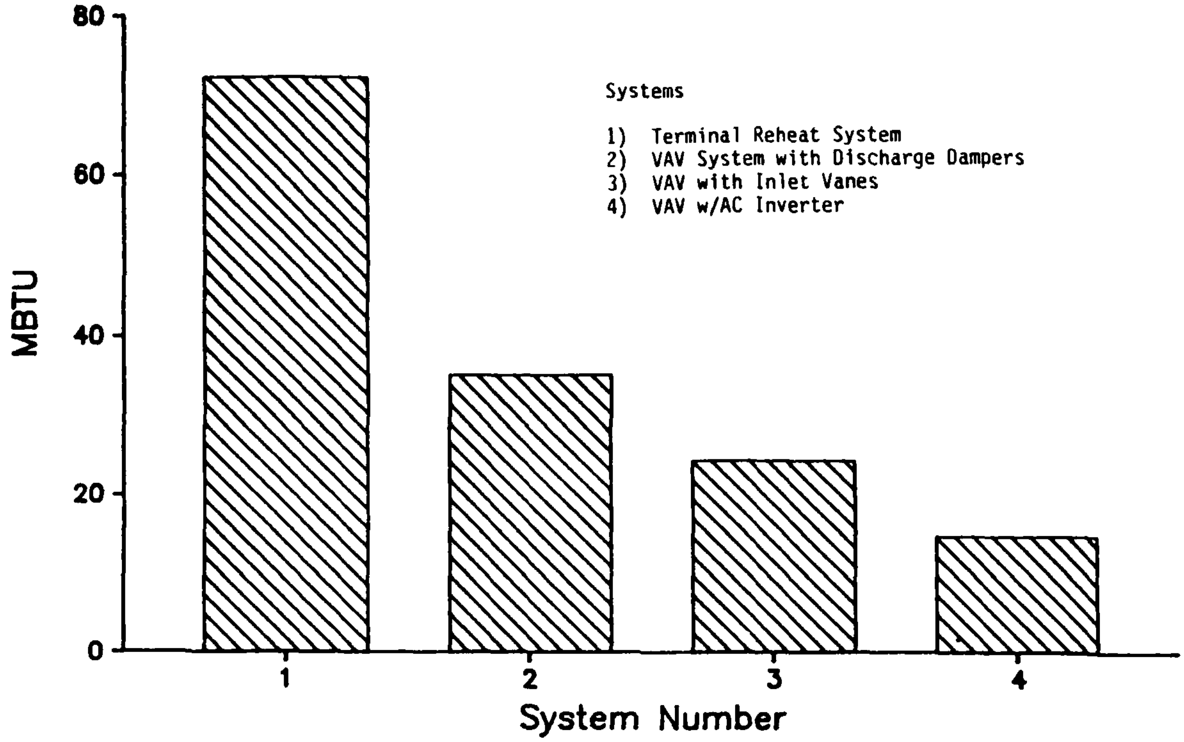


Figure 33. Annual fan electricity consumption (dental clinic, Columbia, MO).

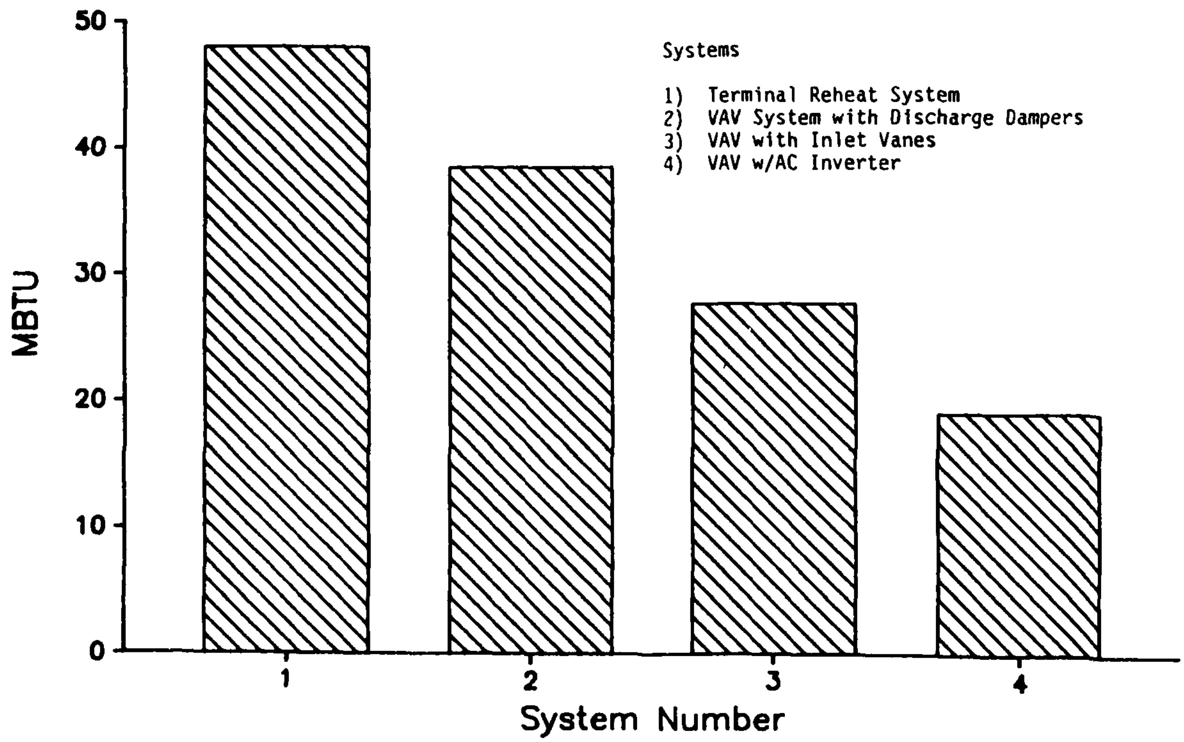


Figure 34. Annual fan electricity consumption (dental clinic, Houston, TX).

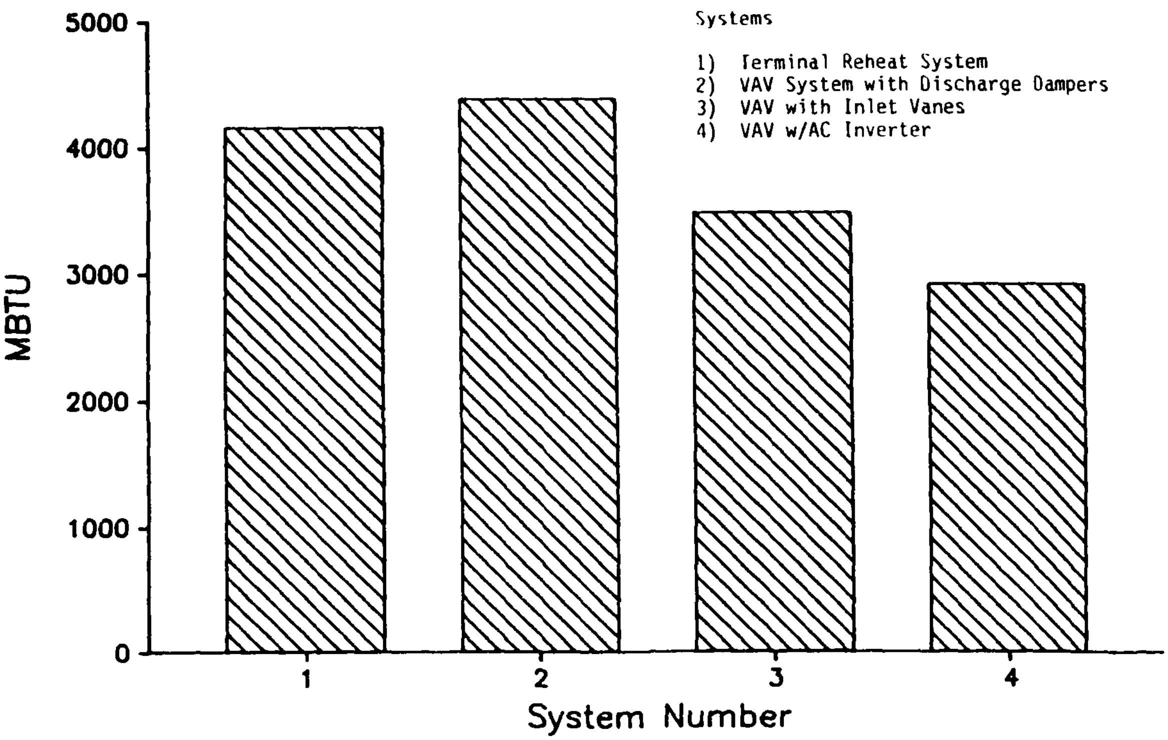


Figure 35. Annual fan electricity consumption (large office building, Phoenix, AZ).

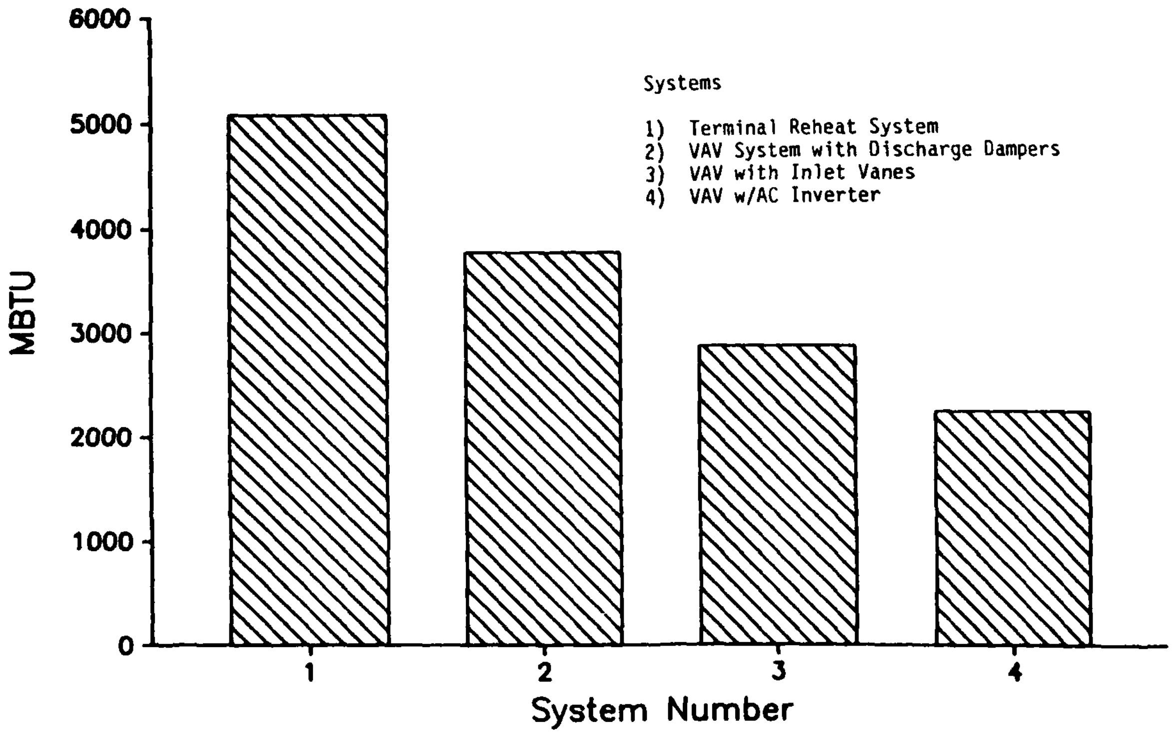


Figure 36. Annual fan electricity consumption (large office building, Colorado Springs, CO).

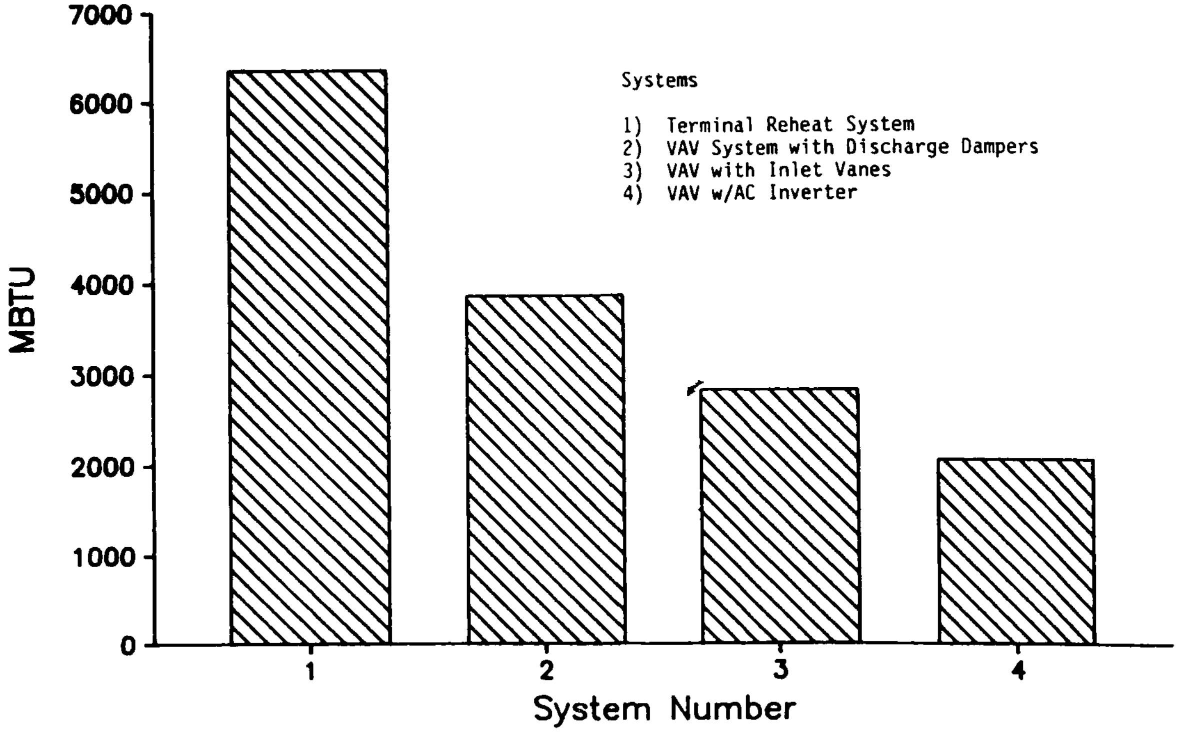


Figure 37. Annual fan electricity consumption (large office building, Minneapolis, MN).

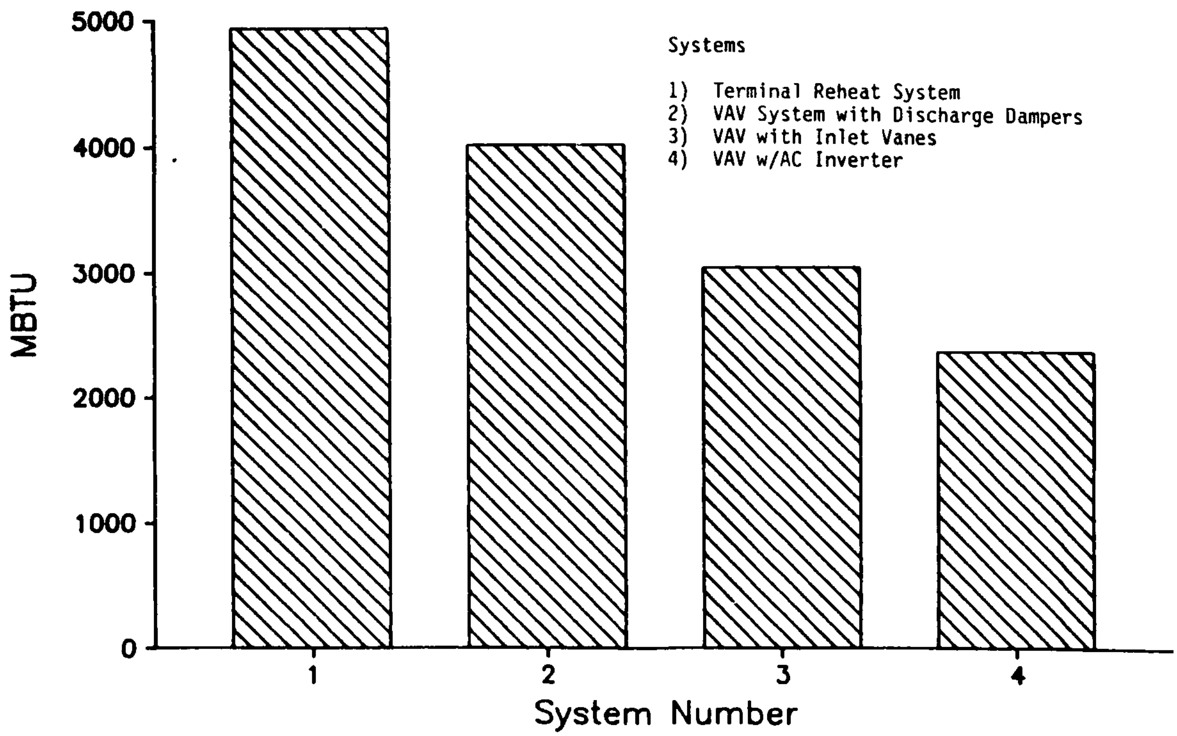


Figure 38. Annual fan electricity consumption (large office building, Columbia, MO).

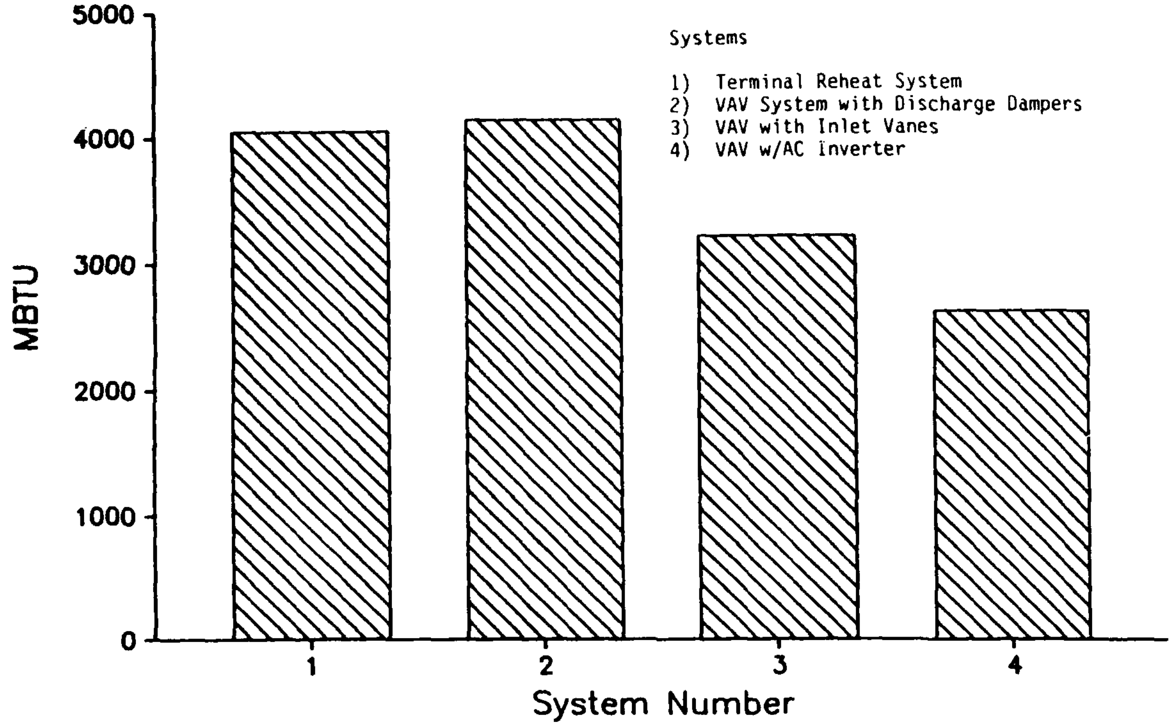


Figure 39. Annual fan electricity consumption (large office building, Houston, TX).

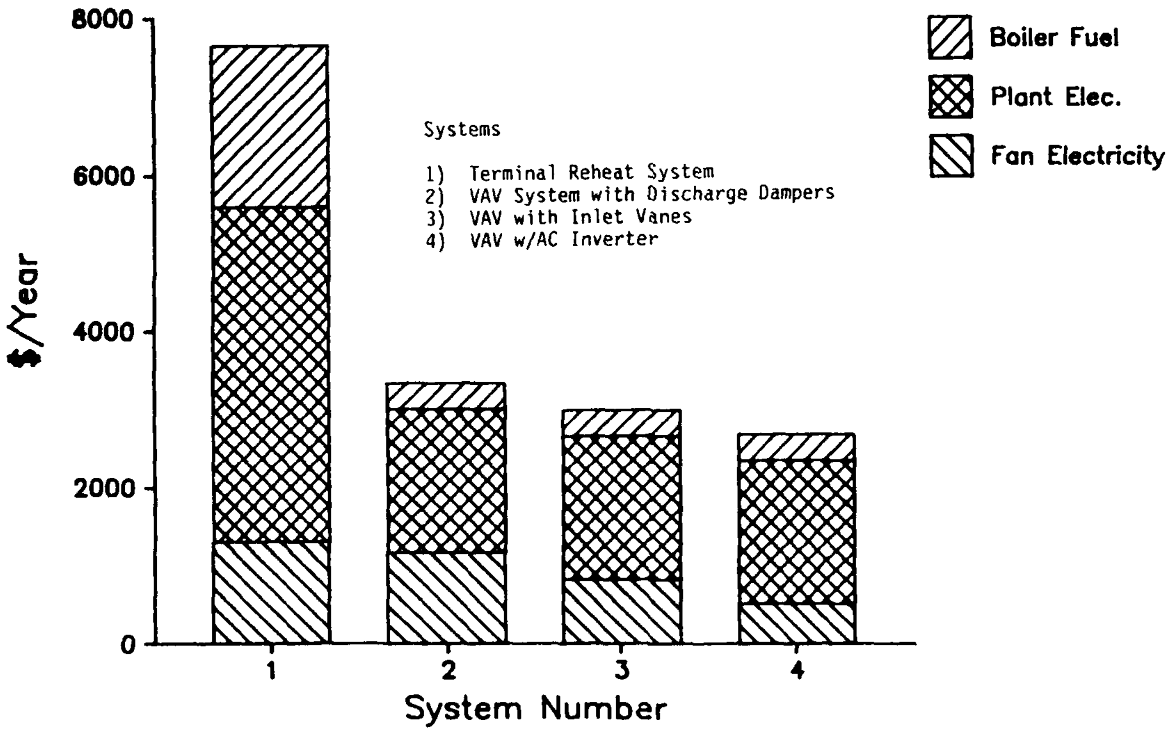


Figure 40. Annual system energy cost (battalion headquarters, Phoenix, AZ).

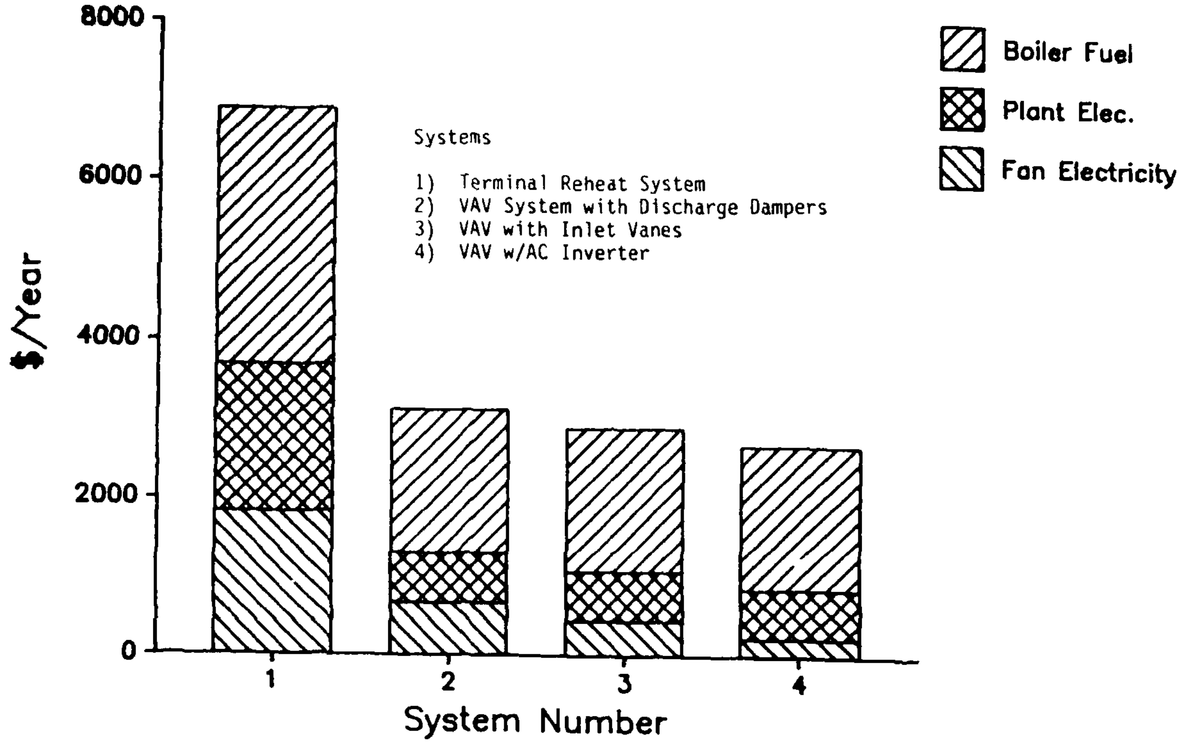


Figure 41. Annual system energy cost (battalion headquarters, Colorado Springs, CO).

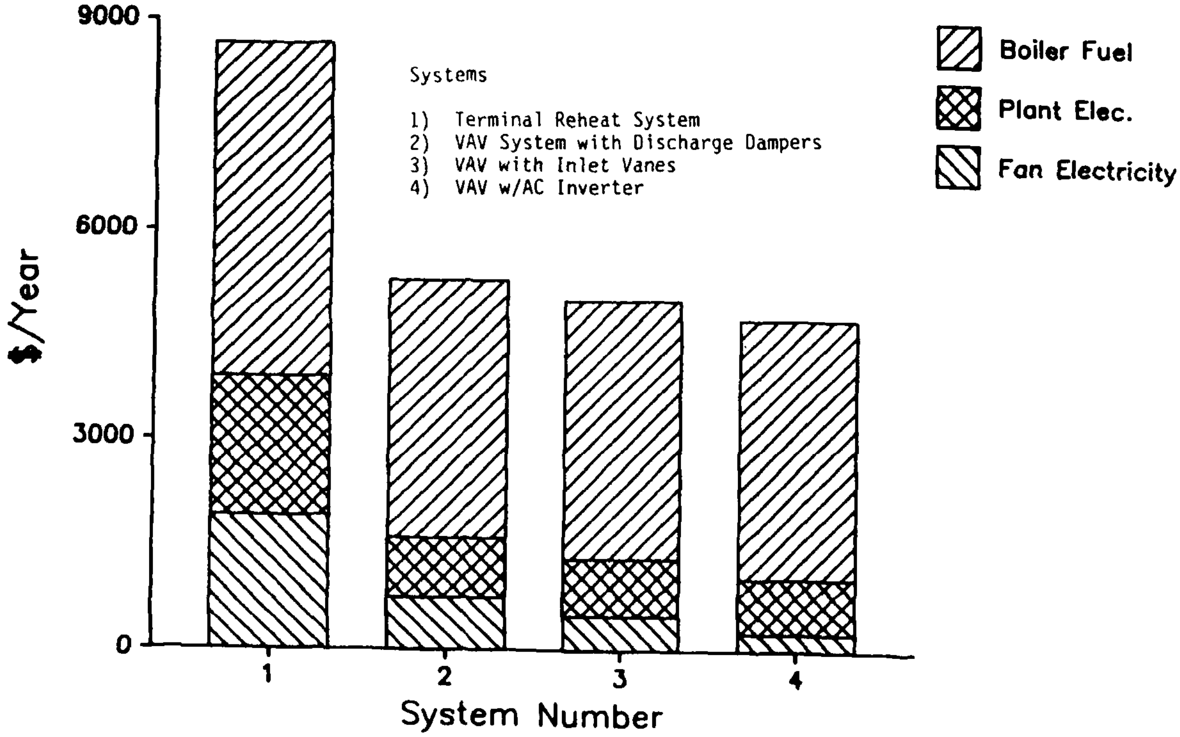


Figure 42. Annual system energy cost (battalion headquarters, Minneapolis, MN).

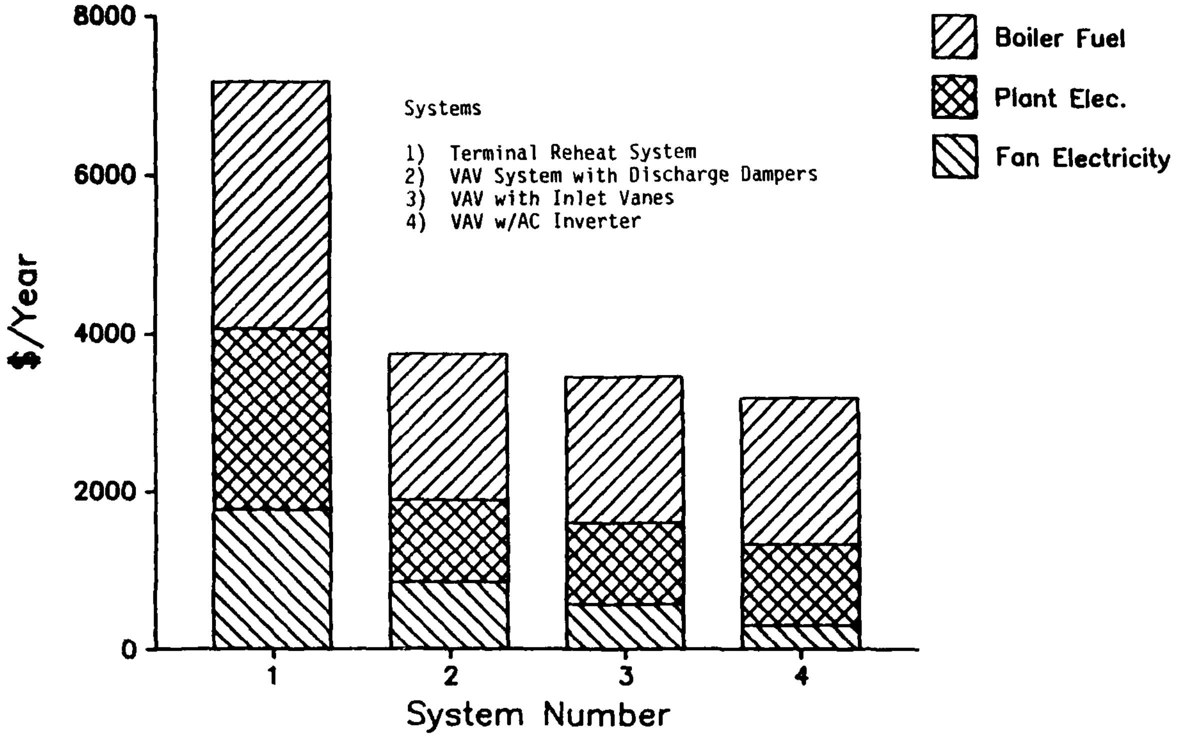


Figure 43. Annual system energy cost (battalion headquarters, Columbia, MO).

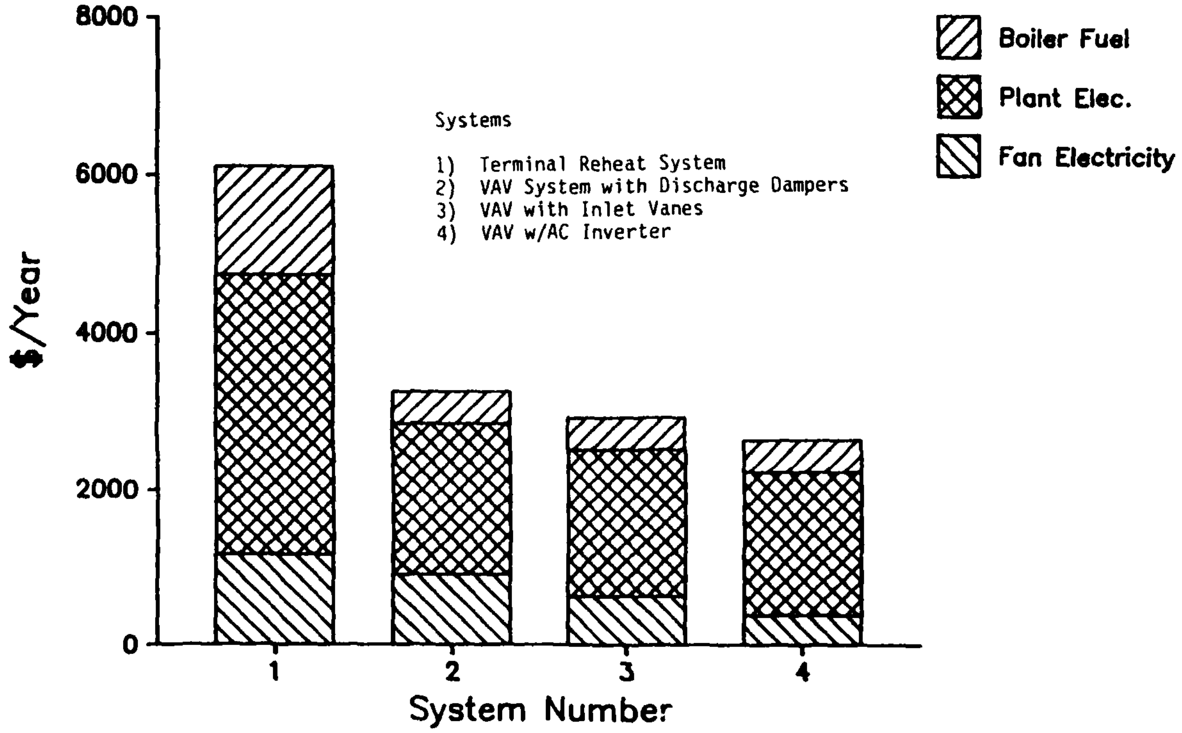


Figure 44. Annual system energy cost (battalion headquarters, Houston, TX).

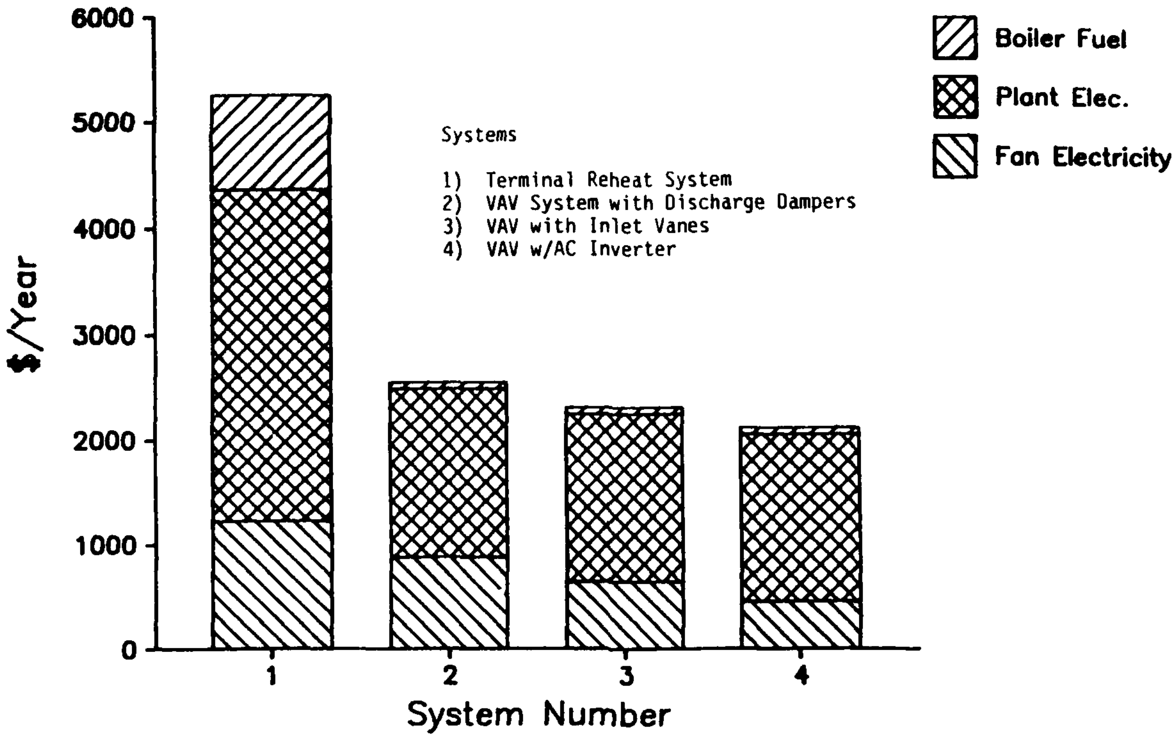


Figure 45. Annual system energy cost (dental clinic, Phoenix, AZ).

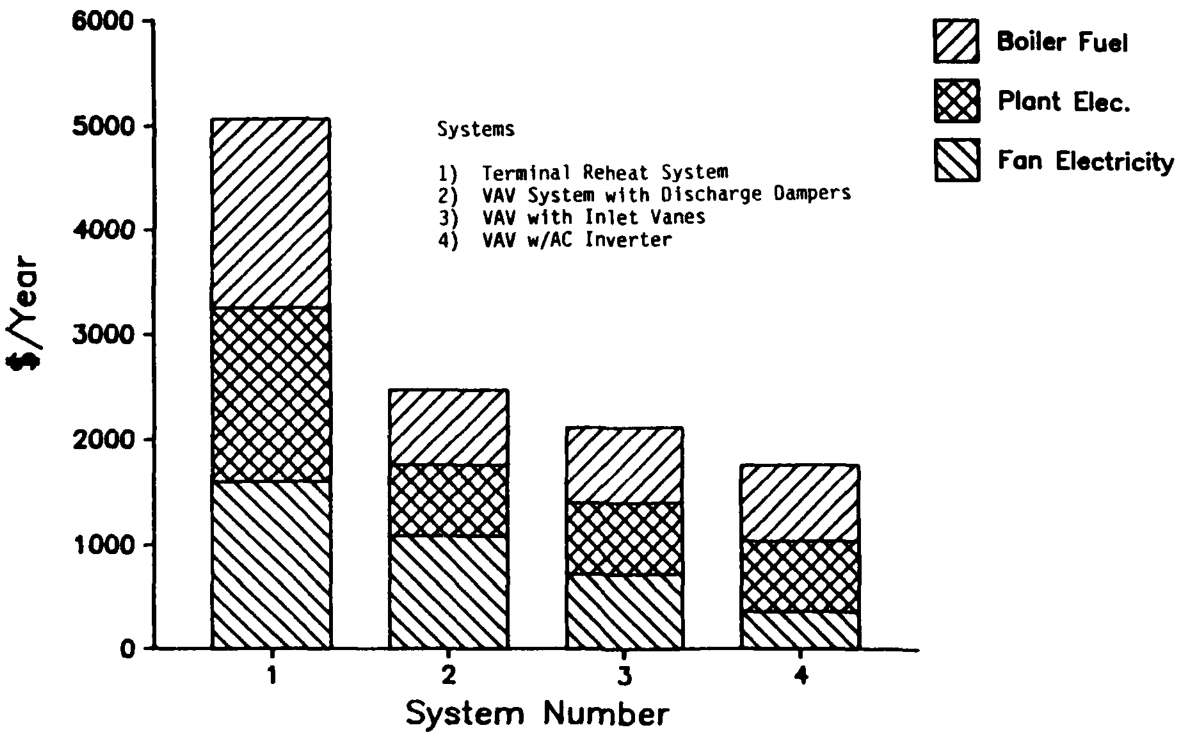


Figure 46. Annual system energy cost (dental clinic, Colorado Springs, CO).

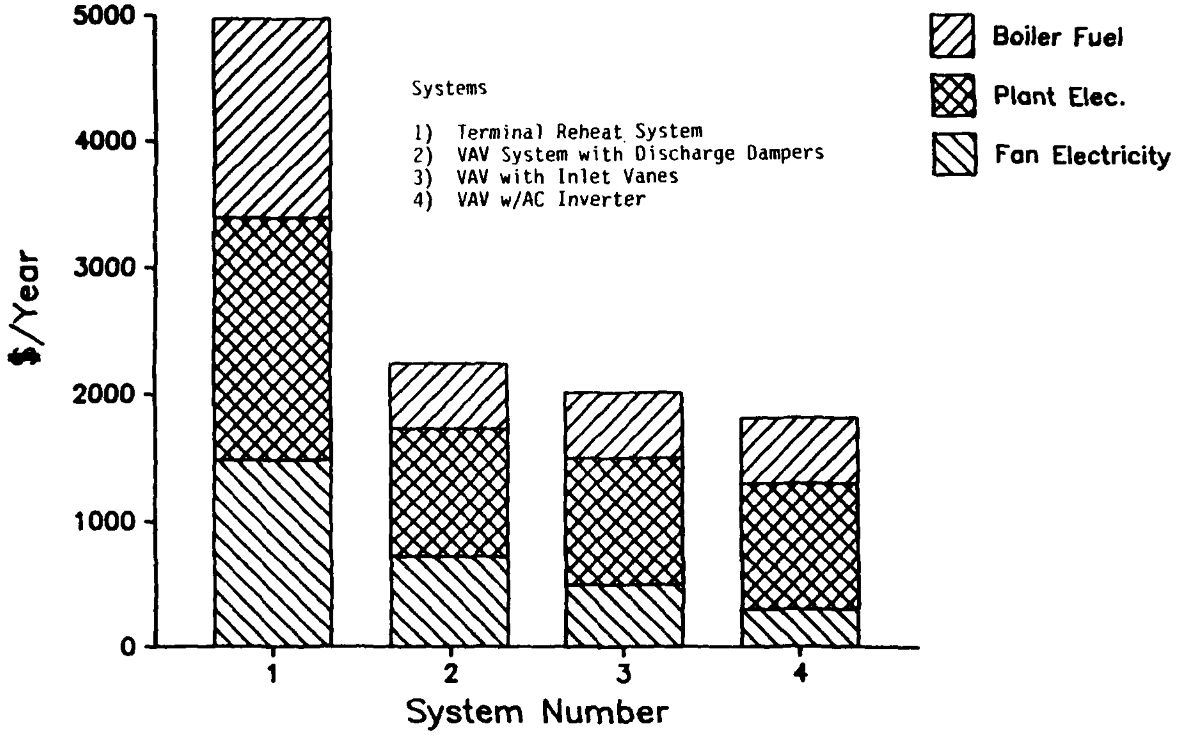


Figure 47. Annual system energy cost (dental clinic, Minneapolis, MN).

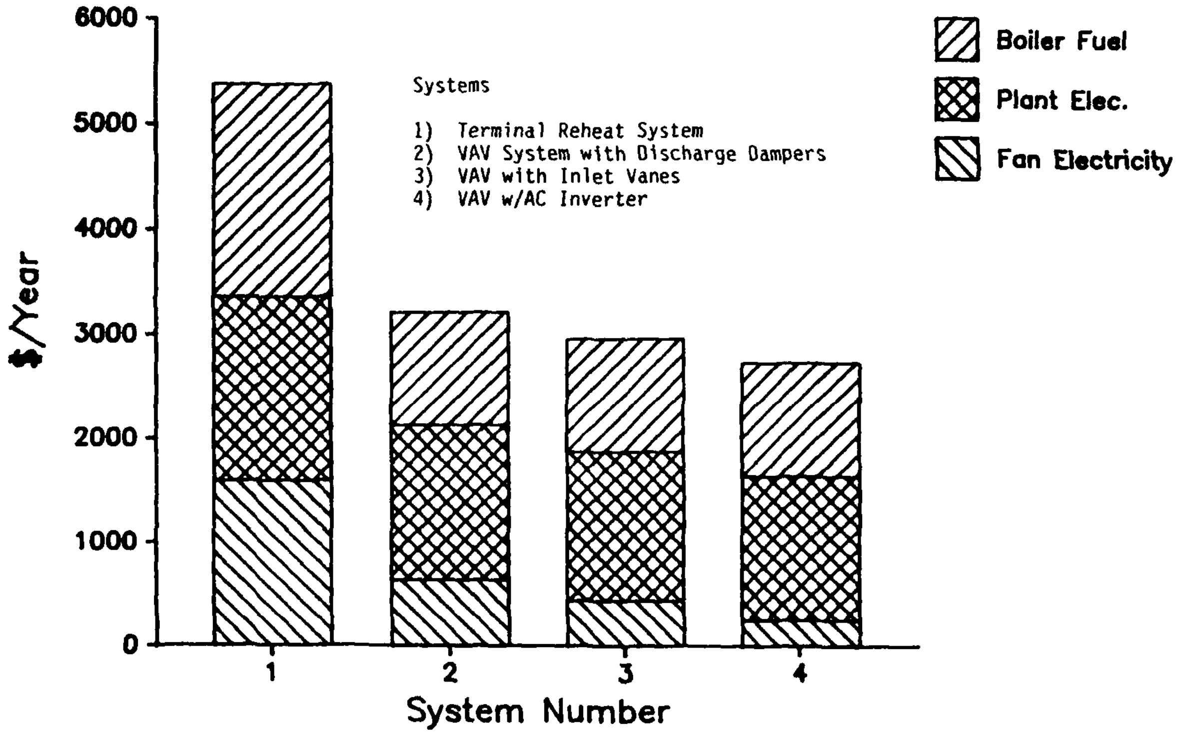


Figure 48. Annual system energy cost (dental clinic, Columbia, MO).

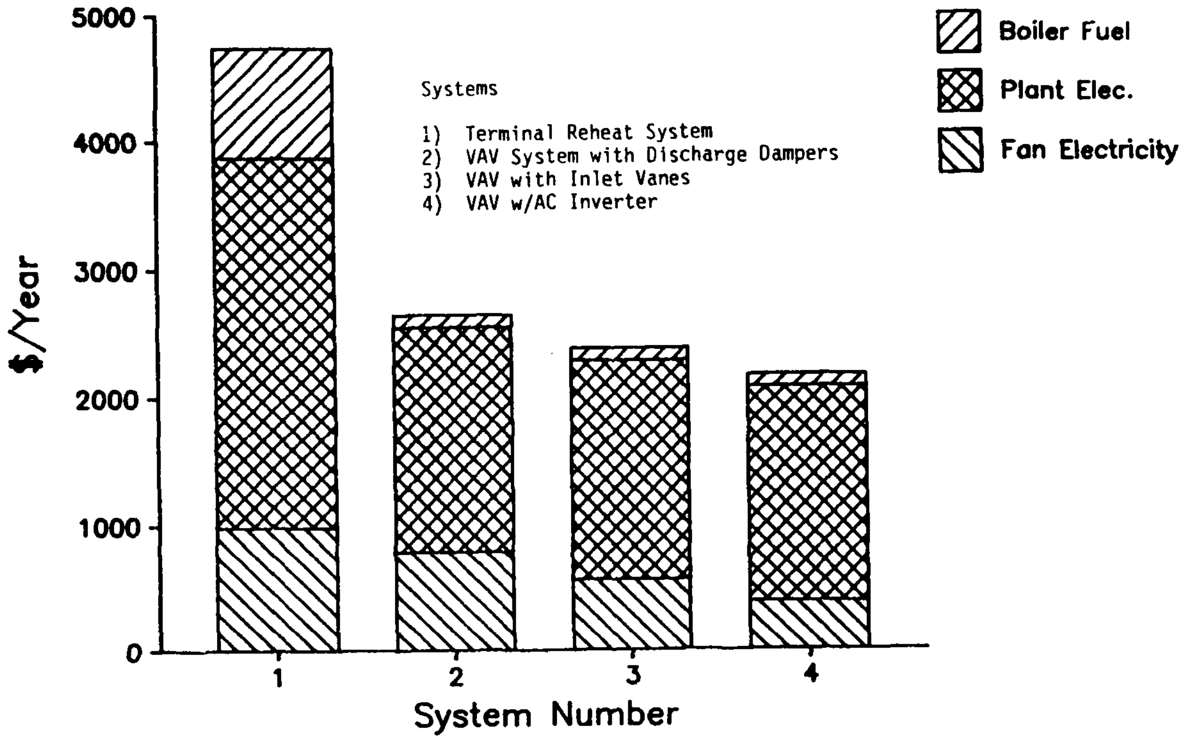


Figure 49. Annual system energy cost (dental clinic, Houston, TX).

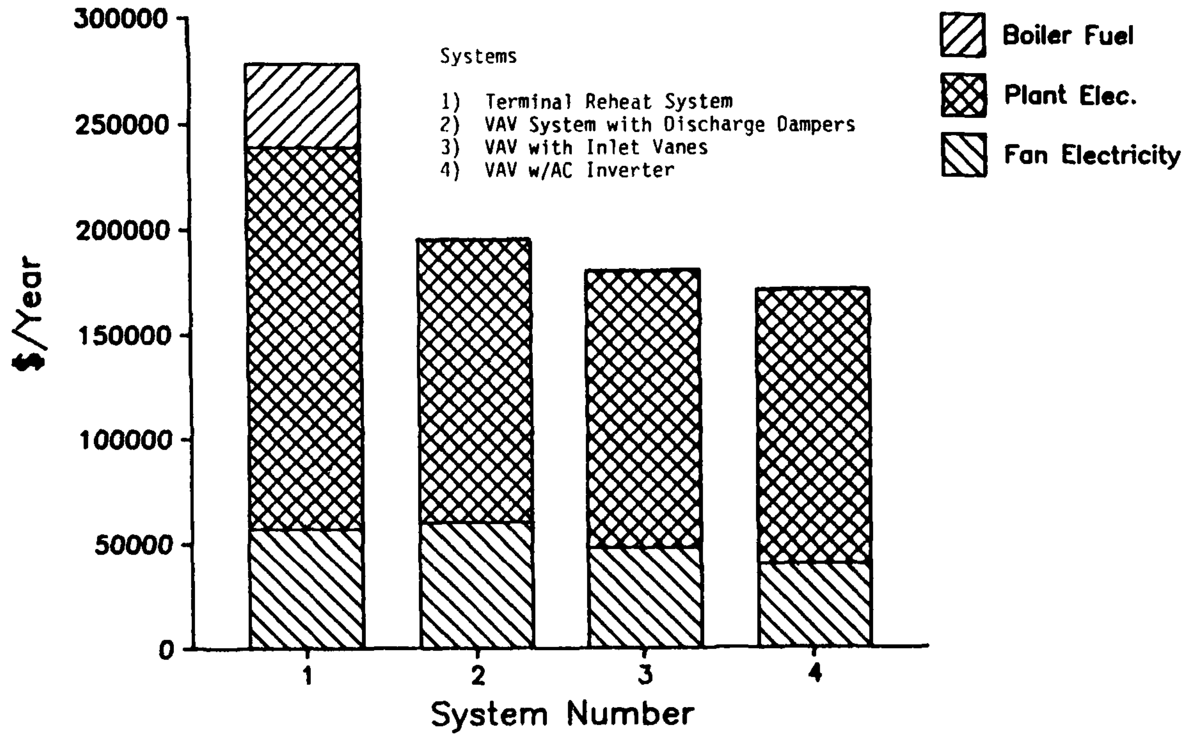


Figure 50. Annual system energy cost (large office building, Phoenix, AZ).

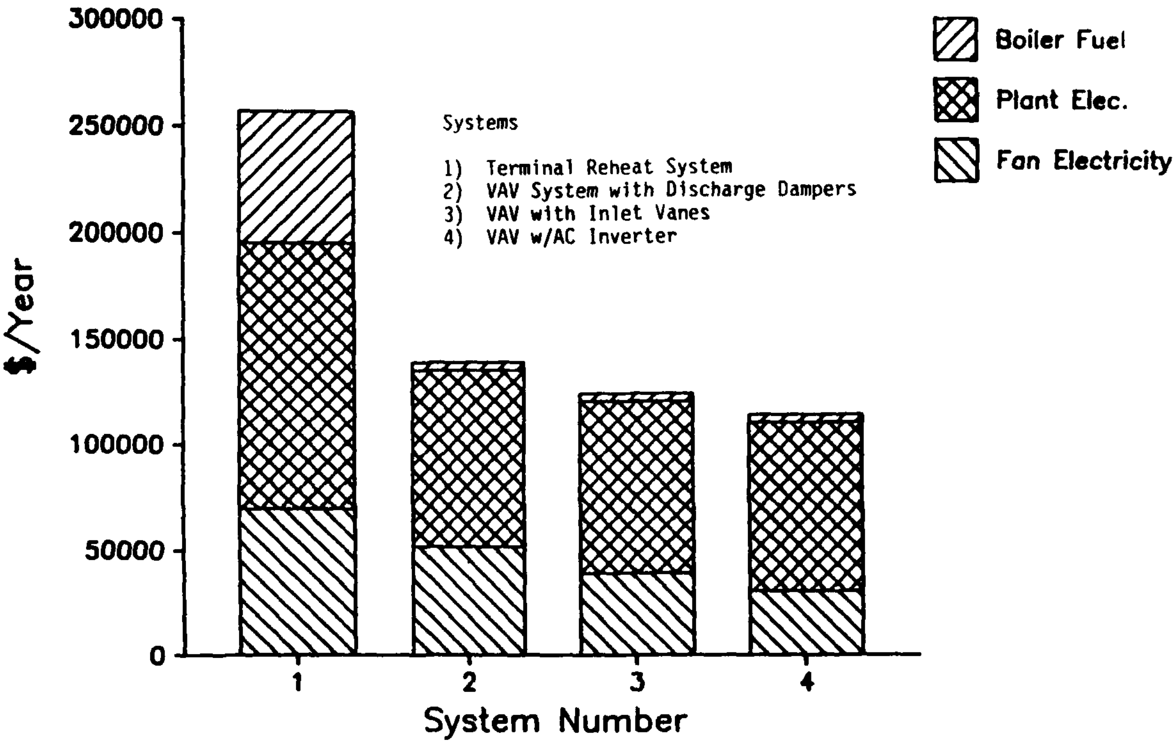


Figure 51. Annual system energy cost (large office building, Colorado Springs, CO).

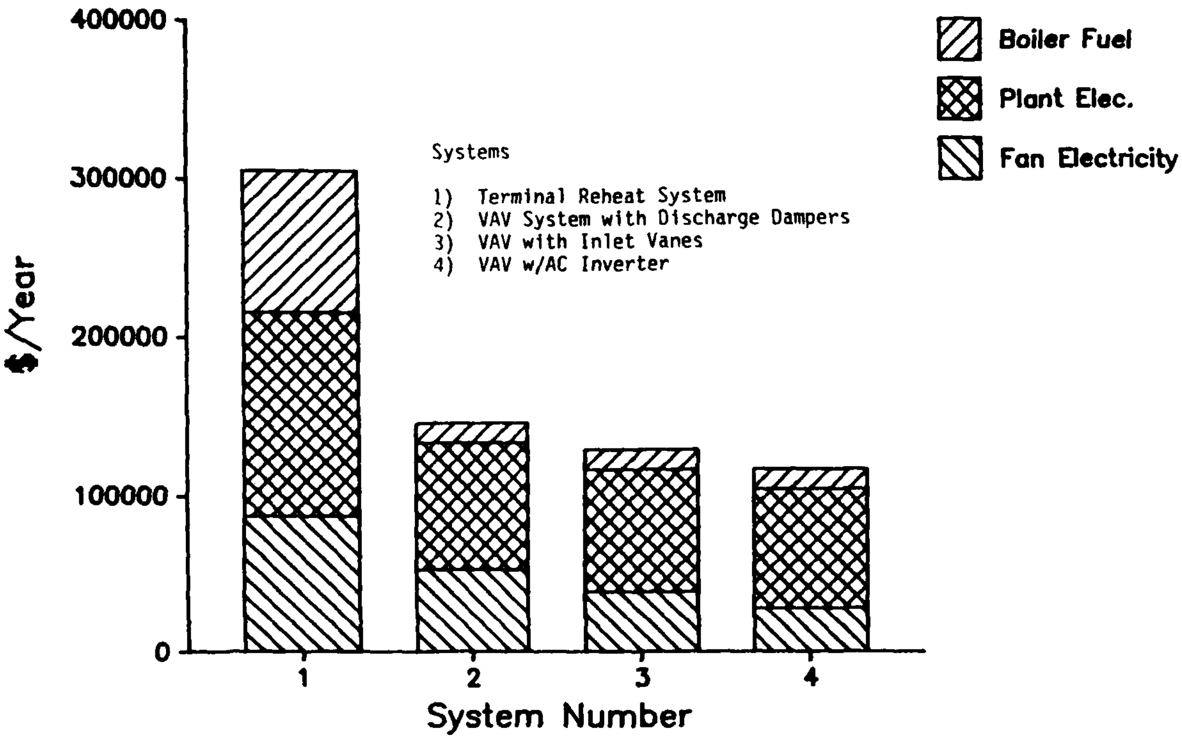


Figure 52. Annual system energy cost (large office building, Minneapolis, MN).

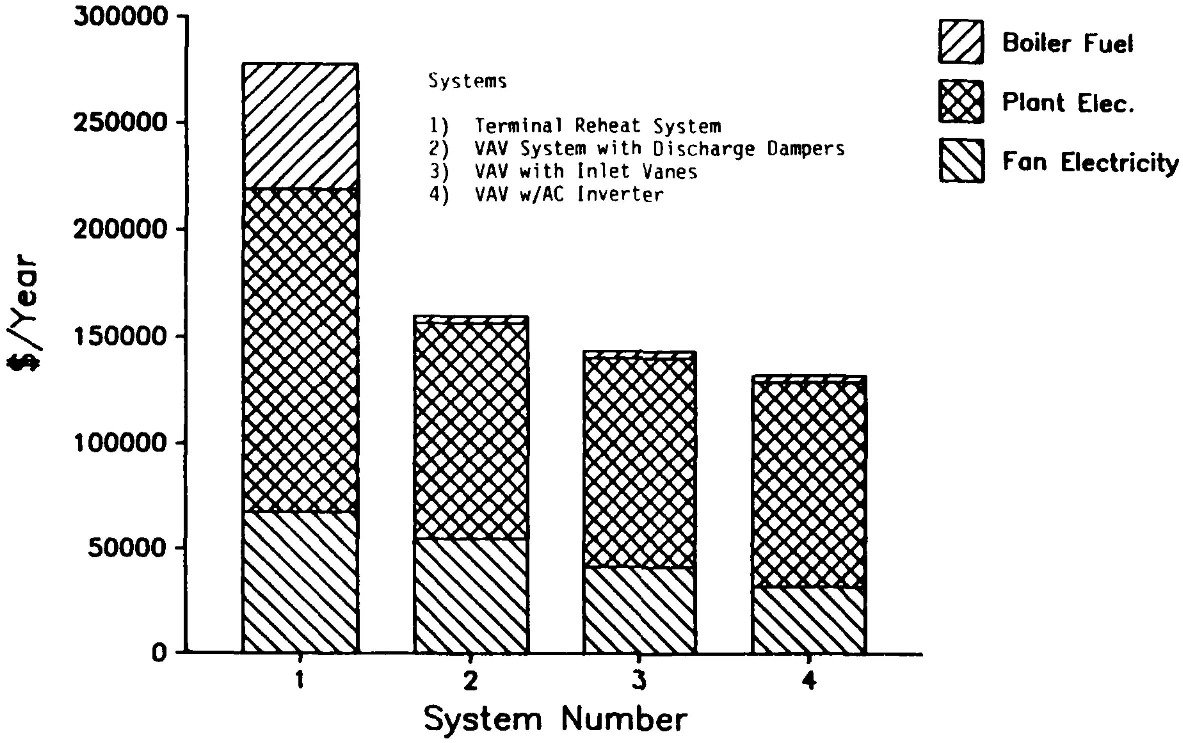


Figure 53. Annual system energy cost (large office building, Columbia, MO).

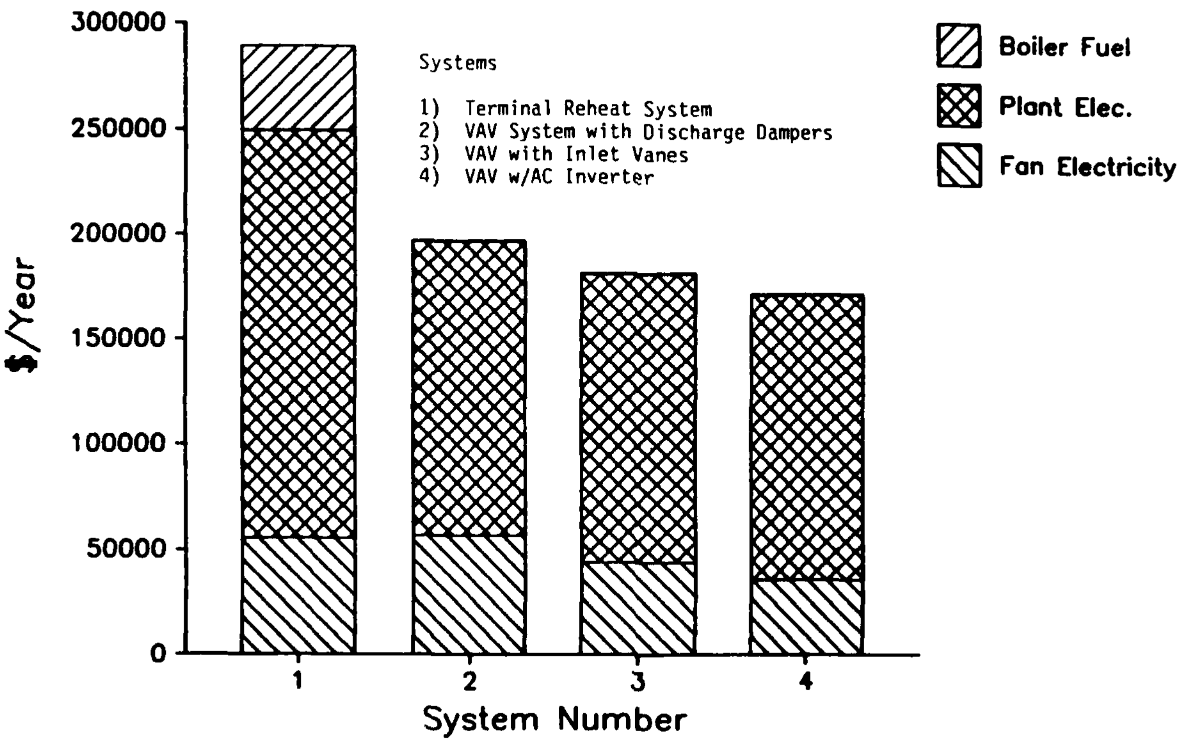


Figure 54. Annual system energy cost (large office building, Houston, TX).

Table 1

Fraction of Fan Electricity Consumed by VAV Systems*
Compared to the Baseline Terminal Reheat System

Building	**Location**	**System Number** 2**	3***	4‡	4/3‡‡
Dental clinic	AZ	.720	.529	.375	.709
Dental clinic	CO	.450	.310	.186	.600
Dental clinic	MN	.401	.275	.161	.585
Dental clinic	MO	.486	.336	.203	.604
Dental clinic	TX	.801	.576	.395	.686
Battalion HQ	AZ	.893	.630	.396	.629
Battalion HQ	CO	.368	.246	.128	.520
Battalion HQ	MN	.396	.266	.137	.515
Battalion HQ	MO	.482	.324	.173	.534
Battalion HQ	TX	.779	.541	.333	.616
Large office bldg.	AZ	1.053	.837	.701	.838
Large office bldg.	CO	.743	.564	.441	.782
Large office bldg.	MN	.608	.445	.325	.730
Large office bldg.	MO	.813	.615	.477	.776
Large office bldg.	TX	1.024	.795	.649	.816

*The baseline system is a terminal reheat system.
**System 2 is a VAV system with discharge dampers.
***System 3 is a VAV system with inlet vanes.
‡System 4 is a VAV system with AC inverters.
‡‡4/3 is VAV system with AC inverters divided by VAV system with inlet vanes.

7 ECONOMICS

The energy savings offered by all VAV systems are quite impressive. However, only the inlet vanes and frequency inverters offer substantial fan electricity savings. As expected, frequency inverters save more energy, but also cost more than inlet vanes. With this in mind, a simple economic analysis was done to determine which of the two options is more cost-effective. Ideally, a general rule of thumb could be developed to help determine which system option should be used. Unfortunately, this is rather difficult because of the anomalous manner in which inlet vanes and AC inverters are priced. At this time, it is probably best to think of the economic analysis more as a sample analysis, rather than as a general rule.

The method used to compare the inlet vanes and AC inverters was a simple payback calculation. Although in some ways inferior to a full-blown life-cycle cost analysis, the simple payback calculation can provide a quick overview of the advantages of one type of fan modulation over another, without adding in additional variables and assumptions. This calculation first involves determining the energy savings, which are then translated into annual cost savings based on some average electricity costs. The next step involves determining the extra initial expenditure due to purchasing an AC inverter instead of inlet vanes. Finally, the extra initial cost is divided by the annual energy savings to determine the simple payback.

One manufacturer was consulted for prices on fans and inlet vanes. Seven manufacturers were contacted for inverter prices. Figure 55* graphs inverter prices. Manufacturers A, B, and C gave firm prices. A fourth manufacturer gave an estimate of \$350 to \$400/hp for inverters between 10 and 50 hp. Another gave an estimate of \$100/hp ± 20 percent. The final two declined to give any prices. As shown by the graph and the estimates, costs vary widely among manufacturers.

Manufacturer B provided prices for centrifugal fans and matching inlet vanes. Prices for actuators were obtained from another manufacturer. Then the initial additional capital cost for inverters was determined by subtracting the cost of the inlet vanes (including the actuator) from the cost of the inverter. The lowest priced inverter from manufacturer A, B, or C was used for comparison.

Calculation of the cost difference showed an interesting phenomenon. The additional cost for an inverter instead of inlet vanes is not a linear function of fan capacity or motor horsepower, nor is it a quadratic or exponential function. As shown in Figure 56, it seems somewhat random. This is because pricing for inlet vanes appears to be based primarily on fan size, whereas pricing for inverters is based primarily on motor horsepower. Also, prices for both inverters and inlet vanes tend to vary nonlinearly.

Ideally, some smooth curve would be developed for a study of this type. However, this would also require more data from different manufacturers. Given the difficulty in acquiring the previous data, it was decided that acquiring more data was infeasible.

Payback was calculated in the following manner. For each building/site, the smallest fan/motor combination that would meet the design criteria (20 percent oversizing) was selected. The initial investment was considered to be the difference in cost between inlet vanes and AC inverters for the selected fan/motor combination.

---

*Figures and table follow the chapter.

Next, the building's energy savings were determined by subtracting the energy consumption of the inverter system from that of the inlet vanes system. The building energy savings were then normalized by multiplying by the fan/motor combination CFM rating divided by the building CFM requirement. This evens out some anomalies that may occur because of sporadic spacing of fan/motor capacities. The annual return on investment was considered to be the annual energy savings multiplied by the unit cost of the energy. The payback was then the initial investment cost divided by the annual return on investment.

Table 2 shows the economic analysis results. A fourth "building," BHQ2, was added, which involved doubling the battalion headquarters' system size and electricity consumption. Admittedly, it is somewhat contrived, but it does demonstrate the effects of the anomalous pricing. The last two columns in Table 2 give payback in years for the stated electricity costs. The eighth column, which reflects somewhat of a worst-case scenario, gives the payback for a building with a high electricity cost and a low-efficiency fan (30 percent instead of 50 percent). While this scenario is the worst case for the building owner, it is the best case for AC inverters.

The paybacks displayed in Table 2 vary greatly. Obviously, there is no definitive general trend in payback that results from climate or system size. This is due to the anomalous pricing discussed earlier. For electricity costing \$0.047/kWh, paybacks range between 2.11 and 9.05 years. This wide swing has little to do with the type of building or climate and instead reflects primarily the peaks and valleys shown in Figure 56. For \$0.09/kWh, the payback ranges between 1.1 and 4.73 years. For the same electricity cost and a 30 percent efficient fan, the payback ranges between 0.66 and 2.84 years.

Although these economic calculations do not provide a general decision-making tool, they do give some insights. At this time, the most beneficial of these is that the choice between inlet vanes and AC inverters will probably have to be evaluated on a case-by-case basis.

Certainly, there will be numerous cases where installing a frequency inverter can be justified. Also, the prices of AC inverters have been declining. Should this trend continue, the desirability of using a frequency inverter will increase.

Another consideration is maintenance. Although no empirical data are available, frequency inverters probably need less maintenance than inlet vanes, because the inverter has no moving parts. Maintenance was not accounted for in the economic analysis done in this study; however, if it had been included, the frequency inverter's lower maintenance costs would have decreased the time required for payback. Noise level is another factor that should be considered. Frequency inverters are much quieter than inlet vanes, and this may be very important in some applications.

More important, unlike inlet guide vanes, they do not become "stuck" in a fixed position in field situations. Lack of lubrication or misaligned linkage is usually the cause of sticking in inlet guide vanes. When all of these factors are considered together, the frequency inverter will likely be the preferred option for many applications.

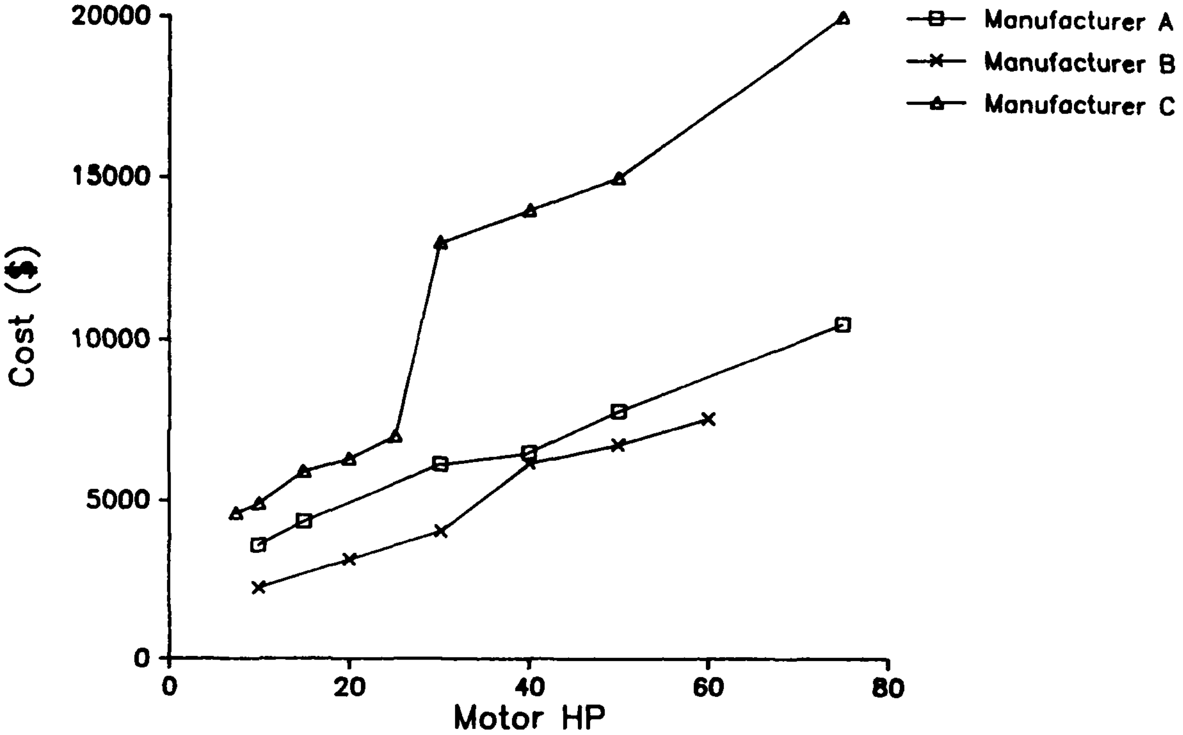


Figure 55. Frequency inverter pricing (September 1985).

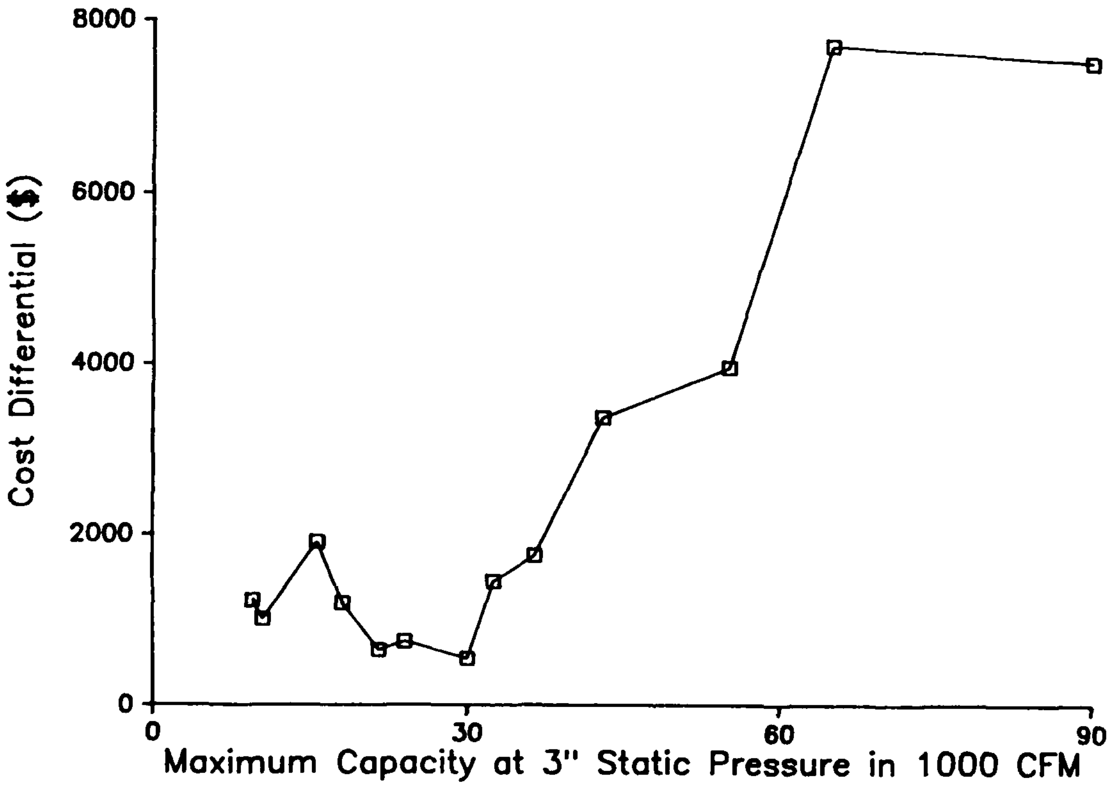


Figure 56. Initial cost due to replacing inlet vanes with frequency inverter.

Table 2

Summary of Payback Calculations

Building	Location	Design CFM	Total Electricity Savings w/ Inverter (MBtu)	Normalized Electricity savings (MBtu)	Payback w/ $.047/kWh	Payback w/ $.09/kWh	Payback w/ $.09/kWh and 30% Efficient Fan
DCL	AZ	9030	9.40	9.89	9.05	4.73	2.84
DCL	CO	6527	9.00	13.10	6.83	3.57	2.14
DCL	MN	7136	11.40	15.18	5.90	3.08	1.85
DCL	MO	7864	9.80	11.84	7.56	3.95	2.37
DCL	TX	8110	10.30	12.07	7.42	3.87	2.32
BHQ	AZ	12118	15.30	19.82	7.01	3.66	2.20
BHQ	CO	7865	10.50	12.68	7.06	3.69	2.21
BHQ	MN	8957	12.40	13.15	6.81	3.55	2.13
BHQ	MO	9834	13.30	14.20	5.18	2.70	1.62
BHQ	TX	9894	13.90	14.75	4.98	2.60	1.56
LOB	AZ	41385	33.60	34.91	7.02	3.66	2.20
LOB	CO	31821	36.30	37.07	2.85	1.49	0.89
LOB	MN	38960	44.10	48.67	5.03	2.63	1.58
LOB	MO	39400	40.00	43.65	5.61	2.93	1.76
LOB	TX	39700	35.70	38.67	6.33	3.31	1.98
BHQ2	AZ	24236	15.30	18.94	2.11	1.10	0.66
BHQ2	CO	15730	10.50	12.02	7.27	3.80	2.28
BHQ2	MN	17914	12.40	12.46	7.01	3.66	2.20
BHQ2	MO	19668	13.30	14.54	3.25	1.70	1.02
BHQ2	TX	19788	13.90	15.10	3.13	1.64	0.98

8 PROPORTIONAL ONLY AND PROPORTIONAL-INTEGRAL FAN CONTROL

To define the potential savings resulting from use of proportional-integral control instead of proportional-only control, a simulation was run for the large office building in Houston, using the model discussed in Chapter 3. Figures 57 and 58 show the simulation results. Use of proportional-integral control provides about an 18 percent savings in fan electricity consumption; however, while these potential savings are significant, proportional-integral control may also be required to ensure stable operations.

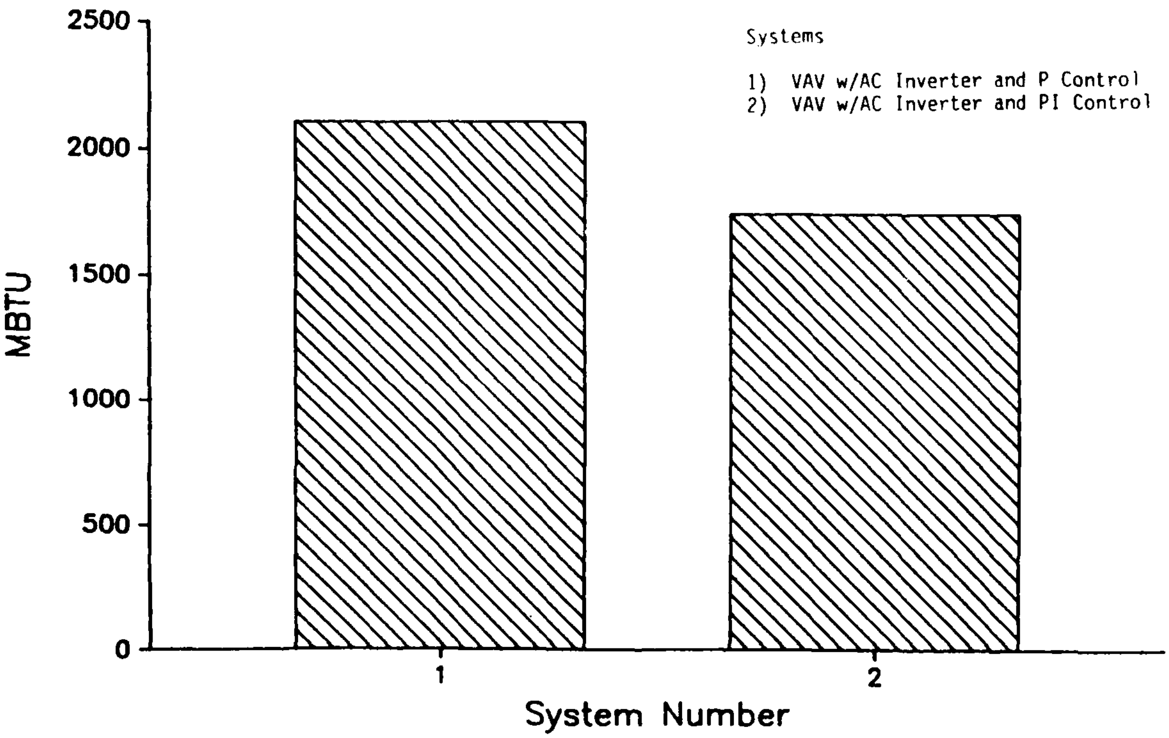


Figure 57. Annual fan electricity consumption for proportional only and proportional-integral fan control (large office building, Houston, TX).

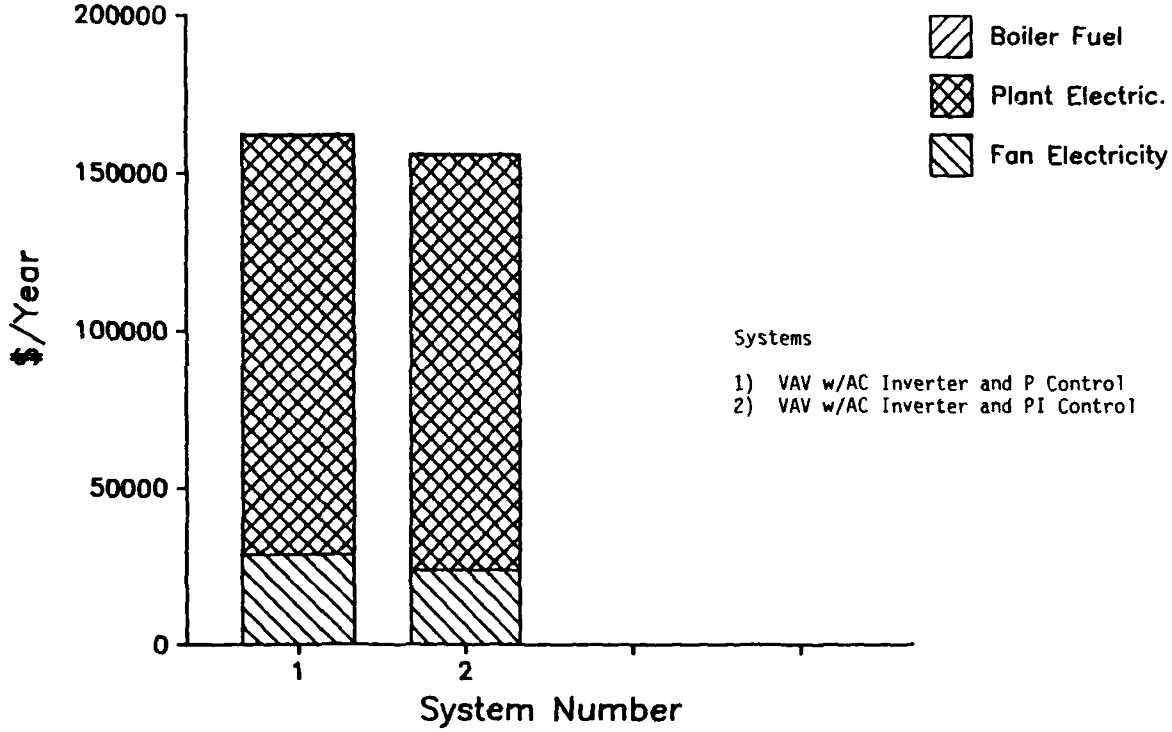


Figure 58. Annual system energy cost for proportional only and proportional-integral fan control (large office building, Houston, TX).

9 VAV TERMINAL UNITS

The VAV terminal unit, or VAV box, is another system component that affects fan energy consumption. The previous simulations assumed efficient VAV boxes with 0.75 in. of water pressure required at the box inlet; however, system-powered VAV boxes may require 1.5 in. of pressure at the inlet. A previous field study* found an example of a VAV box that required 3.0 in. at the box inlet. This type of VAV box had a perforated plate that was probably intended to straighten the flow; however, it added an enormous pressure drop to the box.

Assuming a system resistance of 2.25 in. for the rest of the system, systems with efficient VAV boxes require a pressure drop of 3 in.; systems with system-powered VAV boxes require a pressure drop of 3.75 in., and those with "perforated-plate" boxes require a pressure drop of 5.25 in. The increase in pressure drop across the fan essentially causes a linear increase in the amount of fan electricity consumed. It also adds more heat to the flow, thus increasing the amount of cooling required. Figures 59 and 60 show the fan electricity consumption with the three different types of VAV boxes for the large office buildings in Columbia and Houston. (The system has an AC inverter for fan control.) Figures 61 and 62 show the overall system energy costs, using the same assumptions used in Chapter 6.

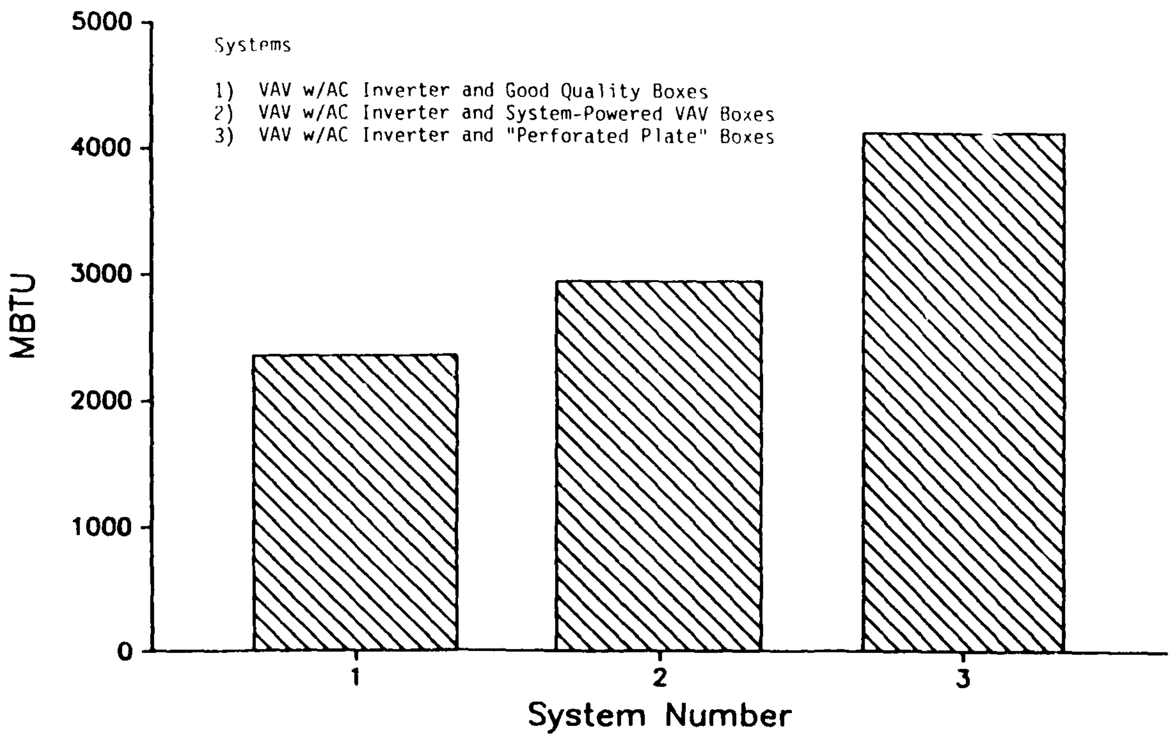


Figure 59. Annual fan electricity consumption for various VAV box types (large office building, Columbia, MO).

---

*Dr. David Johnson of USA-CERL conducted field measurements on a building control system at Tyndall Air Force Base, FL, in January 1985. Purpose of the study was to ascertain the cause of problems with an inoperable system.

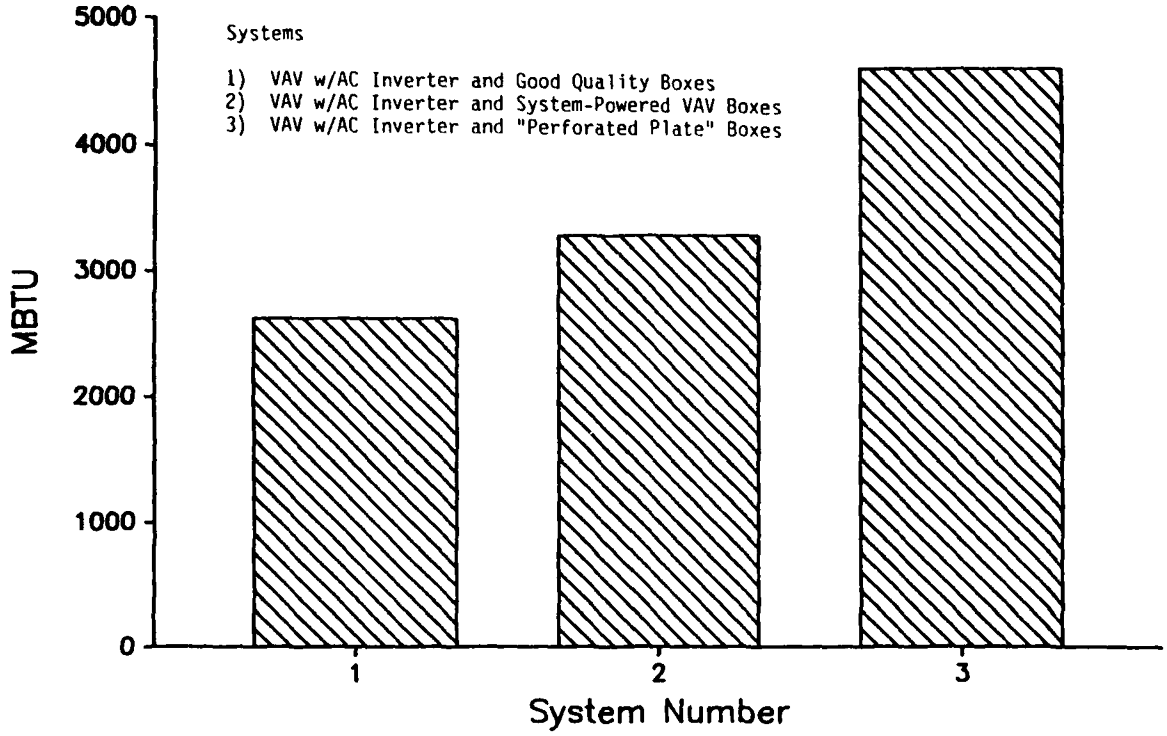


Figure 60. Annual fan electricity consumption for various VAV box types (large office building, Houston, TX).

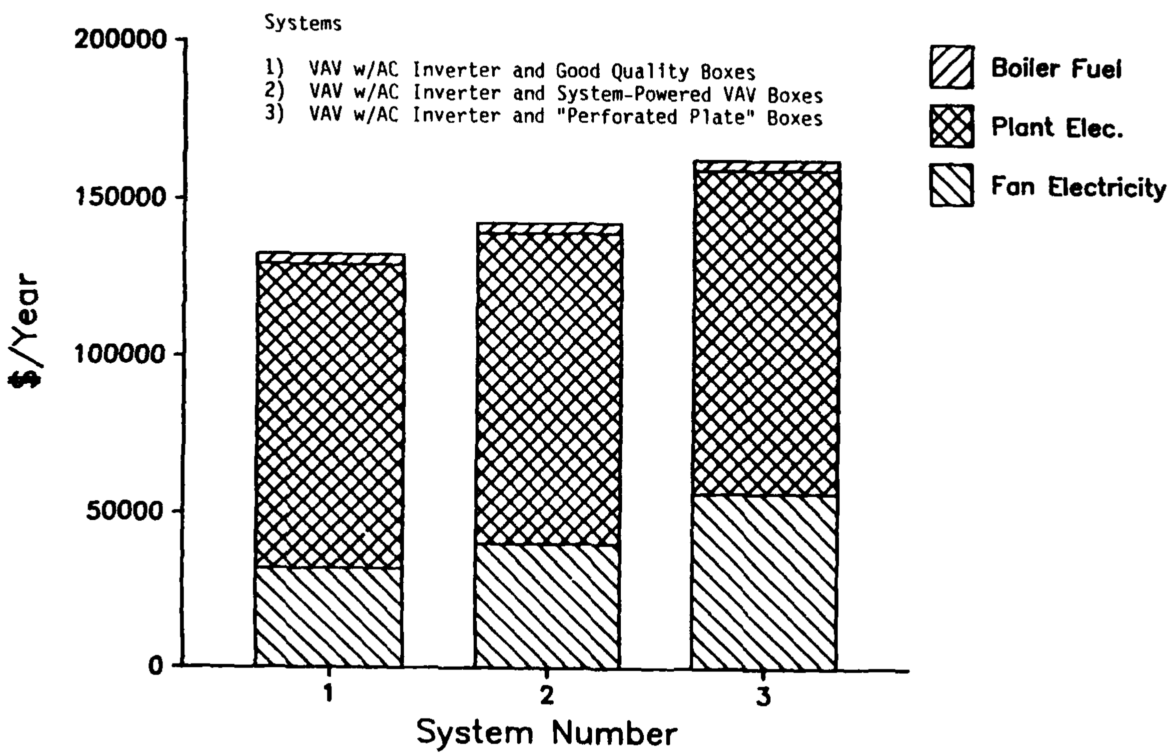


Figure 61. Annual system energy cost for various VAV box types (large office building, Columbia, MO).

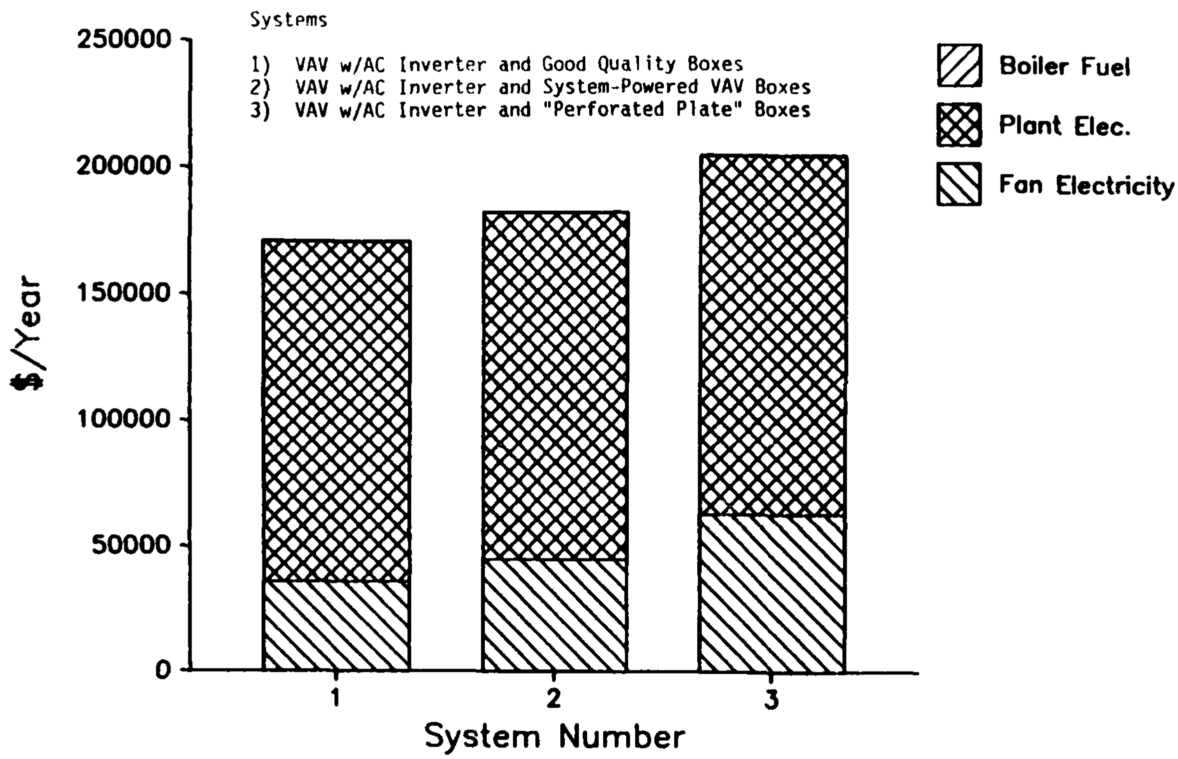


Figure 62. Annual system energy cost for various VAV box types (large office building, Houston, TX).

10 CONCLUSIONS AND RECOMMENDATIONS

Annual fractional flow distributions for the prototypical buildings tested have confirmed several expected trends, including that there are fewer and fewer hours at the minimum fraction as the progression is made from envelope-dominated buildings to core-dominated buildings and from colder climates to warmer climates. For a building that has very large internal loads and is considered core-dominated, the fractional flows vary considerably and VAV systems save substantial amounts of energy.

Comparisons of fan electricity and system energy consumption for a terminal reheat system and three VAV systems with different fan modulation methods in different buildings/climates indicated that:

1. The greatest savings for a VAV system occur for the most envelope-dominated building in cooler climates. These savings are for a VAV system with an AC inverter.

2. The least savings are for large office buildings (the most core-dominated building in warmer climates).

3. Although the VAV system with discharge dampers consumes more electricity than the baseline terminal reheat system, the VAV system still performs much better overall and thus has good potential to reduce energy costs.

4. In comparison to inlet vanes, AC inverters provide significant savings, especially for envelope-dominated buildings in cold climates.

VAV systems offer impressive energy savings, but only the inlet vanes and frequency inverters provide substantial fan electricity savings. Economic calculations indicate that the decision to install frequency inverters or inlet vanes should be based on individual building and climate characteristics.

Experimental fan performance data and models should be developed to improve confidence in energy savings quantification results. A more convenient form of the modification to BLAST, which allows printout of the hourly fraction of full flow, should be considered because it is helpful in visualizing system operation as well as debugging BLAST input file.

Besides economics, factors such as maintenance and noise levels should be considered when choosing a fan control device.

APPENDIX A:

SAMPLE INPUT FILE FOR DENTAL CLINIC

```
BEGIN INPUT;
RUN CONTROL:  NEW ZONES,
              NEW AIR SYSTEMS,
  UNITS(OUT=ENGLISH),
    REPORTS(ZONE LOADS);
TEMPORARY LOCATION: FT HOOD = (LAT=31,LONG=97.8,TZ=6); END;
TEMPORARY DESIGN DAYS:
      FT HOOD WINTER = (HIGH=32,LOW=20,WEEKEND,WB=20,DATE=21JAN),
      FT HOOD SUMMER = (HIGH=99,LOW=77,WB=72,DATE=21JUL,PRES=405,
                        CLEARNESS=.95,WEEKDAY),

  CO WINTER=(HIGH=-3,LOW=-3,WB=-5,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  CO SUMMER=(HIGH=91,LOW=61,WB=78,WEEKDAY),

  MO WINTER=(HIGH=-1,LOW=-1,WB=-3,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  MO SUMMER=(HIGH=97,LOW=75,WB=78,WEEKDAY),

  NC WINTER=(HIGH=16,LOW=16,WB=12,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  NC SUMMER=(HIGH=94,LOW=74,WB=78,WEEKDAY),

  AZ WINTER=(HIGH=31,LOW=31,WB=25,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  AZ SUMMER=(HIGH=109,LOW=82,WB=76,WEEKDAY),

  TX WINTER=(HIGH=17,LOW=17,WB=13,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  TX SUMMER=(HIGH=101,LOW=79,WB=78,WEEKDAY),

  MN WINTER=(HIGH=-16,LOW=-16,WB=-17,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  MN SUMMER=(HIGH=92,LOW=70,WB=77,WEEKDAY);
END DESIGN DAYS;
TEMPORARY SCHEDULE(SYSOP):
    MONDAY THRU FRIDAY=(07 TO 17-1.0,17 TO 07-0.0),
    SATURDAY THRU SUNDAY=(00 TO 24-0.0),
    HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE (OFF):
     SUNDAY THRU SATURDAY = (00 TO 24 - OFF),
     HOLIDAY = SUNDAY;
  END;
  TEMPORARY SCHEDULE(OFFICE VENT):
     MONDAY THRU FRIDAY=(08 TO 17-0.2,17 TO 08-0.1),
     SATURDAY THRU SUNDAY=(00 TO 24-0.1),
     HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE(OFFICE EQUIPMENT):
     MONDAY THRU FRIDAY=(17 TO 08-0.0, 08 TO 17-1.0),
     SATURDAY THRU SUNDAY=(00 TO 24-0.0),
     HOLIDAY=SUNDAY;
  END SCHEDULE;
TEMPORARY CONTROLS (CLINIC CONTROLS):
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        VAVPROFILE = (1 AT 59, .915 AT 68,0 AT 71.4, -.158 AT 72,
```

```
                          -.18 AT 74, -.67 AT 78, -1. AT 86);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - VAVPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
TEMPORARY CONTROLS (SIZING CONTROLS):
**
** THIS CONTROL PROFILE IS SOLELY FOR THE PURPOSE OF DETERMINING
** SYSTEM CAPACITY.
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        DESPROFILE = (1 AT 68, 0 AT 68, 0 AT 78, -1 AT 78);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - DESPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
TEMPORARY WALLS:
      EWALL1 = (BRICK - FACE 4 IN,
                CONCRETE - CEMENT MORTAR 1/2 IN,
                CONCRETE - CEMENT MORTAR 1/2 IN,
                CONCRETE - CEMENT MORTAR 1/2 IN,
                CONCRETE - CEMENT MORTAR 1/2 IN,
                C3 - 4 IN HW CONCRETE BLOCK,
                B1 - AIRSPACE RESISTANCE,
                 BB4),
    PWALL1 = (BB4,
                B1 - AIRSPACE RESISTANCE,
                  BB4),
      PWALL2 = (C8 - 8 IN HW CONCRETE BLOCK,
                B1 - AIRSPACE RESISTANCE,
                  BB4),
      CPWALL = (A1 - 1 IN STUCCO,
                C10 - 8 IN HW CONCRETE,
   E1);
END;
TEMPORARY ROOFS:
      ROOF1 = (E2 - 1/ 2 IN SLAG OR STONE,
               E3 - 3/8 IN FELT AND MEMBRANE,
               A3 - STEEL SIDING,
               E4 - CEILING AIRSPACE,
               B4 - 3 IN INSULATION,
               E5 - ACOUSTIC TILE),
      CPCEIL =(FINISH FLOORING - TILE 1/16 IN,
               C10 - 8 IN HW CONCRETE,
               B1 - AIRSPACE RESISTANCE,
               B2 - 1 IN INSULATION);
END;
TEMPORARY FLOORS:
      FLOOR1 = (B2 - 1 IN INSULATION,
```

```
                B1 - AIRSPACE RESISTANCE,

                C10 - 8 IN HW CONCRETE,
                FINISH FLOORING - TILE 1/16 IN),
      CPFLOOR = (DIRT 12 IN);
END;
TEMPORARY DOORS:
      WINDOW PANEL = (GLASS - HEAT ABSORBING PLATE 1/ 2 IN,
                     IN5,
                      C3 - 4 IN HW CONCRETE BLOCK,
                      BB4);
END;
******************  SITE SPECIFIC INFORMATION  ***************
PROJECT = "DENTAL CLINIC PROTOTYPE ";
**      LOCATION= FT HOOD;
         LOCATION=COLSPRG;
 **      LOCATION=COLUM;
 **      LOCATION=RALEIGH;
 **      LOCATION=PHOENIX;
 **      LOCATION=FORTW;
 **      LOCATION=MINNE;
GROUND TEMPERATURES = (62,61,62,65,68,71,75,75,71,68,65,62);
**
**  DESIGN DAYS = CO WINTER,CO SUMMER;
     WEATHER TAPE FROM 01 JAN 80 THRU 31 DEC 80;
**
**************************************************************
BEGIN BUILDING DESCRIPTION;
      NORTH AXIS = 0.;
      DIMENSIONS: HEIGHT1 = 9.;
CRAWL SPACE 1000 "CRAWL SPACE":
      ORIGIN:(0,0,-2.5);
      NORTH AXIS = 0;
   CRAWL SPACE CEILING:
      STARTING AT (0,0,2.5) FACING (180) CPCEIL (92 BY 102);
   SLAB ON GRADE FLOOR:
      STARTING AT (0,102,0) FACING (180) CPFLOOR (92 BY 102);
   BASEMENT WALLS:
      STARTING AT (0,0,0) FACING (180) CPWALL (92 BY 2.5),
      STARTING AT (92,0,0) FACING (90) CPWALL (102 BY 2.5),
      STARTING AT (92,102,0) FACING (0) CPWALL (92 BY 2.5),
      STARTING AT (0,102,0) FACING (270) CPWALL (102 BY 2.5);
END ZONE;
ZONE 1 "NORTH LAB":
      ORIGIN:(14,83,0);
      NORTH AXIS = 0;
   EXTERIOR WALLS:
      STARTING AT (31,19.,0) FACING (0) EWALL1 (31 BY HEIGHT1)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (10,4)
         WITH DOORS OF TYPE WINDOW PANEL
            (6.66 BY 4.0) AT (10,0)
```

```
        WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW

           (3.33 BY 4.25) AT (27.5,4)
        WITH DOORS OF TYPE WINDOW PANEL
           (3.33 BY 4.0) AT (27.5,0)
        WITH OVERHANGS (50 BY 3) AT (-10,HEIGHT1);
  PARTITIONS:
     STARTING AT (31,0,0) FACING (90) PWALL2 (19. BY HEIGHT1),
     STARTING AT (0,0,0) FACING (180) PWALL1 (31 BY HEIGHT1),
     STARTING AT (0,19.,0) FACING (270) PWALL1 (19 BY HEIGHT1);
  ROOFS:
     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (31 BY 19.);
  FLOOR OVER CRAWL SPACE:
     STARTING AT (0,19.,0) FACING (180) FLOOR1 (31 BY 19.);
     PEOPLE = 4,OFFICE OCCUPANCY;
     ELECTRIC EQUIPMENT = 10.24,OFFICE EQUIPMENT;
     LIGHTS = 5.73,OFFICE LIGHTING;
  CONTROLS = CLINIC CONTROLS,   7.589 HEATING, 29.934 COOLING;
END ZONE;
ZONE 2 "NORTH WEST LAB":
     ORIGIN:(0,83,0);
     NORTH AXIS = 0;
  EXTERIOR WALLS:
     STARTING AT (0,0,0) FACING (180) EWALL1 (4 BY HEIGHT1)
        WITH OVERHANGS (7 BY 83) AT (-3,HEIGHT1)
        WITH WINGS (HEIGHT1 BY 83) AT (4,0),
     STARTING AT (0,19,0) FACING (270) EWALL1 (19 BY HEIGHT1)
        WITH OVERHANGS (108 BY 3) AT (-3,HEIGHT1),
     STARTING AT (14,19,0) FACING (0) EWALL1 (14 BY HEIGHT1)
        WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
           (3.33 BY 4.25) AT (.5,4)
        WITH DOOR OF TYPE WINDOW PANEL
           (3.33 BY 4.0) AT (.5,0)
        WITH OVERHANGS (60 BY 3) AT (-42,HEIGHT1);
  PARTITIONS:
     STARTING AT (14,6.5,0) FACING (90) PWALL1 (11.5 BY HEIGHT1),
     STARTING AT (4,0,0) FACING (180) PWALL1 (10 BY HEIGHT1);
  ROOFS:
     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (14 BY 19);
  FLOOR OVER CRAWL SPACE:
     STARTING AT (0,19,0) FACING (180) FLOOR1 (14 BY 19);
  PEOPLE = 2,OFFICE OCCUPANCY;
  LIGHTS = 2.18,OFFICE LIGHTING;
 ELECTRIC EQUIPMENT = 2.,OFFICE EQUIPMENT;
  CONTROLS = CLINIC CONTROLS,   8.008 HEATING, 8.185 COOLING;
END ZONE;
ZONE 3 "WEST OPER RMS":
     ORIGIN:(0,13,0);
     NORTH AXIS = 0.;
  EXTERIOR WALLS:
     STARTING AT (0,70,0) FACING (270) EWALL1 (70 BY HEIGHT1)
        WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
```

```
            (5 BY 8.9) REVEAL (3.67) AT (.5,0.05)
         WITH OVERHANGS (87  BY 3) AT (-16,HEIGHT1)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (13,4)
         WITH DOORS OF TYPE WINDOW PANEL
            (6.66 BY 4.0) AT (13,0)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (33,4)
         WITH DOORS OF TYPE WINDOW PANEL
            (6.66 BY 4.0) AT (33,0)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (53,4)
         WITH DOORS OF TYPE WINDOW PANEL
            (6.66 BY 4.0) AT (53,0);
   PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (19 BY HEIGHT1),
      STARTING AT (19,5,0) FACING (90) PWALL1 (59 BY HEIGHT1),
      STARTING AT (19,70,0) FACING (0) PWALL1 (19 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (19 BY 70);
   FLOOR OVER CRAWL SPACE:
      STARTING AT (0,70,0) FACING (180) FLOOR1 (19 BY 70);
   PEOPLE = 11,OFFICE OCCUPANCY;
   LIGHTS = 7.14,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 3.41,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   24.785 HEATING, 31.68 COOLING;
END ZONE;
ZONE 4 "LOCKER RMS":
      ORIGIN:(18,19,0);
      NORTH AXIS = 0.;
   PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (13 BY HEIGHT1),
      STARTING AT (13,0,0) FACING (90) PWALL1 (59 BY HEIGHT1),
      STARTING AT (13,59,0) FACING (0) PWALL1 (13 BY HEIGHT1),
      STARTING AT (0,59,0) FACING (270) PWALL1 (59 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (13 BY 59);
   FLOOR OVER CRAWL SPACE:
      STARTING AT (0,59,0) FACING (180) FLOOR1 (13 BY 59);
   PEOPLE = 2,OFFICE OCCUPANCY;
   LIGHTS = 3.96,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 0,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   8.186 HEATING, 9.094 COOLING;
END ZONE;
ZONE 5 "LIBRARY CONF RMS":
      ORIGIN:(31,47,0);
      NORTH AXIS = 0;
   PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (6 BY HEIGHT1),
      STARTING AT (6,0,0) FACING (90) PWALL1 (3 BY HEIGHT1),
      STARTING AT (6,3,0) FACING (180) PWALL1 (12 BY HEIGHT1),
```

```
      STARTING AT (18,3,0) FACING (90) PWALL1 (29 BY HEIGHT1),

      STARTING AT (18,36,0) FACING (0) PWALL1 (30 BY HEIGHT1),
      STARTING AT (-12,36,0) FACING (270) PWALL1 (6 BY HEIGHT1),
      STARTING AT (-12,30,0) FACING (180) PWALL1 (12 BY HEIGHT1),
      STARTING AT (0,30,0) FACING (270) PWALL1 (30 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (6 BY 3),
      STARTING AT (0,3,HEIGHT1) FACING (180) ROOF1 (18 BY 33),
      STARTING AT (-12,30,HEIGHT1) FACING (180) ROOF1 (12 BY 6);
   FLOORS OVER CRAWL SPACE:
      STARTING AT (0,3,0) FACING (180) FLOOR1 (6 BY 3),
      STARTING AT (0,36,0) FACING (180) FLOOR1 (18 BY 33),
      STARTING AT (-12,36,0) FACING (180) FLOOR1 (12 BY 6);
   PEOPLE = 4,OFFICE OCCUPANCY;
   LIGHTS = 3.28,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 3.41,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   4.639 HEATING, 14.143 COOLING;
END ZONE;
ZONE 6 "WAITING ROOM":
      ORIGIN:(19,13,0);
      NORTH AXIS = 0.;
   PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (42 BY HEIGHT1),
      STARTING AT (42,5.5,0) FACING (0) PWALL1 (12 BY HEIGHT1),
      STARTING AT (30,5.5,0) FACING (90) PWALL1 (31 BY HEIGHT1),
      STARTING AT (30,36.5,0) FACING (0) PWALL1 (12 BY HEIGHT1),
      STARTING AT (18,36.5,0) FACING (270) PWALL1 (3 BY HEIGHT1),
      STARTING AT (18,33.5,0) FACING (0) PWALL1  (6 BY HEIGHT1),
      STARTING AT (12,33.5,0) FACING (270) PWALL1 (28 BY HEIGHT1),
      STARTING AT (12,5.5,0) FACING (0) PWALL1 (12 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (42 BY 5.5),
      STARTING AT (12,5.5,HEIGHT1) FACING (180) ROOF1 (18 BY 28),
      STARTING AT (18,33.5,HEIGHT1) FACING (180) ROOF1 (12 BY 3);
   FLOORS OVER CRAWL SPACE:
      STARTING AT (0,5.5,0) FACING (180) FLOOR1 (42 BY 5.5),
      STARTING AT (12,33.5,0) FACING (180) FLOOR1 (18 BY 28),
      STARTING AT (18,36.5,0) FACING (180) FLOOR1 (12 BY 3);
   PEOPLE = 31,OFFICE OCCUPANCY;
   LIGHTS = 2.73,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 1.82,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   0. HEATING, 19.512 COOLING;
END ZONE;
ZONE 7 "RECORDS AND SUPPLY":
      ORIGIN:(49,18.5,0);
      NORTH AXIS = 0.;
   PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (12 BY HEIGHT1),
      STARTING AT (12,0,0) FACING (90) PWALL1 (45 BY HEIGHT1),
      STARTING AT (12,45,0) FACING (180) PWALL1 (6 BY HEIGHT1),
      STARTING AT (18,45,0) FACING (90) PWALL1 (13 BY HEIGHT1),
```

```
      STARTING AT (18,58,0) FACING (180) PWALL1 (7 BY HEIGHT1),

      STARTING AT (25,64.5,0) FACING (0) PWALL2 (25 BY HEIGHT1),
      STARTING AT (0,64.5,0) FACING (270) PWALL1 (64.5 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (12 BY 64.5),
      STARTING AT (12,45,HEIGHT1) FACING (180) ROOF1 (6 BY 18.5),
      STARTING AT (18,58,HEIGHT1) FACING (180) ROOF1 (7 BY 5.5);
   FLOORS OVER CRAWL SPACE:
      STARTING AT (0,64.5,0) FACING (180) FLOOR1 (12 BY 64.5),
      STARTING AT (12,64.5,0) FACING (180) FLOOR1 (6 BY 18.5),
      STARTING AT (18,64.5,0) FACING (180) FLOOR1 (7 BY 5.5);
   PEOPLE = 7,OFFICE OCCUPANCY;
   LIGHTS = 4.37,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 3.41,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   7.256 HEATING, 17.428 COOLING;
END ZONE;
ZONE 8 "XRAY":
      ORIGIN:(61,13,0);
      NORTH AXIS = 0.;
  PARTITIONS:
      STARTING AT (0,0,0) FACING (180) PWALL1 (16 BY HEIGHT1),
      STARTING AT (16,0,0) FACING (90) PWALL1 (69 BY HEIGHT1),
      STARTING AT (16,69,0) FACING (0) PWALL2 (4 BY HEIGHT1),
      STARTING AT (12,64,0) FACING (0) PWALL1 (7 BY HEIGHT1),
      STARTING AT (5,64,0) FACING (270) PWALL1 (14 BY HEIGHT1),
      STARTING AT (5,50,0) FACING (0) PWALL1 (5 BY HEIGHT1),
      STARTING AT (0,50,0) FACING (270) PWALL1 (45 BY HEIGHT1);
   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (16 BY 50),
      STARTING AT (5,50,HEIGHT1) FACING (180) ROOF1 (11 BY 14),
      STARTING AT (12,64,HEIGHT1) FACING (180) ROOF1 (4 BY 5);
   FLOORS OVER CRAWL SPACE:
      STARTING AT (0,50,0) FACING (180) FLOOR1 (16 BY 50),
      STARTING AT (5,64,0) FACING (180) FLOOR1 (11 BY 14),
      STARTING AT (12,69,0) FACING (180) FLOOR1 (4 BY 5);
   PEOPLE = 5,OFFICE OCCUPANCY;
   LIGHTS = 3.96,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 2.9,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   10.374 HEATING, 15.217 COOLING;
END ZONE;
ZONE 9 "SOUTH OPER RMS":
      ORIGIN:(0,0,0);
      NORTH AXIS = 0.;
   EXTERIOR WALLS:
      STARTING AT (0,0,0) FACING (180) EWALL1 (92 BY HEIGHT1)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (9,4)
         WITH DOORS OF TYPE WINDOW PANEL
            (6.66 BY 4.0) AT (9,0)
         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
            (6.66 BY 4.25) AT (28,4)
```

```
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (28,0)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (8 BY 8.9) REVEAL (4) AT (42,.05)
      WITH OVERHANGS (98 BY 3) AT (-3,HEIGHT1)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (6.66 BY 4.25) AT (58,4)
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (58,0)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (6.66 BY 4.25) AT (78,4)
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (78,0),
   STARTING AT (92,0,0) FACING (90) EWALL1 (13.5 BY HEIGHT1)
      WITH OVERHANGS (100 BY 3) AT (-3,HEIGHT1),
   STARTING AT (0,13.5,0) FACING (270) EWALL1 (13.5 BY HEIGHT1)
      WITH OVERHANGS (100 BY 3) AT (-93.5,HEIGHT1);
PARTITIONS:
   STARTING AT (92,13.5,0) FACING (0) PWALL1 (92 BY HEIGHT1);
ROOFS:
   STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (92 BY 13.5);
FLOOR OVER CRAWL SPACE:
   STARTING AT (0,13.5,0) FACING (180) FLOOR1 (92 BY 13.5);
PEOPLE = 11,OFFICE OCCUPANCY;
LIGHTS = 9.28,OFFICE LIGHTING;
ELECTRIC EQUIPMENT = 3.41,OFFICE EQUIPMENT;
CONTROLS = CLINIC CONTROLS,   33.431 HEATING, 32.094 COOLING;
END ZONE;
ZONE 10 "EAST OPER RMS":
   ORIGIN:(77,13,0);
   NORTH AXIS = 0.;
PARTITIONS:
   STARTING AT (0,0,0) FACING (180) PWALL1 (15 BY HEIGHT1),
   STARTING AT (0,70,0) FACING (270) PWALL1 (70 BY HEIGHT1),
   STARTING AT (15,70,0) FACING (0) PWALL2 (15 BY HEIGHT1);
EXTERIOR WALLS:
   STARTING AT (15,0,0) FACING (90) EWALL1 (70 BY HEIGHT1)
     WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (6.66 BY 4.25) AT (12,4)
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (12,0)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (6.66 BY 4.25) AT (32,4)
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (32,0)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (6.66 BY 4.25) AT (51,4)
      WITH DOORS OF TYPE WINDOW PANEL
         (6.66 BY 4.0) AT (51,0)
      WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
         (5 BY 8.9) REVEAL (3.67) AT (65,0)
```

```
        WITH OVERHANGS (76 BY 3) AT (-3,HEIGHT1);

   ROOFS:
      STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (15 BY 70);
   FLOOR OVER CRAWL SPACE:
      STARTING AT (0,70,0) FACING (180) FLOOR1 (15 BY 70);
   PEOPLE = 8,OFFICE OCCUPANCY;
   LIGHTS = 6.41,OFFICE LIGHTING;
   ELECTRIC EQUIPMENT = 3.41,OFFICE EQUIPMENT;
   CONTROLS = CLINIC CONTROLS,   23.698 HEATING, 27.324 COOLING;
END ZONE;
END BUILDING DESCRIPTION;
**
**
**       FAN SYSTEM DESCRIPTION SECTION
BEGIN FAN SYSTEM DESCRIPTION;
  TERMINAL REHEAT SYSTEM 10 "BASE CASE- CONSTANT VOLUME FAN " SERVING
    ZONES 1,2,3,4,5,6,7,8,9,10;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 955;
      REHEAT CAPACITY = 6.95;
**    EXHAUST AIR VOLUME=1000.;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 261;
      REHEAT CAPACITY = 7.34;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1010;
      REHEAT CAPACITY = 22.70;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 290;
      REHEAT CAPACITY =7.50;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 451;
      REHEAT CAPACITY = 4.25;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 622;
      REHEAT CAPACITY = 2.0;
    END ZONE;
    FOR ZONE 7:
      SUPPLY AIR VOLUME = 556;
      REHEAT CAPACITY = 6.65;
    END ZONE;
    FOR ZONE 8:
      SUPPLY AIR VOLUME = 485;
      REHEAT CAPACITY = 9.50;
    END ZONE;
```

```
    FOR ZONE 9:
      SUPPLY AIR VOLUME = 1024;
      REHEAT CAPACITY = 30.62;
    END ZONE;
    FOR ZONE 10:
      SUPPLY AIR VOLUME = 871;
      REHEAT CAPACITY = 21.71;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      COLD DECK TEMPERATURE = 55;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
  VARIABLE VOLUME SYSTEM 11  "VAV WITH INLET VANES " SERVING
    ZONES 1,2,3,4,5,6,7,8,9,10;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 955;
      REHEAT CAPACITY = 6.95;
**    EXHAUST AIR VOLUME=1000.;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 261;
      REHEAT CAPACITY = 7.34;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1010;
      REHEAT CAPACITY = 22.70;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 290;
      REHEAT CAPACITY =7.50;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 451;
      REHEAT CAPACITY = 4.25;
    END ZONE;
    FOR ZONE 6:
```

```
      SUPPLY AIR VOLUME = 622;

      REHEAT CAPACITY = 2.0;
    END ZONE;
    FOR ZONE 7:
      SUPPLY AIR VOLUME = 556;
      REHEAT CAPACITY = 6.65;
    END ZONE;
    FOR ZONE 8:
      SUPPLY AIR VOLUME = 485;
      REHEAT CAPACITY = 9.50;
    END ZONE;
    FOR ZONE 9:
      SUPPLY AIR VOLUME = 1024;
      REHEAT CAPACITY = 30.62;
    END ZONE;
    FOR ZONE 10:
      SUPPLY AIR VOLUME = 871;
      REHEAT CAPACITY = 21.71;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
       HOT DECK TEMPERATURE=160;
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      FAN POWER COEFFICIENTS = (.46528,-.97137,3.24901,-2.97682,1.23543);
      COLD DECK TEMPERATURE = 59;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
  VARIABLE VOLUME SYSTEM 12 "VAV WITH DISCHARGE DAMPERS" SERVING
    ZONES 1,2,3,4,5,6,7,8,9,10;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 955;
      REHEAT CAPACITY = 6.95;
**    EXHAUST AIR VOLUME=1000.;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 261;
      REHEAT CAPACITY = 7.34;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1010;
```

```
      REHEAT CAPACITY = 22.70;

    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 290;
      REHEAT CAPACITY =7.50;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 451;
      REHEAT CAPACITY = 4.25;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 622;
      REHEAT CAPACITY = 2.0;
    END ZONE;
    FOR ZONE 7:
      SUPPLY AIR VOLUME = 556;
      REHEAT CAPACITY = 6.65;
    END ZONE;
    FOR ZONE 8:
      SUPPLY AIR VOLUME = 485;
      REHEAT CAPACITY = 9.50;
    END ZONE;
    FOR ZONE 9:
      SUPPLY AIR VOLUME = 1024;
      REHEAT CAPACITY = 30.62;
    END ZONE;
    FOR ZONE 10:
      SUPPLY AIR VOLUME = 871;
      REHEAT CAPACITY = 21.71;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
       HOT DECK TEMPERATURE=160;
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      FAN POWER COEFFICIENTS =(.28376,1.43027,-1.19437,.46465,0);
      COLD DECK TEMPERATURE = 59;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
```

```
**

  VARIABLE VOLUME SYSTEM 13 " VAV WITH AC INVERTER" SERVING
    ZONES 1,2,3,4,5,6,7,8,9,10;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 955;
      REHEAT CAPACITY = 6.95;
**    EXHAUST AIR VOLUME=1000.;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 261;
      REHEAT CAPACITY = 7.34;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1010;
      REHEAT CAPACITY = 22.70;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 290;
      REHEAT CAPACITY =7.50;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 451;
      REHEAT CAPACITY = 4.25;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 622;
      REHEAT CAPACITY = 2.0;
    END ZONE;
    FOR ZONE 7:
      SUPPLY AIR VOLUME = 556;
      REHEAT CAPACITY = 6.65;
    END ZONE;
    FOR ZONE 8:
      SUPPLY AIR VOLUME = 485;
      REHEAT CAPACITY = 9.50;
    END ZONE;
    FOR ZONE 9:
      SUPPLY AIR VOLUME = 1024;
      REHEAT CAPACITY = 30.62;
    END ZONE;
    FOR ZONE 10:
      SUPPLY AIR VOLUME = 871;
      REHEAT CAPACITY = 21.71;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
       HOT DECK TEMPERATURE=160;
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      FAN POWER COEFFICIENTS = (.26614,-1.13998,2.78771,-.9096,0);
```

```
      COLD DECK TEMPERATURE = 59;

      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
END FAN SYSTEM DESCRIPTION;
BEGIN CENTRAL PLANT DESCRIPTION;
     PLANT 1 "DUMMY PLANT" SERVING ALL SYSTEMS;
      EQUIPMENT SELECTION:
         1 BOILER OF SIZE 100;
      END EQUIPMENT SELECTION;
**          OTHER PLANT PARAMETERS:
**             REPORT VARIABLES = (1,2,3,4,8);
**          END;
     END PLANT;
  END CENTRAL PLANT DESCRIPTION;
END INPUT;
```

APPENDIX B:

SAMPLE INPUT FILE FOR BATTALION HEADQUARTERS

```
** BATTALION HEADQUARTERS PROTOTYPE BUILDING
 **
** THIS BUILDING WAS ORIGINALLY USED FOR THE LEDEMO PROJECT
**THIS BASELINE MODEL IS OF THE FRBL SERIES, COMPLETED 12/83.
 **THIS IS THE BASIC BASELINE BUILDING WITH NO MODIFICATIONS.
 BEGIN INPUT;
 RUN CONTROL:
    NEW ZONES, NEW AIR SYSTEMS, UNITS(ENGLISH);
**  REPORTS(ZONE LOADS);
  TEMPORARY SCHEDULE (CLASSROOM):
    MONDAY THRU THURSDAY = (11 TO 09-0.0, 09 TO 11-1.0),
    FRIDAY THRU SUNDAY = (00 TO 24-0.0),
    HOLIDAY = SUNDAY;
  END;
TEMPORARY SCHEDULE(SYSOP):
    MONDAY THRU FRIDAY=(07 TO 17-1.0,17 TO 07-0.0),
    SATURDAY THRU SUNDAY=(00 TO 24-0.0),
    HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE(OFFICE VENT):
     MONDAY THRU FRIDAY=(08 TO 17-0.2,17 TO 08-0.1),
     SATURDAY THRU SUNDAY=(00 TO 24-0.1),
     HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE (VENT):
    MONDAY THRU FRIDAY = (07 TO 17-0.1, 17 TO 07-0),
    SATURDAY THRU SUNDAY = (00 TO 24-0),
    HOLIDAY = SUNDAY;
  END;
 TEMPORARY SCHEDULE (HV):
   MONDAY THRU FRIDAY = (06 TO 17-ON, 17 TO 06-OFF),
   SATURDAY THRU SUNDAY = (00 TO 24-OFF),
   HOLIDAY = SUNDAY;
 END;
TEMPORARY DESIGN DAYS:

  CO WINTER=(HIGH=-3,LOW=-3,WB=-5,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  CO SUMMER=(HIGH=91,LOW=61,WB=78,WEEKDAY),

  MO WINTER=(HIGH=-1,LOW=-1,WB=-3,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  MO SUMMER=(HIGH=97,LOW=75,WB=78,WEEKDAY),

  NC WINTER=(HIGH=16,LOW=16,WB=12,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  NC SUMMER=(HIGH=94,LOW=74,WB=78,WEEKDAY),

  AZ WINTER=(HIGH=31,LOW=31,WB=25,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  AZ SUMMER=(HIGH=109,LOW=82,WB=76,WEEKDAY),

  TX WINTER=(HIGH=17,LOW=17,WB=13,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  TX SUMMER=(HIGH=101,LOW=79,WB=78,WEEKDAY),

  MN WINTER=(HIGH=-16,LOW=-16,WB=-17,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
```

```
  MN SUMMER=(HIGH=92,LOW=70,WB=77,WEEKDAY);

END DESIGN DAYS;
TEMPORARY CONTROLS (OFFICE CONTROLS):
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        VAVPROFILE = (1 AT 59, .915 AT 68,0 AT 71.4, -.158 AT 72,
                    -.18 AT 74, -.67 AT 78, -1. AT 86);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - VAVPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
TEMPORARY CONTROLS (SIZING CONTROLS):
**
** THIS CONTROL PROFILE IS SOLELY FOR THE PURPOSE OF DETERMINING
** SYSTEM CAPACITY.
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        DESPROFILE = (1 AT 68, 0 AT 68, 0 AT 78, -1 AT 78);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - DESPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
  TEMPORARY CONTROLS (MECHANICAL AND VESTIBULE CONTROLS):
    PROFILES:
      SETBACK = (1.0 AT 48, 0.0 AT 50);
    SCHEDULES:
      SUNDAY THRU SATURDAY = (00 TO 24-SETBACK),
      HOLIDAY = SUNDAY;
  END;
 TEMPORARY CONTROLS (STORAGE CONTROLS):
   PROFILES:
     SETBACK = (1.0 AT 38, 0.0 AT 40);
   SCHEDULES:
     SUNDAY THRU SATURDAY = (00 TO 24 - SETBACK),
     HOLIDAY = SUNDAY;
 END;
  TEMPORARY MATERIALS:
    JUMBO BRICK = (L=0.500,K=0.420,D=120,CP=0.20,TABS=0.90,ABS=0.70,ROUGH);
  END;
  TEMPORARY ROOFS:
    ROOF1 = (RF3,WD5,IN3),
    ROOF2 = (E5);
  END;
    TEMPORARY FLOORS:
    FLOOR1 = (E5);
  END;
  TEMPORARY WALLS:
    EXWAL1 = (JUMBO BRICK,IN23,CB18),
    EXWAL2 = (JUMBO BRICK,IN23,CB14),
```

```
   INWAL1 = (PL4,AR4,PL4),

   INWAL2 = (PL4,AR4,IN9,AR4,PL4);
  END;
******************  SITE SPECIFIC INFORMATION  **********************

   PROJECT = "BATTALION HEADQUARTERS PROTOTYPE BLDG.";
 **     LOCATION=FTRILY ;
        LOCATION=COLSPRG;
 **     LOCATION=COLUM;
 **     LOCATION=RALEIGH;
 **     LOCATION=PHOENIX;
 **     LOCATION=FORTW;
 **     LOCATION=MINNE;
 **   DESIGN DAYS = CO SUMMER, CO WINTER;
    WEATHER TAPE FROM 1 JAN THRU 31 DEC;
   GROUND TEMPERATURES = (54,55,58,62,67,74,72,68,64,62,58,55);
**
*********************************************************************
  **  BUILDING DESCRIPTION
  BEGIN BUILDING DESCRIPTION;
    SOLAR DISTRIBUTION = -1;
   NORTH AXIS=   0.0;
 ** START OF ZONE
   ZONE     1  "MECH ROOM":
     ORIGIN:(  98.5,   58.4,    0.0);
       EXTERIOR WALLS:
         STARTING AT (  16.2,   36.3,    0.0) FACING(   0.0)
           EXWAL2 (  39.80 BY    8.0)
           WITH DOORS OF TYPE ALUMINUM DOOR
             (   6.7 BY    6.6) AT (  10.8,    0.0);
       INTERZONE PARTITIONS:
         STARTING AT ( -23.6,   36.3,    0.0) FACING( 270.0)
           PT21 (   10.0 BY    8.0) ADJACENT TO ZONE (4),
         STARTING AT ( -23.6,   26.3,    0.0) FACING(   0.0)
           PT21 (    7.8 BY    8.0) ADJACENT TO ZONE (4),
         STARTING AT ( -31.3,   26.3,    0.0) FACING( 270.0)
           PT21 (   10.7 BY    8.0) ADJACENT TO ZONE (5),
         STARTING AT ( -31.3,   15.7,    0.0) FACING( 180.0)
           PT21 (  31.3 BY    8.0) ADJACENT TO ZONE (5),
         STARTING AT (    0.0,   15.7,    0.0) FACING( 270.0)
           PT21 (   15.7 BY    8.0) ADJACENT TO ZONE (5),
         STARTING AT (    0.0,    0.0,    0.0) FACING( 180.0)
           PT22 (   16.2 BY    8.0) ADJACENT TO ZONE (5),
         STARTING AT (   16.2,    0.0,    0.0) FACING(  90.0)
           PT21 (   36.3 BY    8.0) ADJACENT TO ZONE (3);
       INTERZONE CEILING:
         STARTING AT (  0.0,    0.0,   8.0) FACING(    180.0)
           ROOF2 (   31.8 BY    36.3) ADJACENT TO ZONE (7);
       SLAB ON GRADE FLOOR:
         STARTING AT (  0.0,    36.3,    0.0) FACING(180.)
           FL18 (   31.84 BY   36.3);
```

```
      INFILTRATION =     228., CONSTANT,

      WITH COEFFICIENT^ (.212, .00719, .000213, 0.0);
      CONTROLS= MECHANICAL AND VESTIBULE CONTROLS, 15 HEATING, 0 COOLING;
    END ZONE;
**  START OF ZONE
    ZONE     2  "STORAGE AREA":
      ORIGIN:(   6.9,  58.4,   0.0);
        EXTERIOR WALLS:
          STARTING AT (   0.0,   36.3,    0.0) FACING( 270.0)
            EXWAL1 (  36.3 BY   8.0),
          STARTING AT (  15.9,   36.3,    0.0) FACING(   0.0)
            EXWAL2 (  15.9 BY   8.0);
        INTERZONE PARTITIONS:
          STARTING AT (   0.0,    0.0,    0.0) FACING( 180.0)
            PT22 (    7.2 BY   8.0) ADJACENT TO ZONE (5),
          STARTING AT (   7.2,    0.0,    0.0) FACING(  90.0)
            PT21 (   16.7 BY   8.0) ADJACENT TO ZONE (5),
          STARTING AT (   7.2,   16.7,    0.0) FACING( 180.0)
            PT21 (    5.3 BY   8.0) ADJACENT TO ZONE (5),
          STARTING AT (  12.6,   16.7,    0.0) FACING(  90.0)
            PT21 (    9.7 BY   8.0) ADJACENT TO ZONE (5),
          STARTING AT (  12.6,   26.3,    0.0) FACING( 180.0)
            PT21 (    3.3 BY   8.0) ADJACENT TO ZONE (5),
          STARTING AT (  15.9,   26.3,    0.0) FACING(  90.0)
            PT21 (   10.0 BY   8.0) ADJACENT TO ZONE (4);
        INTERZONE CEILING:
          STARTING AT (  0.0,   0.0,   8.0) FACING(   180.0)
            ROOF2 (  20.0 BY   20.0) ADJACENT TO ZONE (7);
        SLAB ON GRADE FLOOR:
          STARTING AT (  20.0,    0.0,    0.0) FACING(   0.0)
            FL18 (  20.0 BY   20.0);
        INFILTRATION =    120., CONSTANT,
          WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
        CONTROLS= STORAGE CONTROLS, 11 HEATING, 0 COOLING;
    END ZONE;
**  START OF ZONE
    ZONE     3  "CLASS":
      ORIGIN:( 114.7,  58.4,   0.0);
        EXTERIOR WALLS:
          STARTING AT (  63.5,    7.0,    0.0) FACING(  90.0)
            EXWAL1 (  29.3 BY   8.0),
          STARTING AT (  63.5,   36.3,    0.0) FACING(   0.0)
            EXWAL2 (  63.5 BY   8.0)
            WITH WINDOWS OF TYPE DOUBLE PANE WINDOW
              (  6.7 BY    6.7) AT (  36.0,    1.0)
            WITH DOORS OF TYPE ALUMINUM DOOR
              ( 13.3 BY    6.6) AT (  48.4,    0.0),
          STARTING AT (  63.5,    0.0,    0.0) FACING(  90.0)
            EXWAL1 (    7.0 BY   8.0);
        INTERZONE PARTITIONS:
          STARTING AT (   0.0,   36.3,    0.0) FACING( 270.0)
```

```
        PT21 (  36.3 BY   8.0) ADJACENT TO ZONE (1),
      STARTING AT (   0.0,    0.0,    0.0) FACING( 180.0)
        PT22 (  63.5 BY   8.0) ADJACENT TO ZONE (5);
    INTERZONE CEILING:
      STARTING AT (  0.,   0.0, 8.0) FACING(   180.0)
        ROOF2 (  36.3 BY   63.5) ADJACENT TO ZONE (7);
    SLAB ON GRADE FLOOR:
      STARTING AT (  0.0,  36.3,    0.0) FACING (180.0)
        FL18 (  63.5 BY   36.3);
    INFILTRATION =    383., CONSTANT,
    WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
    PEOPLE=  90, CLASSROOM;
    LIGHTS=  20.45, CLASSROOM;
    CONTROLS= OFFICE CONTROLS,   73.491 HEATING, 44.640 COOLING;
    INTERNAL MASS:
   INWAL1 (  48.33 BY   24.00);
END ZONE;
** START OF ZONE
ZONE     4  "N OFFICE":
  ORIGIN:(  22.8,  84.8,   0.0);
    EXTERIOR WALLS:
      STARTING AT (  52.1,  10.0,    0.0) FACING(   0.0)
        EXWAL2 (  52.1 BY   8.0)
        WITH WINDOWS OF TYPE DOUBLE PANE WINDOW
          ( 16.7 BY   6.7) AT (   8.8,   1.0);
    INTERZONE PARTITIONS:
      STARTING AT (   0.0,  10.0,    0.0) FACING( 270.0)
        PT21 (  10.0 BY   8.0) ADJACENT TO ZONE (2),
      STARTING AT (   0.0,    0.0,    0.0) FACING( 180.0)
        INWAL1 (  44.4 BY   8.0) ADJACENT TO ZONE (5),
      STARTING AT (  44.4,    0.0,    0.0) FACING( 180.0)
        PT21 (   7.7 BY   8.0) ADJACENT TO ZONE (1),
      STARTING AT (  52.1,    0.0,    0.0) FACING(  90.0)
        PT21 (  10.0 BY   8.0) ADJACENT TO ZONE (1);
    INTERZONE CEILING:
      STARTING AT (  0.0,   0.0, 8.0) FACING(   180.0)
        ROOF2 (  52.1 BY   10.0) ADJACENT TO ZONE (7);
    SLAB ON GRADE FLOOR:
      STARTING AT (  52.1,    0.0,    0.0) FACING(   0.0)
        FL18 (  52.1 BY   10.0);
    INFILTRATION =    113., CONSTANT,
    WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
    PEOPLE=   5.0,OFFICE OCCUPANCY;
    LIGHTS=   4.62,OFFICE LIGHTING;
    CONTROLS= OFFICE CONTROLS, 22.807  HEATING, 16.056 COOLING;
    INTERNAL MASS:
   INWAL1 (  40.00 BY   24.00);
END ZONE;
** START OF ZONE
ZONE     5  "INTERIOR":
  ORIGIN:(   6.9,  28.8,   0.0);
```

```
EXTERIOR WALLS:

  STARTING AT ( 171.3,    7.3,    0.0) FACING(  90.0)
    EXWAL1 (  22.3 BY   8.0),
  STARTING AT (   0.0,   29.7,    0.0) FACING( 270.0)
    EXWAL1 (  29.6 BY   8.0)
    WITH DOORS OF TYPE ALUMINUM DOOR
      (  6.7 BY   6.6) AT (   5.1,   0.0),
  STARTING AT ( 161.6,    7.3,    0.0) FACING( 180.0)
    EXWAL2 (   9.7 BY   8.0)
    WITH WINDOWS OF TYPE DOUBLE PANE WINDOW
      (  3.3 BY   6.7) AT (   1.5,   1.0);
INTERZONE PARTITIONS:
  STARTING AT ( 171.3,  29.6,    0.0) FACING(   0.0)
    PT22 (  63.5 BY   8.0) ADJACENT TO ZONE (3),
  STARTING AT (107.8, 29.6, 0.0) FACING (0.0)
    PT22 (16.2 BY  8.0) ADJACENT TO ZONE (1),
  STARTING AT (  91.6,  29.6,    0.0) FACING(  90.0)
    PT21 (   15.8  BY   8.0) ADJACENT TO ZONE (1),
  STARTING AT (  91.6,  45.3,    0.0) FACING(   0.0)
    PT21 (  31.3 BY   8.0) ADJACENT TO ZONE (1),
  STARTING AT (  60.2,  45.3,    0.0) FACING(  90.0)
    PT21 (  10.7 BY   8.0) ADJACENT TO ZONE (1),
  STARTING AT (  60.2,  56.0,    0.0) FACING(   0.0)
    INWAL1 (  44.4 BY   8.0) ADJACENT TO ZONE (4),
  STARTING AT (  15.9,  56.0,    0.0) FACING(   0.0)
    PT21 (   3.3 BY   8.0) ADJACENT TO ZONE (2),
  STARTING AT (  12.6,  56.0,    0.0) FACING( 270.0)
    PT21 (   9.7 BY   8.0) ADJACENT TO ZONE (2),
  STARTING AT (  12.6,  46.3,    0.0) FACING(   0.0)
    PT21 (   5.3 BY   8.0) ADJACENT TO ZONE (2),
  STARTING AT (   7.2,  46.3,    0.0) FACING( 270.0)
    PT21 (  16.7 BY   8.0) ADJACENT TO ZONE (2),
  STARTING AT (   7.2,  29.6,    0.0) FACING(   0.0)
    PT22 (   7.2 BY   8.0) ADJACENT TO ZONE (2),
  STARTING AT (   0.0,   0.0,    0.0) FACING( 180.0)
    INWAL1 (  25.9 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (  25.9,   0.0,    0.0) FACING(  90.0)
    INWAL1 (   4.3 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (  25.9,   4.3,    0.0) FACING( 180.0)
     INWAL2( 14.4 BY 8.0 ) ADJACENT TO ZONE (6),
  STARTING AT (  40.3,   4.3,    0.0) FACING( 270.0)
    INWAL1 (   4.3 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (  40.3,   0.0,    0.0) FACING( 180.0)
    INWAL1 (  54.3 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (  94.6,   0.0,    0.0) FACING(  90.0)
    INWAL1 (  19.3 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (  94.6,  19.3,    0.0) FACING( 180.0)
    INWAL1 (  31.7 BY   8.0) ADJACENT TO ZONE (6),
  STARTING AT (126.3, 19.3, 0.0) FACING (180)
    INWAL1 (17.2 BY 8.0) ADJACENT TO ZONE (8),
  STARTING AT (143.5, 19.3, 0.0) FACING (180.0)
```

```
      INWAL1 (16.4 BY 8.0) ADJACENT TO ZONE (6),

    STARTING AT ( 161.6,  19.3,   0.0) FACING( 270.0)
      INWAL1 (  12.0 BY   8.0) ADJACENT TO ZONE (6);
  INTERZONE CEILING:
    STARTING AT (  0.0,  0.0,  8.0) FACING(  180.0)
      ROOF2 (  94.6 BY  59.21) ADJACENT TO ZONE(7);
  SLAB ON GRADE FLOOR:
    STARTING AT (  0.0,  59.21,   0.0) FACING(  180.)
      FL18 (  94.6 BY  59.21);
  INFILTRATION =   1458., CONSTANT,
  WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
  PEOPLE=  23,OFFICE OCCUPANCY;
  LIGHTS=   49.7,OFFICE LIGHTING;
  CONTROLS= OFFICE CONTROLS, 182.09  HEATING, 114.75 COOLING;
  INTERNAL MASS:
 INWAL1 ( 391.01 BY   24.00);
END ZONE;
** START OF ZONE
ZONE     6  "S OFFICE":
  ORIGIN:(   6.9,  16.8,   0.0);
  EXTERIOR WALLS:
    STARTING AT ( 145.2,  19.3,   0.0) FACING( 180.0)
      EXWAL2 (  16.4 BY   8.0)
      WITH WINDOWS OF TYPE DOUBLE PANE WINDOW
        (  3.3 BY   6.7) AT (   4.0,   1.0),
    STARTING AT (   0.0,  12.0,   0.0) FACING( 270.0)
      EXWAL1 (  12.0 BY   8.0),
    STARTING AT (   0.0,   0.0,   0.0) FACING( 180.0)
      EXWAL2 ( 128.0 BY   8.0)
      WITH WINDOWS OF TYPE DOUBLE PANE WINDOW
        ( 30.0 BY   6.7) AT (  26.7,   1.0),
    STARTING AT ( 128.0,   0.0,   0.0) FACING(  90.0)
      EXWAL1 (  19.3 BY   8.0);
  INTERZONE PARTITIONS:
    STARTING AT ( 161.6,  19.3,   0.0) FACING(  90.0)
      INWAL1 (  12.0 BY   8.0) ADJACENT TO ZONE (5),
    STARTING AT ( 161.6,  31.3,   0.0) FACING(   0.0)
      INWAL1 (  16.4 BY   8.0) ADJACENT TO ZONE (5),
    STARTING AT (145.2, 31.3, 0.0) FACING (270)
      INWAL2 (12.0 BY 8.0) ADJACENT TO ZONE (8),
    STARTING AT (128.0, 19.3, 0.0) FACING (90)
      INWAL2 (12.0 BY 8.0) ADJACENT TO ZONE (8),
    STARTING AT (128.0, 31.3, 0.0) FACING (0)
      INWAL1 (31.7 BY 8.0) ADJACENT TO ZONE (5),
    STARTING AT (  94.6,  31.3,   0.0) FACING( 270.0)
      INWAL1 (  19.3 BY   8.0)  ADJACENT TO ZONE (5),
    STARTING AT (  94.6,  12.0,   0.0) FACING(   0.0)
      INWAL1 (  54.3 BY   8.0) ADJACENT TO ZONE (5),
    STARTING AT (  40.3,  12.0,   0.0) FACING(  90.0)
      INWAL1 (   4.3 BY   8.0) ADJACENT TO ZONE (5),
    STARTING AT (  40.3,  16.3,   0.0) FACING(   0.0)
```

```
           INWAL2 (  14.4 BY   8.0) ADJACENT TO ZONE (5),
         STARTING AT (  25.9,  16.3,   0.0) FACING( 270.0)
           INWAL1 (   4.3 BY   8.0) ADJACENT TO ZONE (5),
         STARTING AT (  25.9,  12.0,   0.0) FACING(   0.0)
           INWAL1 (  25.9 BY   8.0) ADJACENT TO ZONE (5);
       INTERZONE CEILING:
         STARTING AT (  0.0,  0.0,  8.0) FACING(   180.0)
           ROOF2 ( 128.0 BY   17.5) ADJACENT TO ZONE (7),
         STARTING AT (145.2, 19.3, 8.0) FACING (180.0)
           ROOF2 (16.5 BY 12.0) ADJACENT TO ZONE (7);
       SLAB ON GRADE FLOOR:
         STARTING AT (  0.,  17.5,   0.0) FACING( 180.0)
           FL18 ( 128.0 BY   17.5),
         STARTING AT (145.2, 31.3, 0.0) FACING (180.0)
           FL18 (16.5 BY 12.0);
       INFILTRATION =    811., CONSTANT,
       WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
       PEOPLE=  12,OFFICE OCCUPANCY;
       LIGHTS=  23.44,OFFICE LIGHTING;
       CONTROLS= OFFICE CONTROLS,   103.058 HEATING, 71.118 COOLING;
       INTERNAL MASS:
      INWAL1 ( 153.41 BY   24.00);
   END ZONE;
** START OF ZONE
  ZONE      7  "ATTIC":
      ROOF:
         STARTING AT (0.0, 0.0,  11.3)  FACING (180.0)
           TILTED (13.71) ROOF1 (128 BY 42.2),
         STARTING AT (145.7, 19.3,  16.0) FACING (180.0)
           TILTED (13.71) ROOF1 (25.7 BY 22.33),
         STARTING AT (128.0, 16.3, 15.28) FACING (180.0)
           TILTED(13.71)  ROOF1 (17.7 BY 25.42),
         STARTING AT (171.3, 78.0,  12.0)  FACING (0.0)
           TILTED (14.11) ROOF1 (171.33 BY 38.15);
      EXTERIOR WALLS:
          STARTING AT (0.0, 0.0, 8.0) FACING (180.0)
            EXWAL2 (128.0 BY 3.3),
         STARTING AT (128.0, 19.3, 8.0) FACING (180.0)
           EXWAL2 (43.3 BY 8.0),
         STARTING AT (171.3, 78.0, 8.0) FACING (0.0)
           EXWAL2 (171.3 BY 4.0),
         STARTING AT (0.0, 78.0, 8.0)
           EXWAL1 ((37.0, 0.0), (37.0, 13.3), (0.0, 4.0)) FACING (270.0),
         STARTING AT (0.0, 41.0, 8.0)
           EXWAL1 ((41.0, 0.0), (41.0, 3.3), (0.0, 13.3)) FACING (270.0),
         STARTING AT (128.0, 0.0, 8.0)
           EXWAL1 ((19.3, 0.0), (19.3, 8.0), (0.0, 3.3)) FACING (90.0),
         STARTING AT (171.3, 19.3, 8.0)
           EXWAL1 ((21.7, 0.0), (21.7, 13.3), (0.0, 8.0)) FACING (90),
         STARTING AT (171.3, 41.0, 8.0)
           EXWAL1 ((37.0, 0.0), (37.0, 4.0), (0.0, 13.3)) FACING(90);
```

```
        INTERZONE FLOORS:

          STARTING AT (98.5, 58.4, 8.0) FACING (0.0)
            FLOOR1 (31.8 BY 36.3) ADJACENT TO ZONE(1),
          STARTING AT (6.9, 58.4, 8.0) FACING (0.0)
            FLOOR1 (20 BY 20) ADJACENT TO ZONE (2),
          STARTING AT (114.7, 58.4, 8.0) FACING (0.0)
            FLOOR1 (36.3 BY 63.5) ADJACENT TO ZONE (3),
          STARTING AT (22.8, 84.8, 8.0) FACING (0.0)
            FLOOR1 (52.1 BY 10.0) ADJACENT TO ZONE (4),
          STARTING AT (6.9, 28.8, 8.0) FACING (0.0)
            FLOOR1 (94.6 BY 59.2) ADJACENT TO ZONE (5),
          STARTING AT (6.9, 16.8, 8.0) FACING (0.0)
            FLOOR1 (128.0 BY 17.5) ADJACENT TO ZONE (6),
          STARTING AT (134.9, 16.8, 8.0) FACING (0.0)
            FLOOR1 (16.5 BY 12.0) ADJACENT TO ZONE (6),
          STARTING AT (151.4, 16.8, 8.0) FACING (0.0)
            FLOOR1 (17.2 BY 12.0) ADJACENT TO ZONE (8);
      END ZONE;
 ** START OF ZONE
 ZONE 8  "VESTIBULE":
   EXTERIOR WALLS:
     STARTING AT (128.0, 19.3, 0.0) FACING (180.0)
       EXWAL2 (17.2 BY 8.0)
       WITH DOORS OF TYPE ALUMINUM DOOR
         (6.7 BY 6.6) AT (5.0, 0.0);
   INTERZONE PARTITIONS:
     STARTING AT (128.0, 31.3, 0.0) FACING (270.0)
       INWAL2 (12.0 BY 8.0) ADJACENT TO ZONE (6),
     STARTING AT (145.2, 31.3, 0.0) FACING (0.0)
       INWAL1 (17.2 BY 8.0) ADJACENT TO ZONE (5),
     STARTING AT (145.2, 19.3, 0.0) FACING (90.0)
       INWAL2 (12.0 BY 8.0) ADJACENT TO ZONE (6);
   INTERZONE CEILING:
     STARTING AT (128.0, 19.3, 8.0) FACING (180.0)
       ROOF2 (17.2 BY 12.0) ADJACENT TO ZONE (7);
   SLAB ON GRADE FLOOR:
     STARTING AT (128.0, 31.3, 0.0) FACING (180.0)
       FL18 (17.2 BY 12.0);
   INFILTRATION = 100., CONSTANT,
     WITH COEFFICIENTS (.212, .00719, .000213, 0.0);
   CONTROLS = MECHANICAL AND VESTIBULE CONTROLS, 15 HEATING, 0 COOLING;
 END ZONE;
  END BUILDING DESCRIPTION;
**       FAN SYSTEM DESCRIPTION SECTION
BEGIN FAN SYSTEM DESCRIPTION;
  TERMINAL REHEAT SYSTEM 10 "BASE CASE- CONSTANT VOLUME FAN " SERVING
    ZONES 3,4,5,6;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1424;
      REHEAT CAPACITY = 67.32;
    END ZONE;
```

```
    FOR ZONE 4:

      SUPPLY AIR VOLUME = 512;
      REHEAT CAPACITY =20.892;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 3660;
      REHEAT CAPACITY = 166.8;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 2268;
      REHEAT CAPACITY = 94.404;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      COLD DECK TEMPERATURE = 55;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 215;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
  VARIABLE VOLUME SYSTEM 11  "VAV WITH INLET VANES " SERVING
    ZONES 3,4,5,6;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1424;
      BASEBOARD HEAT CAPACITY = 67.32;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 512;
      BASEBOARD HEAT CAPACITY =20.892;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 3660;
      BASEBOARD HEAT CAPACITY = 166.8;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 2268;
      BASEBOARD HEAT CAPACITY = 94.404;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
```

```
        VAV MINIMUM AIR FRACTION=0.3;

        SUPPLY FAN EFFICIENCY = 0.5;
         SUPPLY FAN PRESSURE =0.5;
        FAN POWER COEFFICIENTS = (.46528,-.97137,3.24901,-2.97682,1.23543);
        COLD DECK TEMPERATURE = 59;
        COLD DECK THROTTLING RANGE= 0.0;
        HOT DECK TEMPERATURE = 215;
        HEATING SAT DIFFERENCE=72.;
        COOLING SAT DIFFERENCE=18.;
      END OTHER SYSTEM PARAMETERS;
     EQUIPMENT SCHEDULES:
       MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
       SYSTEM OPERATION=SYSOP;
       COOLING COIL OPERATION=SYSOP;
        TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;
     END EQUIPMENT SCHEDULES;
    END SYSTEM;
    VARIABLE VOLUME SYSTEM 12 "VAV WITH DISCHARGE DAMPERS" SERVING
      ZONES 3,4,5,6;
      FOR ZONE 3:
        SUPPLY AIR VOLUME = 1424;
        BASEBOARD HEAT CAPACITY = 67.32;
      END ZONE;
      FOR ZONE 4:
        SUPPLY AIR VOLUME = 512;
        BASEBOARD HEAT CAPACITY =20.892;
**      EXHAUST AIR VOLUME=600.;
      END ZONE;
      FOR ZONE 5:
        SUPPLY AIR VOLUME = 3660;
        BASEBOARD HEAT CAPACITY = 166.8;
      END ZONE;
      FOR ZONE 6:
        SUPPLY AIR VOLUME = 2268;
        BASEBOARD HEAT CAPACITY = 94.404;
      END ZONE;
      OTHER SYSTEM PARAMETERS:
        VAV MINIMUM AIR FRACTION=0.3;
        SUPPLY FAN EFFICIENCY = 0.5;
         SUPPLY FAN PRESSURE =0.5;
        FAN POWER COEFFICIENTS =(.28376,1.43027,-1.19437,.46465,0);
        COLD DECK TEMPERATURE = 59;
        COLD DECK THROTTLING RANGE= 0.0;
        HOT DECK TEMPERATURE = 215;
        HEATING SAT DIFFERENCE=72.;
        COOLING SAT DIFFERENCE=18.;
      END OTHER SYSTEM PARAMETERS;
     EQUIPMENT SCHEDULES:
       MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
       SYSTEM OPERATION=SYSOP;
       COOLING COIL OPERATION=SYSOP;
```

```
      TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;

   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
  VARIABLE VOLUME SYSTEM 13 " VAV WITH AC INVERTER" SERVING
    ZONES 3,4,5,6;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 1424;
      BASEBOARD HEAT CAPACITY = 67.32;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 512;
      BASEBOARD HEAT CAPACITY =20.892;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 3660;
      BASEBOARD HEAT CAPACITY = 166.8;
    END ZONE;
    FOR ZONE 6:
      SUPPLY AIR VOLUME = 2268;
      BASEBOARD HEAT CAPACITY = 94.404;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE =0.5;
      FAN POWER COEFFICIENTS = (.26614,-1.13998,2.78771,-.9096,0);
      COLD DECK TEMPERATURE = 59;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 215;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
     COOLING COIL OPERATION=SYSOP;
      TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
END FAN SYSTEM DESCRIPTION;
BEGIN CENTRAL PLANT DESCRIPTION;
     PLANT 1 "DUMMY PLANT" SERVING ALL SYSTEMS;
      EQUIPMENT SELECTION:
         1 BOILER OF SIZE 100;
      END EQUIPMENT SELECTION;
**         OTHER PLANT PARAMETERS:
```

```
**            REPORT VARIABLES = (1,2,3,4,8);

**         END;
     END PLANT;
  END CENTRAL PLANT DESCRIPTION;
END INPUT;
```

APPENDIX C:

SAMPLE INPUT FILE FOR LARGE OFFICE BUILDING

```
**        BLAST INPUT FILE
**
**
BEGIN INPUT;
**
**
**       RUN CONTROL SECTION
RUN CONTROL: NEW ZONES,   NEW AIR SYSTEMS;
 **  REPORTS(ZONE LOADS);
**
TEMPORARY SCHEDULE(SYSOP):
    MONDAY THRU FRIDAY=(07 TO 17-1.0,17 TO 07-0.0),
    SATURDAY THRU SUNDAY=(00 TO 24-0.0),
    HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE(OFFICE VENT):
     MONDAY THRU FRIDAY=(08 TO 17-0.2,17 TO 08-0.1),
     SATURDAY THRU SUNDAY=(00 TO 24-0.1),
     HOLIDAY=SUNDAY;
  END SCHEDULE;
  TEMPORARY SCHEDULE (VENT):
    MONDAY THRU FRIDAY = (07 TO 17-0.1, 17 TO 07-0),
    SATURDAY THRU SUNDAY = (00 TO 24-0),
    HOLIDAY = SUNDAY;
  END;
 TEMPORARY SCHEDULE (HV):
   MONDAY THRU FRIDAY = (06 TO 17-ON, 17 TO 06-OFF),
   SATURDAY THRU SUNDAY = (00 TO 24-OFF),
   HOLIDAY = SUNDAY;
 END;
TEMPORARY DESIGN DAYS:

  CO WINTER=(HIGH=-3,LOW=-3,WB=-5,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  CO SUMMER=(HIGH=91,LOW=61,WB=78,WEEKDAY),

  MO WINTER=(HIGH=-1,LOW=-1,WB=-3,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  MO SUMMER=(HIGH=97,LOW=75,WB=78,WEEKDAY),

  NC WINTER=(HIGH=16,LOW=16,WB=12,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  NC SUMMER=(HIGH=94,LOW=74,WB=78,WEEKDAY),

  AZ WINTER=(HIGH=31,LOW=31,WB=25,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  AZ SUMMER=(HIGH=109,LOW=82,WB=76,WEEKDAY),

  TX WINTER=(HIGH=27,LOW=27,WB=23,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  TX SUMMER=(HIGH=101,LOW=79,WB=78,WEEKDAY),

  MN WINTER=(HIGH=-16,LOW=-16,WB=-17,DATE=21JAN,CLEARNESS=0.0,WEEKDAY),
  MN SUMMER=(HIGH=92,LOW=70,WB=77,WEEKDAY);
END DESIGN DAYS;
TEMPORARY CONTROLS (OFFICE CONTROLS):
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        VAVPROFILE = (1 AT 59, .915 AT 68,0 AT 71.4, -.158 AT 72,
```

```
                    -.18 AT 74, -.67 AT 78, -1. AT 86);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - VAVPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
TEMPORARY CONTROLS (SIZING CONTROLS):
**
** THIS CONTROL PROFILE IS SOLELY FOR THE PURPOSE OF DETERMINING
** SYSTEM CAPACITY.
      PROFILES:
        SETBACK=(1 AT 59, 0 AT 60),
        DESPROFILE = (1 AT 68, 0 AT 68, 0 AT 78, -1 AT 78);
      SCHEDULES:
         MONDAY THRU FRIDAY = (07 TO 17 - DESPROFILE, 17 TO 07-SETBACK),
         SATURDAY THRU SUNDAY =(00 TO 24-SETBACK),
         HOLIDAY = SUNDAY;
END;
***********************************************************************
**
**       PROJECT PARAMETER SECTION
PROJECT = "MODIFIED PSA BUILDING-  PROTOTYPICAL LARGE OFFICE BUILDING";
        LOCATION=COLSPRG;
 **     LOCATION=COLUM;
 **     LOCATION=PHOENIX;
 **  LOCATION=HOUSTON;
 **     LOCATION=MINNE;
 ** DESIGN DAYS = CO SUMMER,CO WINTER;
WEATHER TAPE FROM 01 JAN 80 THRU 31 DEC 80;
**
**************************************************************************
**
**       BUILDING DESCRIPTION SECTION
BEGIN BUILDING DESCRIPTION;
**
**  GLOBAL DUMMY VARIABLES
**
DIMENSIONS:  WHEIGHT1=5,
             WHEIGHT2=4.5;
**
**
ZONE  1 "SOUTH FACING OFFICES":
  ORIGIN: (0,0,0);
**
**
  EXTERIOR WALLS:
**
     STARTING AT (-75,-75,0)
       FACING ( 180 )
       EXTWALL04( 150 BY 10)
         WITH WINDOWS OF TYPE
           DPW ( 140  BY WHEIGHT1 )
           AT ( 5,WHEIGHT2),
**
```

```
     STARTING AT ( -75,-60, 0 )
       FACING ( 270 )
       EXTWALL04( 15 BY 10)
         WITH WINDOWS OF TYPE
           DPW ( 12  BY WHEIGHT1 )
           AT ( 1,WHEIGHT2),
**
     STARTING AT ( 75, -75, 0 )
       FACING ( 90 )
       EXTWALL04( 15 BY 10)
         WITH WINDOWS OF TYPE
           DPW ( 12  BY WHEIGHT1 )
           AT ( 1,WHEIGHT2);
**
**
  PARTITIONS:
**
     STARTING AT (  75,-60, 0 )
       FACING ( 0 )
       PARTITION23( 150 BY 10);
**
**
  CEILING:
**
     STARTING AT ( -75, -75, 10 )
       FACING ( 180 )
       CEILING39( 150 BY 15);
**
**
  FLOOR:
**
     STARTING AT ( -75, -60, 0 )
       FACING ( 180 )
       FLOOR39( 150 BY 15);
  INTERNAL MASS: PARTITION23  ( 360, 2 );
  PEOPLE = 30, OFFICE OCCUPANCY;
  LIGHTS = 20.25, OFFICE LIGHTING;
  ELECTRIC EQUIPMENT = 34, OFFICE OCCUPANCY;
  CONTROLS = OFFICE CONTROLS, 38.75 HEATING, 169.4 COOLING;
  MIXING = 375, HE, FROM ZONE 5;
END ZONE;
**
ZONE  2 "NORTH FACING OFFICES":
  ORIGIN: ( 0, 0,0);
  SAME AS ZONE 1 EXCEPT:
    MIRROR X;
    MIRROR Y;
  CONTROLS = OFFICE CONTROLS, 38.75 HEATING, 148.1 COOLING;
END ZONE;
**
ZONE  3 "SUNSET FACING OFFICES":
  ORIGIN: (-75,60,0);
**
**
```

```
  EXTERIOR WALLS:
**
     STARTING AT (0, 0, 0 )
       FACING ( 270 )
       EXTWALL04( 120 BY 10)
         WITH WINDOWS OF TYPE
           DPW ( 110  BY WHEIGHT1 )
           AT ( 5,WHEIGHT2);
**
**
  PARTITIONS:
**
     STARTING AT ( 15, 0, 0 )
       FACING ( 0 )
       PARTITION23( 15 BY 10),
**
     STARTING AT ( 15,-120, 0 )
       FACING ( 90 )
       PARTITION23( 120 BY 10),
**
     STARTING AT ( 0, -120, 0 )
       FACING ( 180 )
       PARTITION23( 15 BY 10);
**
**
  CEILING:
**
     STARTING AT ( 0,-120, 10 )
       FACING ( 180 )
       CEILING39( 15 BY 120);
**
**
  FLOOR:
**
     STARTING AT ( -0, 0, 0 )
       FACING ( 180 )
       FLOOR39( 15 BY 120);
  INTERNAL MASS: PARTITION23  ( 300, 10 );
  PEOPLE = 24, OFFICE OCCUPANCY;
  LIGHTS = 16.2, OFFICE LIGHTING;
  ELECTRIC EQUIPMENT = 27, OFFICE OCCUPANCY;
  CONTROLS = OFFICE CONTROLS, 27.9 HEATING, 160.1 COOLING;
  MIXING = 300, HE, FROM ZONE 5;
END ZONE;
**
ZONE  4 "SUNRISE FACING OFFICES":
  ORIGIN: (75,60,0);
  SAME AS ZONE 3 EXCEPT:
    MIRROR X;
  CONTROLS = OFFICE CONTROLS, 27.9 HEATING, 177.1 COOLING;
END ZONE;
**
ZONE  5 "INTERIOR OFFICES":
**
```

```
**
  PARTITIONS:
**
      STARTING AT ( -60, -60, 0 )
        FACING ( 180 )
        PARTITION23( 120 BY 10),
**
      STARTING AT ( -60, 60, 0 )
        FACING ( 270 )
        PARTITION23( 120 BY 10),
**
      STARTING AT ( 60, 60, 0 )
        FACING ( 0 )
        PARTITION23( 120 BY 10),
**
      STARTING AT ( 60, -60, 0 )
        FACING ( 90 )
        PARTITION23( 120 BY 10),
**
      STARTING AT ( -35, -35, 0 )
        FACING ( 90 )
        PARTITION23( 70 BY 10),
**
      STARTING AT ( -35, 35, 0 )
        FACING ( 180 )
        PARTITION23( 70 BY 10),
**
      STARTING AT ( 35, 35, 0 )
        FACING ( 270 )
        PARTITION23( 70 BY 10),
**
      STARTING AT ( 35, -35, 0 )
        FACING ( 0 )
        PARTITION23( 70 BY 10);
**
**
  CEILING:
**
      STARTING AT ( -60,-60, 10 )
        FACING ( 180 )
        CEILING39( 120 BY 120);
**
**
  FLOOR:
**
      STARTING AT ( -60, 60, 0 )
        FACING ( 180 )
        FLOOR39( 120 BY 120);
  INTERNAL MASS: PARTITION23  ( 1000, 10 );
  PEOPLE = 160, OFFICE OCCUPANCY;
  LIGHTS = 85.5, OFFICE LIGHTING;
  ELECTRIC EQUIPMENT = 142.5, OFFICE OCCUPANCY;
  CONTROLS = OFFICE CONTROLS, 0 HEATING, 497.4 COOLING;
  MIXING = 375, HE, FROM ZONE 1;
```

```
  MIXING = 375, HE, FROM ZONE 2;
  MIXING = 300, HE, FROM ZONE 3;
  MIXING = 300, HE, FROM ZONE 4;
END ZONE;
**
END BUILDING DESCRIPTION;
**       FAN SYSTEM DESCRIPTION SECTION
BEGIN FAN SYSTEM DESCRIPTION;
  TERMINAL REHEAT SYSTEM 10 "BASE CASE- CONSTANT VOLUME FAN " SERVING
    ZONES 1,2,3,4,5;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 4485;
      REHEAT CAPACITY = 3;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 3923;
      REHEAT CAPACITY =4;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 4238;
      REHEAT CAPACITY = 5;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 4690;
      REHEAT CAPACITY = 6;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 13171;
      REHEAT CAPACITY = 5;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE= 3.0;
      COLD DECK TEMPERATURE = 55;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
    COOLING COIL OPERATION=SYSOP;
      REHEAT COIL OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
  VARIABLE VOLUME SYSTEM 11  "VAV WITH INLET VANES " SERVING
    ZONES 1,2,3,4,5;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 5429;
```

```
    BASEBOARD HEAT CAPACITY = 3;
  END ZONE;
  FOR ZONE 2:
    SUPPLY AIR VOLUME = 4748;
    BASEBOARD HEAT CAPACITY =4;
**  EXHAUST AIR VOLUME=600.;
  END ZONE;
  FOR ZONE 3:
    SUPPLY AIR VOLUME = 5131;
    BASEBOARD HEAT CAPACITY = 5;
  END ZONE;
  FOR ZONE 4:
    SUPPLY AIR VOLUME = 5670;
    BASEBOARD HEAT CAPACITY = 6;
  END ZONE;
  FOR ZONE 5:
    SUPPLY AIR VOLUME = 15944;
    BASEBOARD HEAT CAPACITY = 5;
  END ZONE;
  OTHER SYSTEM PARAMETERS:
    VAV MINIMUM AIR FRACTION=0.3;
    SUPPLY FAN EFFICIENCY = 0.5;
     SUPPLY FAN PRESSURE= 3.0;
    FAN POWER COEFFICIENTS = (.46528,-.97137,3.24901,-2.97682,1.23543);
    COLD DECK TEMPERATURE = 59;
    COLD DECK THROTTLING RANGE= 0.0;
    HOT DECK TEMPERATURE = 140;
    HEATING SAT DIFFERENCE=72.;
    COOLING SAT DIFFERENCE=18.;
  END OTHER SYSTEM PARAMETERS;
 EQUIPMENT SCHEDULES:
   MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
   SYSTEM OPERATION=SYSOP;
    TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;
 END EQUIPMENT SCHEDULES;
END SYSTEM;
VARIABLE VOLUME SYSTEM 12 "VAV WITH DISCHARGE DAMPERS" SERVING
  ZONES 1,2,3,4,5;
  FOR ZONE 1:
    SUPPLY AIR VOLUME = 5429;
    BASEBOARD HEAT CAPACITY = 3;
  END ZONE;
  FOR ZONE 2:
    SUPPLY AIR VOLUME = 4748;
    BASEBOARD HEAT CAPACITY =4;
**  EXHAUST AIR VOLUME=600.;
  END ZONE;
  FOR ZONE 3:
    SUPPLY AIR VOLUME = 5131;
    BASEBOARD HEAT CAPACITY = 5;
  END ZONE;
  FOR ZONE 4:
    SUPPLY AIR VOLUME = 5670;
    BASEBOARD HEAT CAPACITY = 6;
```

```
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 15944;
      BASEBOARD HEAT CAPACITY = 5;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE= 3.0;
      FAN POWER COEFFICIENTS =(.28376,1.43027,-1.19437,.46465,0);
      COLD DECK TEMPERATURE = 59;
      COLD DECK THROTTLING RANGE= 0.0;
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
      TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
  VARIABLE VOLUME SYSTEM 13 " VAV WITH AC INVERTER" SERVING
    ZONES 1,2,3,4,5;
    FOR ZONE 1:
      SUPPLY AIR VOLUME = 5429;
      BASEBOARD HEAT CAPACITY = 3;
    END ZONE;
    FOR ZONE 2:
      SUPPLY AIR VOLUME = 4748;
      BASEBOARD HEAT CAPACITY =4;
**    EXHAUST AIR VOLUME=600.;
    END ZONE;
    FOR ZONE 3:
      SUPPLY AIR VOLUME = 5131;
      BASEBOARD HEAT CAPACITY = 5;
    END ZONE;
    FOR ZONE 4:
      SUPPLY AIR VOLUME = 5670;
      BASEBOARD HEAT CAPACITY = 6;
    END ZONE;
    FOR ZONE 5:
      SUPPLY AIR VOLUME = 15944;
      BASEBOARD HEAT CAPACITY = 5;
    END ZONE;
    OTHER SYSTEM PARAMETERS:
      VAV MINIMUM AIR FRACTION=0.3;
      SUPPLY FAN EFFICIENCY = 0.5;
       SUPPLY FAN PRESSURE= 3.0;
      FAN POWER COEFFICIENTS = (.26614,-1.13998,2.78771,-.9096,0);
      COLD DECK TEMPERATURE = 59;
      COLD DECK THROTTLING RANGE= 0.0;
```

```
      HOT DECK TEMPERATURE = 140;
      HEATING SAT DIFFERENCE=72.;
      COOLING SAT DIFFERENCE=18.;
    END OTHER SYSTEM PARAMETERS;
   EQUIPMENT SCHEDULES:
     MINIMUM VENTILATION SCHEDULE=OFFICE VENT;
     SYSTEM OPERATION=SYSOP;
      TSTAT BASEBOARD HEAT OPERATION = OFF, FROM 01 APR THRU 30 SEP;
   END EQUIPMENT SCHEDULES;
  END SYSTEM;
**
**
END FAN SYSTEM DESCRIPTION;
BEGIN CENTRAL PLANT DESCRIPTION;
     PLANT 1 "DUMMY PLANT" SERVING ALL SYSTEMS;
      EQUIPMENT SELECTION:
         1 BOILER OF SIZE 100;
      END EQUIPMENT SELECTION;
**         OTHER PLANT PARAMETERS:
**            REPORT VARIABLES = (1,2,3,4,8);
**         END;
     END PLANT;
  END CENTRAL PLANT DESCRIPTION;
END INPUT;
```

APPENDIX D:

DESCRIPTION OF SYSTEM SIZING METHOD

The following method was used to size the systems and control profiles for the simulations described in this report.

1. Perform winter and summer design day simulations for the building in question.

   The winter design day has the following characteristics:

   Inside: 68°F (constant) during working hours, 60°F night setback

   Weekday (typically maximum load will come at first hour when temperature setting is raised from 60 to 68°F).

   Outside: ASHRAE 99 percent design temperature
   No sun (clearness = 0.0).

   The summer design day has the following characteristics:

   Inside: 78°F (well-controlled) during working hours, allowed to float at night

   Weekday (typically, maximum load will come in mid-afternoon).

   Outside: ASHRAE 99 percent design temperature is maximum, with range as specified by ASHRAE
   Clearness = 1.0.

   Peak heating loads (PHL) and peak cooling loads (PCL) were determined.

2. System sizing

   CFM: Sizing of the system CFM is typically based on the peak cooling load. For a given cold-deck temperature (59°F for VAV systems and 55°F for reheat systems) and the interior temperature (78°F), and the previously determined peak cooling load, the CFM is given by:

$$CFM = OSZ*PCL/([T_i - T_{cd}]*1.10)$$

   where:

   CFM is cubic feet per minute (cu ft/min)
   PCL is peak cooling load (Btu/hr)
   T_i is the interior temperature (°F)
   T_{cd} is the cold-deck temperature
   OSZ is the oversize factor (OSZ = 1.1 for 10 percent oversizing).

Typically, it is only necessary to use the peak heating load if the maximum reheat temperature needs to be set above the default (140°F). Otherwise, it is only necessary to specify a reheat or baseboard heat capacity that is greater than zero.

3. Control Profile

Once the system is sized correctly, it must be accurately represented as a control profile in the loads section of BLAST. The methodology is detailed in the BLAST manual.

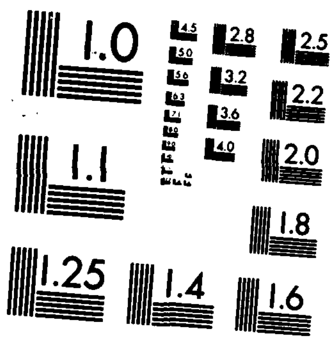
APPENDIX E:

LISTING OF HISTANL AND SAMPLE OUTPUT

```
      PROGRAM HISTANL(INPUT,OUTPUT,TAPE5,TAPE6)
      IMPLICIT REAL(A-Z)
      INTEGER NDAYS,NBINS,I,J,K,AOFF,MOFF,AMINF,MMINF,BINNUM
      DIMENSION NDAYS(12),BINBND(50),MOFF(12),MMINF(12)
      DIMENSION MBIN(12,50),ABIN(50)
      COMMON /BINFO/BINBND,NBINS
      DATA NDAYS/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA NBINS/14/
      DATA MINFRAC/0.3/
      DATA DELTA/0.00001/
*
* **     INITIALIZE BINS
*
      BINSIZ=(1.0-MINFRAC)/NBINS
      BINBND(1)=MINFRAC+DELTA
      DO 100 I=1,NBINS
100      BINBND(I+1)=BINBND(I)+BINSIZ
*
* **     INITIALIZE COUNTERS
*
      AOFF=0
      AMINF=0.0
      DO 150 I=1,12
         MMINF(I)=0
         DO 150 J=1,NBINS
         MOFF(I)=0
            ABIN(J)=0
            MBIN(I,J)=0
150      CONTINUE
*
      ZERO=0.0+DELTA
*
* **     READ LOOP
*
      DO 1000 I=1,12
         DO 900 J=1,NDAYS(I)
            DO 900 K=1,24
               READ(5,*,END=5000) VAL
               IF (VAL .LE. ZERO) THEN
                 MOFF(I)=MOFF(I)+1
               ELSE IF (VAL .LE. MINFRAC) THEN
                 MMINF(I)=MMINF(I)+1
               ELSE
                 CALL BINFND(VAL,BINNUM)
                 MBIN(I,BINNUM)=MBIN(I,BINNUM)+1
               END IF
900      CONTINUE
1000  CONTINUE
*
* **     SUM MONTHLY VALUES
*
      DO 1200 I=1,12
```

AD-A173 399 FAN ELECTRICITY CONSUMPTION FOR VARIABLE-AIR-VOLUME 2/2
SYSTEMS(U) ILLINOIS UNIV AT URBANA J D SPITLER ET AL.
SEP 86 CERL-TR-E-86/06 DACW88-84-D-0031

UNCLASSIFIED F/G 13/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
          AOFF=MOFF(I)+AOFF

          AMINF=AMINF+MMINF(I)
          DO 1200 J=1,NBINS
             ABIN(J)=ABIN(J)+MBIN(I,J)
1200      CONTINUE
*
* **      OUTPUT SECTION
*
       WRITE(6,*)'1                          ANNUAL SUMMARY'
       WRITE(6,*)'0    HOURS FAN IS OFF: ',AOFF
       WRITE(6,*)'0    HOURS FAN IS AT MINIMUM FRACTION: ',AMINF
       WRITE(6,*)'0'
       DO 2000 I=1,NBINS
          WRITE(6,*)'0  FROM ',BINBND(I),' TO ',BINBND(I+1),'   ',ABIN(I)
2000   CONTINUE
       PRINT*,'IGNORE NEXT MESSAGE: '
5000   PRINT*,'WARNING NOT ENOUGH DATA POINTS'
       STOP
       END
*
*
*
       SUBROUTINE BINFND(VAL,BINNUM)
       IMPLICIT REAL(A-Z)
       INTEGER I,BINNUM,NBINS
       DIMENSION BINBND(50)
       COMMON /BINFO/BINBND,NBINS
*
       DO 100 I=1,NBINS
       IF(VAL .LE. BINBND(I+1)) THEN
          BINNUM=I
          RETURN
          END IF
100       CONTINUE
          IF(VAL .GT. BINBND(NBINS+1)) THEN
          PRINT*,'WARNING UPPER LIMIT EXCEEDED'
          END IF
       RETURN
       END
       END
N
```

type,hsum20/cc

ANNUAL SUMMARY

HOURS FAN IS OFF: 6240

HOURS FAN IS AT MINIMUM FRACTION: 54

FROM	.30001	TO	.35001	225.
FROM	.35001	T0	.40001	354.
FROM	.40001	TO	.45001	300.
FROM	.4500	TO	.50001	199.
FROM	.50001	TO	.55001	163.
FROM	.55001	TO	.60001	118.
FROM	.60001	TO	.65001	120.
FROM	.65001	TO	.70001	134.
FROM	.70001	TO	.75001	160.
FROM	.75001	TO	.80001	166.
FROM	.80001	TO	.85001	221.
FROM	.85001	TO	.90001	201.
FROM	.90001	TO	.95001	97.
FROM	.95001	TO	1.00001	8.

USA-CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-IMS-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-EC
ATTN: DAEN-ECC
ATTN: DAEN-ECE
ATTN: DAEN-ECR
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCF
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

FESA, ATTN: Library 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)

US Army Europe
AEAEN-ODCS/Engr 09403
ISAE 09081
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (15)
21st Support Command
ATTN: DEH (12)
USA Berlin
ATTN: DEH (11)
USASETAF
ATTN: DEH (10)
Allied Command Europe (ACE)
ATTN: DEH (3)

8th USA, Korea (19)

USA Japan (USARJ)
ATTN: AJEN-DEH 96343
ATTN: DEH-Honshu 96343
ATTN: DEH-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10966
ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science
ATTN: DSCPER/MAEN-A

AMMRC, ATTN: DRXMR-WE 02172

USA ARRCOM 61299
ATTN: DRCIS-RI-I
ATTN: DRSAR-IS

AMC - Dir., Inst., & Servc
ATTN: DEH (23)

DLA ATTN: DLA-WI 22314

DNA ATTN: NADS 20305

FORSCOM
FORSCOM Engr, ATTN: AFEN-DEH
ATTN: DEH (23)

HSC
ATTN: HSLO-F 78234
ATTN: Facilities Engineer
Fitzsimons AMC 80240
Walter Reed AMC 20012

INSCOM - Ch, Instl. Div
ATTN: Facilities Engineer (3)

ROK/US Combined Forces Command 96301
ATTN: EUSA-HHC-CFC/Engr

MDW, ATTN: DEH (3)

MTMC
ATTN: MTMC-SA 20315
ATTN: Facilities Engineer (3)

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac. Div. 48090

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH
ATTN: DEH (19)

TSARCOM, ATTN: STSAS-F 63120

USACC, ATTN: Facilities Engr (2)

WESTCOM
ATTN: DEH, Ft. Shafter 96858
ATTN: APEN-IM

SHAPE 09055
ATTN: Surv. Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

FORT BELVOIR, VA 22060 (7)
ATTN: Canadian Liaison Officer
ATTN: British Liaison Officer
ATTN: Australian Liaison Officer
ATTN: French Liaison Officer
ATTN: German Liaison Officer
ATTN: Water Resources Support Ctr
ATTN: Engr Studies Center
ATTN: Engr Topographic Lab.
ATTN: ATZA-DTE-SU
ATTN: ATZA-DTE-EM
ATTN: R&D Command

CRREL, ATTN: Library 03755

WES, ATTN: Library 39180

HQ, XVIII Airborn Corps
and Fort Bragg
ATTN: AFZA-FE-EE 28307

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

Chanute AFB, IL 61868
3345 CES/DE, Stop 27

Norton AFB, CA 92409
ATTN: AFRCE-MX/DEE

AFESC, Tyndall AFB FL 32403

NAVFAC
ATTN: Engineering Command (7)
ATTN: Division Offices (6)
ATTN: Naval Public Works Center (9)
ATTN: Naval Civil Engr Lab. (3)

ATTN: Library, Code L08A NCEL 93043

Defense Technical Info. Center 22314
ATTN: DDA (2)

Engr Societies Library, NY 10017

Natl Guard Bureau Instl. Div 20310

US Govt Print Office 22304
Receiving Sect/Depository Copies (2)

US Army Env. Hygiene Agency
ATTN: HSHB-E 21010

National Bureau of Standards 20899

325
08/86

ESH TEAM DISTRIBUTION

Savannah, GA 31402-0889
ATTN: SASEN-OF

Portland, OR 97208-2870
ATTN: NPDEN-TE

Omaha, NE 68102-4978
ATTN: MROED-MC
ATTN: MROED-DA
ATTN: MROED-TM

Mobile, AL 36628-0001
ATTN: SAMEN-CH

Norfolk, VA 23510
ATTN: NAOOP-C

Kansas City, MO 64106-2896
ATTN: MRK-EDDN

Sacramento, CA 95814-4794
ATTN: SPK-ED

APO New York 09757
ATTN: USAREUR,ODCSENGR

Ft. McPherson, GA 30330-6000
ATTN: AFEN-FDC-ES

Ft. Belvoir, VA 22060-1305
ATTN: FESA-EM

Ft. Monroe, VA 23651
ATTN: ATEN-FE

END

12-86

DTIC