NBSIR 87-3619

Thermal and Economic Analysis of Three HVAC System Types in a Typical VA Patient Facility

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U.S. DEPARTMENT OF COMMERCE, Clarence J. Brown, *Acting Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

Abstract

Thermal and economic analyses were performed for three different types of heating, ventilating, and cooling systems for a patient room in a typical VA patient facility in each of four locations. Thermal analysis was done with the U.S. Army's Building Loads Analysis and System Thermodynamics (BLAST) energy analysis program. Radiant Panel, variable air volume (VAV), and fan coil systems were simulated. Some subroutines were developed and added to the BLAST program in order to simulate the radiant panel system. The predicted energy requirements, energy cost projections, and system costs were then evaluated using the NBS Federal Building Life-Cycle Cost (FBLCC) program to determine the 20-year life-cycle cost of each system in each location.

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SI Conversion

In view of the presently accepted practice of the sponsor (the Veterans Administration) and of the building industry in the United States, common U.S. units of measurement have been used throughout this report. In recognition of the position of the United States as a signatory to the General Conference of Weights and Measures, which gave official status to the SI system of units in 1960, appropriate conversion factors have been provided in the table below.

Length:	1 foot (ft) = 0.3048 meter (m) 1 inch (in) = 0.0254 m
Area:	1 square foot (sq ft) = 0.0929 m^2
Mass:	1 pound (lb) = 0.4536 kilogram (kg)
Pressure:	1 inch of water (in H_2O) = 249.1 Pascal (Pa)
Temperature:	1 °F = 1.8 °C + 32
Temperature Interval:	1 °F = 5/9 °C
Energy:	1 Btu = 1.055 kilojoules (kJ) 1 Watt-hour (Wh) = 3600 J
Energy Flux:	1 Btu/($h \cdot ft^2$) = 3.152 W/m^2
Heat Flow Rate:	1 Btu/h (Btuh) = 0.293 Watt (W)
Heat Transfer Coefficient:	1 Btu/($h \cdot ft^2 \cdot F$) = 5.678 $W/(m^2 \cdot K)$
Volumetric Flow Rate:	1 cubic foot per minute (cfm) = .000472 m^3/s

1. Introduction

At the request of the Office of Facilities, Veterans Administration (VA), the Center for Building Technology (CBT), National Bureau of Standards (NBS), and the Center for Applied Mathematics (CAM), NBS, performed thermal and economic analyses, respectively, for three different types of heating, ventilating, and cooling (HVAC) systems for a patient room in a typical VA patient facility in each of four locations. This report describes the thermal analysis in Section 2 and economic analysis in Section 3.

2. Thermal Analysis

Thermal analyses of the VA patient facilities were performed with the U.S. Army's Building Loads Analysis and System Thermodynamics (BLAST) [1] energy analysis program. Radiant Panel, variable air volume (VAV), and fan coil systems were simulated. Some subroutines were developed and added to the BLAST program in order to simulate the radiant panel system.

2.1 Thermal Computational Models

The BLAST program was selected for this analysis because (1) it is a recognized public domain energy analysis computer program, (2) it includes models of conventional air handling systems, and (3) its multiroom heat balance procedure could be modified to accurately model radiant panel systems.

Subroutines were developed for a detailed analysis of a two-zone module using heat balance techniques with direct solution of the simultaneous surface and air heat balance equations. This subroutine development was needed to model radiant exchange in detail instead of using the radiant approximations in BLAST. The two zones represent a patient room and the related plenum space above the room. Transient heat conduction is accurately modeled by conduction transfer functions. Default convection coefficients are used on all surfaces except the radiant panels. The panel convection coefficient is critical during cooling. Calculations based on manufacturers data indicate a convection coefficient of 1.18 $Btu/hr \cdot ft^2 \cdot F$ with a room ventilation rate of 0.4 cfm/sq ft of floor area. This value is used in the simulations because it includes the effect of forced convective motion within the room. It is slightly higher than the 1.0 $Btu/hr \cdot ft^2 \cdot F$ recommended by ASHRAE [2] for preliminary design.

Three air handling systems were modeled: radiant panel, variable air volume, and four-pipe fan coil (figures 1, 2, and 3, respectively). In the radiant panel system a constant amount of outside air is delivered to each room and exhausted through the bathroom. The outside air is preconditioned to a relatively low temperature to provide dehumidification in addition to fresh air. This preconditioning may involve cooling warm outside air or heating and humidifying cold outside air. Heat is added to or removed from an area on the ceiling near the outside wall representing the radiant panels used to control the room temperature. The two zone model accurately accounts for energy lost through the ceiling into the plenum space.

Figure 1. Schematic Diagram of the Radiant Panel System

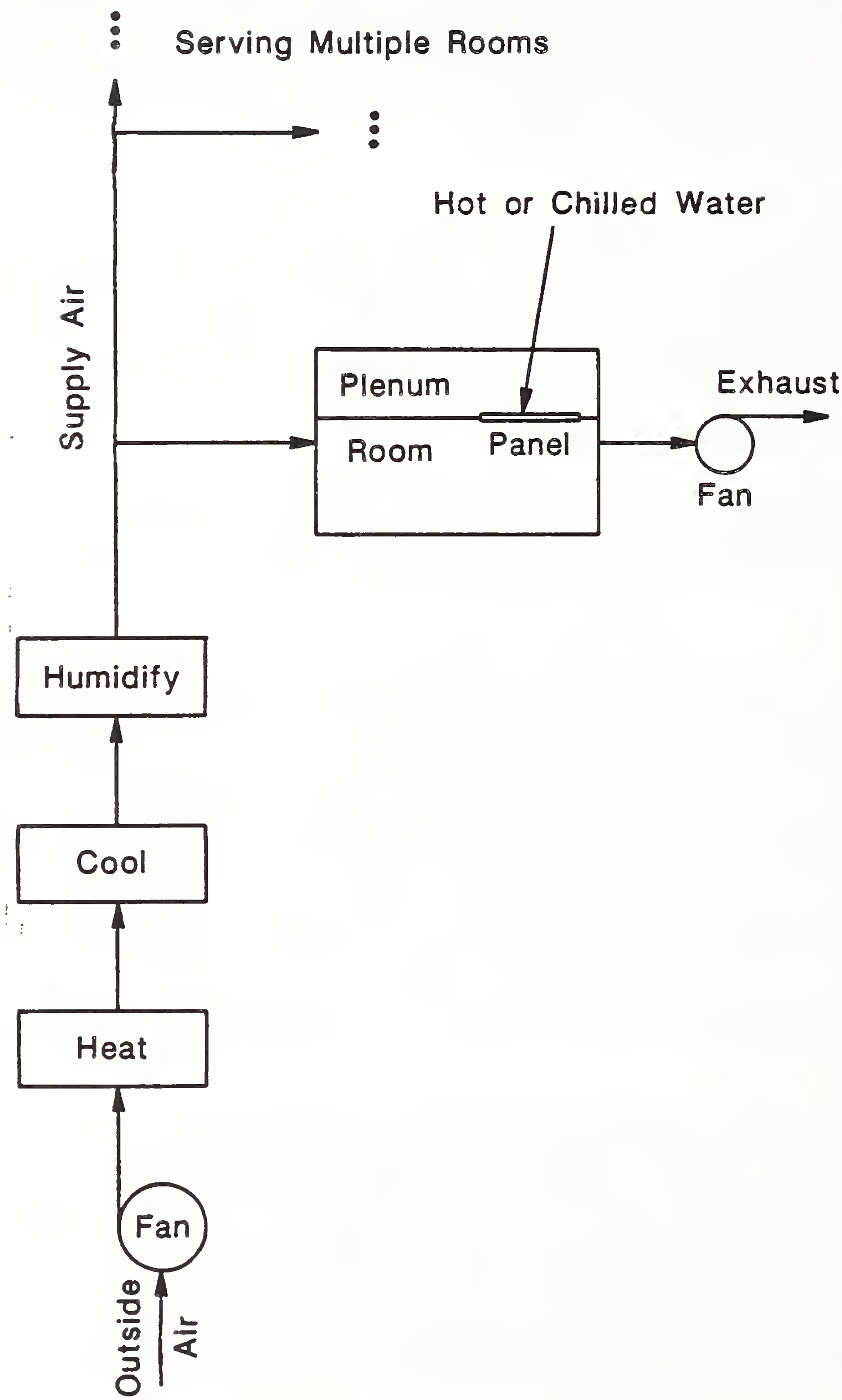


Figure 2. Schematic Diagram of the Variable Air Volume System

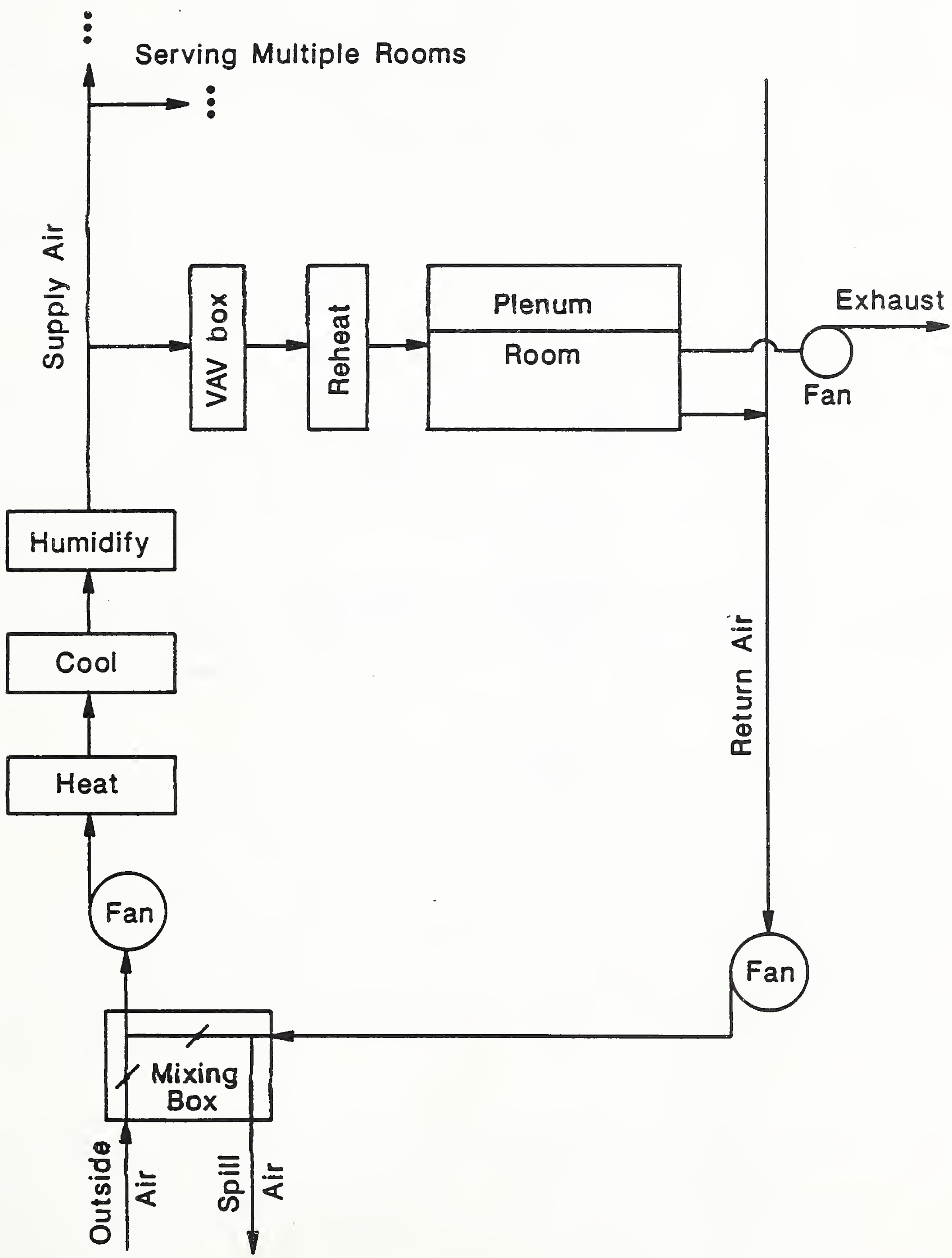
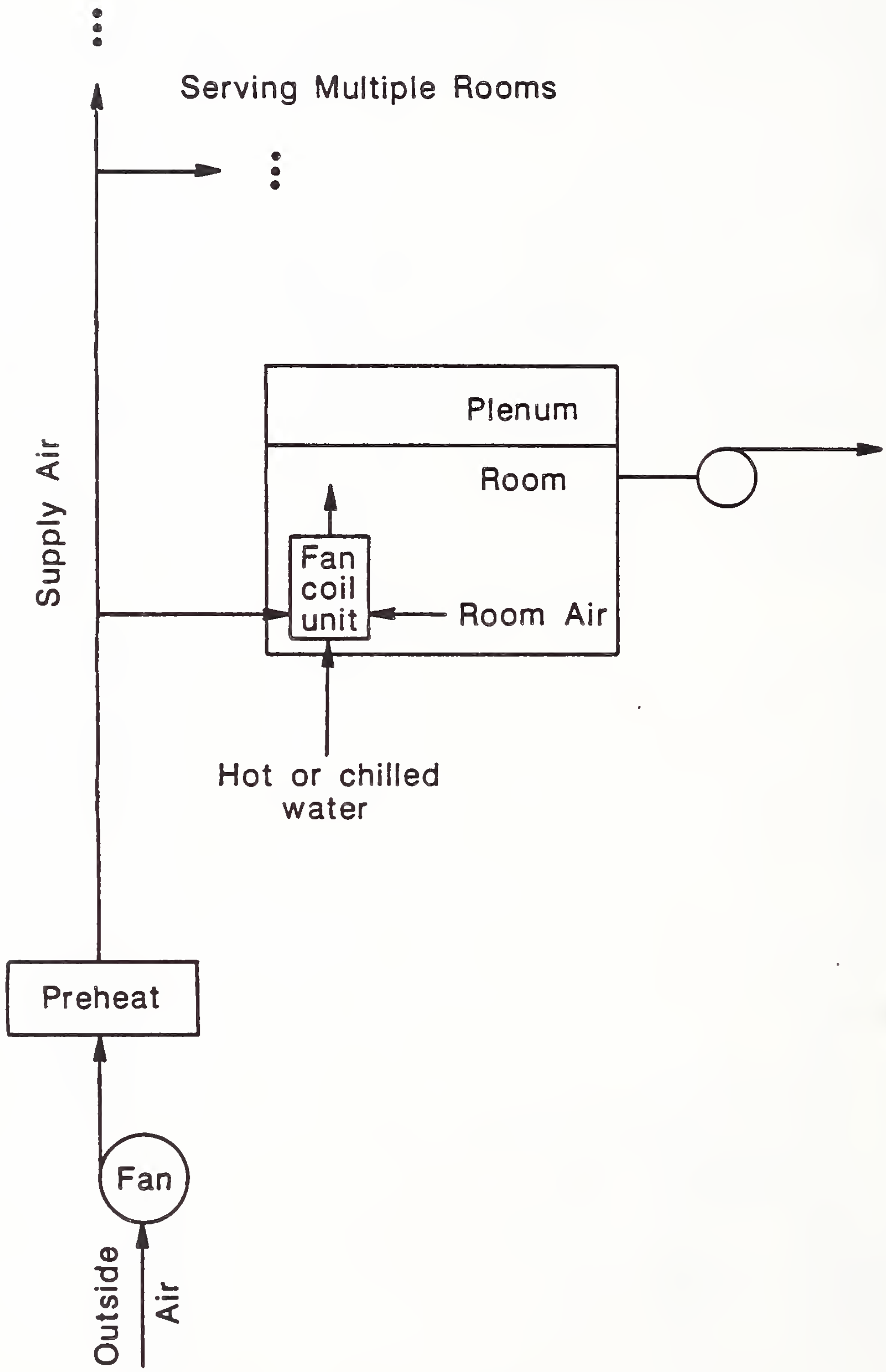


Figure 3. Schematic Diagram of the Fan Coil System



Note that temperature control is based on a function of air and radiant temperatures, rather than air temperature alone. This is intended to account for the comfort effects of a radiant temperature different from the air temperature [3]. The equivalent uniform temperature is given by (0.55 * air temperature) + (0.45 * mean radiant temperature). This formula for equivalent uniform temperature is used in all three systems since it is assumed that, when the radiant and air temperature differ, the occupants will adjust the thermostat to give a comfortable equivalent temperature.

The four-pipe fan coil system is assumed to introduce outside air to the rooms after minimal preconditioning involving some preheat and humidification. Within each room the outside air is mixed with room air and either heated or cooled to the desired temperature. The four-pipe arrangement allows some rooms to be heated while others are cooled. The BLAST fan coil system does not provide humidity control for the rooms.

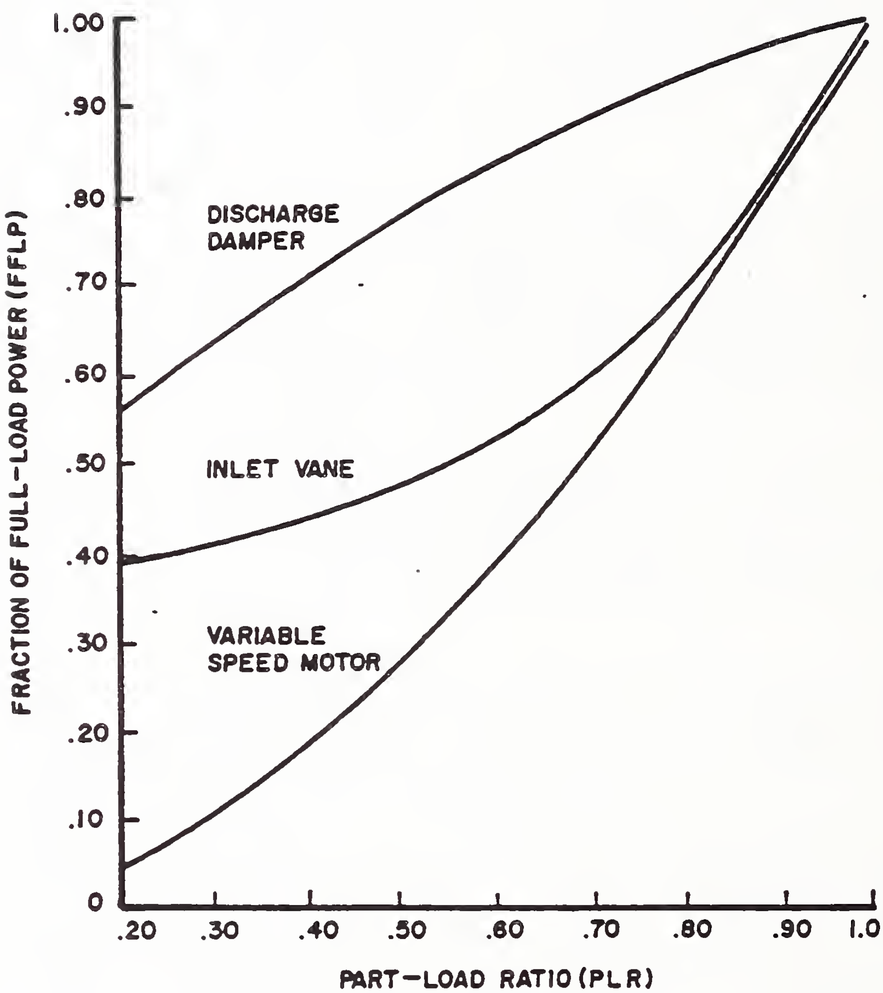
The variable air volume (VAV) system includes an enthalpy economy cycle to reduce chilled water demand. The primary air stream is conditioned as in the radiant system. The amount of cool air entering each room is controlled by the VAV boxes. If heating is required in the room, the airflow is minimized and the air is heated by the reheat coil. A constant amount of air is exhausted from each room. The difference between the supply air and the exhaust air is returned to the mixing box where it is mixed with the outside air in a ratio determined by an enthalpy economy cycle.

The BLAST fan model has two parts. The fan power at the design flow rate is given by (volume flow rate) * (static pressure rise)/(fan efficiency). The fan power at a reduced flow rate (needed for the VAV system) is based on the ratio of actual flow to design flow and the fan type as indicated in figure 4. For this study the variable speed drive fan was selected.

The heating coil acts to increase the enthalpy of the air stream without changing the humidity ratio. It is controlled to produce a desired air temperature downstream from the coil. The humidifier acts to increase the humidity ratio of the air stream without increasing the temperature. It is controlled to reach a desired humidity ratio in the air stream. (In actual practice, the humidifier will reduce the air temperature, but the heating coil will add more energy to the air to produce the same net effect as described.) The cooling coil reduces both the temperature and the humidity ratio of the air stream. Its performance is based on a curve fit to the performance characteristics of a real 4-row coil. It is controlled to reduce the air stream temperature to a desired level with the humidity removal being a consequence of the temperature reduction. Therefore, exact humidity control is not achieved.

The boiler performance is calculated in two steps. First, the air/fuel ratio, heat content of the fuel, and the stack temperature are used along with the ambient temperature and humidity ratio to compute the theoretical full-load boiler efficiency and theoretical fuel requirement to meet the load. Then the actual fuel consumption is related to the theoretical fuel requirement by a polynomial expression in terms of the boiler part load ratio. The chiller performance is calculated in four steps. First the equivalent temperature difference between the leaving chilled water and the leaving condenser water is computed. The ratio of available capacity to nominal capacity is then

Figure 4. Full Load Fan Power for VAV Fan System



computed from this equivalent temperature difference. Then the power required to run the chiller at full load is computed from the nominal full load power ratio and the ratio of available to nominal capacity. Finally the fraction of full load power is computed in terms of the ratio of load to actual capacity. The cooling tower model computes the energy to pump the condenser water and run its fan in proportion to the energy which must be removed from the condenser water by the tower. Energies to pump the hot water and the chilled water are proportional to the installed boiler and chiller capacities, respectively. All of these models are explained in more detail in the BLAST User's Manual.

2.2 Description of the Structure and Systems Modeled

An extensive set of data is required to perform a simulation with the thermal and equipment performance models described above. These data were determined jointly with the project sponsor.

The room shape is a simple rectangle 13 ft wide (on the exterior wall) by 26.42 ft deep by 8 ft high. This gives a total floor area of 320 sq ft which represents 260 sq ft of patient area for two patient beds plus 60 sq ft of bathroom. The plenum zone is 4.5 ft high and includes a 13 ft wide section of exterior wall. Each computer run simulated four rooms. They are identical except that they face toward the four cardinal directions. This is done to provide a diversity of loads due to different solar gains. The room consists of 10 surfaces: exterior wall, window, 3 partitions, floor, panel portion of ceiling, remainder of ceiling, and 2 surfaces representing interior furnishings. The plenum consists of 7 surfaces: exterior wall, 3 partitions, ceiling (which is the floor of a patient room above), panel portion of the plenum floor, and the remainder of the plenum floor. The thermal model computes the transient heat transfer for each of the four rooms and associated plenums as if there were an identical room and plenum above and below and on the other side of each of the three partition surfaces. The radiation view factors are computed separately [4] from the configuration data. Different view factors must be computed for each radiant panel area. The radiant panel portion of the ceiling is located nearest the outside wall.

The exterior wall is composed of 4 in face brick, 4 in light weight concrete block, fiberglass insulation, an air gap, and 5/8 in thick gypsum board. The thickness of the insulation was adjusted to give an overall U-value of 0.12 $Btu/hr \cdot ft^2 \cdot F$ for the wall. Included in the wall is a 32 sq ft window consisting of two panes of glass and a blind which combine to give a 0.65 shading coefficient. This window covers 20% of the combined room and plenum exterior wall area. The floor is assumed to consist of tile on 4 in thick heavy weight concrete. Partition walls consist of 5/8 in gypsum board on both sides of an air space. The stud portion of the partition wall is not modeled separately. The radiant panels and the normal ceiling panels are both modeled as a thin layer of sheet metal with 1.5 in of insulation on top. Furnishings in the room are modeled as weighing 780 pounds with a total surface area of 250 sq ft. This area interacts radiatively with the other room surfaces and convectively with the room air.

The internal loads for each room are based on default values from the VA's Preliminary Energy Program (PEP) [5]. Each room is assumed to be occupied continuously by two persons. Each person produces a sensible load of 240

Btu/hr and a latent load of 210 Btu/hr. The design lighting load is 2.42 W/sq ft, or 629 W for each 260 sq ft room. The lighting level is adjusted hourly according to PEP profile #1 which has the following percentages of the design load:

hour	1	2	3	4	5	6	7	8	9	10	11	12
% load	10	10	10	10	10	10	10	30	70	90	90	90

hour	13	14	15	16	17	18	19	20	21	22	23	24
% load	90	60	60	60	70	80	90	90	90	70	20	10

There is also an equipment load of 0.24 W/sq ft, or 62.4 W for each room. This load is 17% latent and 83% sensible and is constant at each hour. The occupancy, lighting, and equipment loads are the same for every day of the week. The room equivalent temperature is not allowed to exceed 78 F or to fall below 72 F.

The radiant panel system supplies 0.40 cfm/sq ft of outside air to each room (104 cfm/room), while the VAV and fan coil systems supply 0.25 cfm/sq ft (65 cfm/room). The fan coils move a total of 325 cfm of mixed air per room, and the VAV system can supply up to that amount of air to each room. All fans are assumed to be 70% efficient. The supply fans for the radiant and fan coil systems operate at pressures of 4.0 in-H_2O and the VAV system at 4.5 in-H_2O. The VAV return fan pressure is 1.5 in-H_2O, as are all exhaust fans.

All plant equipment was modeled using the BLAST default performance parameters. Of particular significance is the leaving chilled water temperature of 44F. Raising this value greatly reduces the ability of the cooling coil to remove moisture; lowering it reduces chiller efficiency. Boiler and chillers capacities were determined by an initial simulation which computed the peak hot and chilled water demands. The equipment was then sized so those demands would not be exceeded.

2.3 Results of Modeling

The performance of the three systems was determined using one year's typical weather data for four cities: Dayton, Boston, Tampa, and Phoenix. The weather data was taken from ASHRAE's Weather Year for Energy Calculations (WYEC) weather tapes [6]. Table 2.1 summarizes the climate in each of the cities. It includes the lowest and highest temperatures observed in the year, the average of all 8760 hourly temperatures, heating and cooling degree days (base 65F), and the daily average solar flux on a horizontal surface.

The total energy required to condition the four rooms for each system in each of the cities is summarized in Table 2.2. The first two columns are the total energy requirements. The next three columns show the electric energy subdivided according to the portions that were scheduled (lights, etc.), used by fans, and used by the chiller and pumps in the plant equipment. The last two columns give the total energy of hot and chilled water required by the system coils or radiant panels.

The peak hot water and chilled water demands are summarized in Table 2.3. It repeats the coil total hot and chilled water energy requirements from Table 2.2 and also gives the peak requirements, the assumed plant capacities, and the average annual operating ratios for heating and cooling.

2.4 Discussion of Thermal Analysis

Several factors stand out in the above results. First is the greatly increased loads and energy requirements of the radiant panel system compared to the two conventional systems. Earlier tests indicated that this is primarily due to the increased outdoor air requirements of the radiant system. The increased loads mean that higher capacity equipment will be required. The airflow rates used in the thermal analysis were provided by VA. It might be possible to use a lower airflow rate with the radiant panel system, but this would reduce the convection coefficient at the panel thus requiring a larger panel area to prevent condensation. The analysis did not include infiltration because the HVAC system is supposed to provide positive pressurization and prevent infiltration. Infiltration commonly would benefit a radiant system because less energy is used to heat or cool the infiltration air.

The second factor is the very low electrical energy used by the VAV system fans. This is due to the shape of the part load power curve for fans with variable speed motors (see figure 4). This curve is identical to the one used in the DOE-2 program and agrees with manufacturers data. Other types of airflow control would require considerably more electricity.

Another factor is low heating and cooling requirements of the fan coil system which occurs because there is no reheating of the supply air. However, this also means there is less control over the room humidity than with the other systems.

Table 2.1 Summary of Annual Weather Data

Location	Temperatures (F) low	high	mean	Degree Days heating	cooling	Sunshine ($Btu/h\ ft^2$)
Dayton, OH	-16.0	97.0	52.1	5630	903	1236.
Boston, MA	-4.0	97.0	51.4	5698	985	1212.
Tampa, FL	25.0	95.0	71.9	605	3115	1643.
Phoenix, AZ	23.0	112.0	71.3	1356	3661	1717.

Table 2.2 Summary of Energy Requirements for Four 320 sq ft Rooms*

Location / System	Gas to Boiler (kBtu)	Total Elec. (kWh)	Scheduled Elec. (kWh)	Fan Elec. (kWh)	Plant Elec. (kWh)	Total Heating (kBtu)	Total Cooling (kBtu)
Dayton, OH							
Radiant	97,200	24,900	13,500	3,400	8,000	56,500	63,200
VAV	63,800	21,400	13,500	1,300	6,600	36,100	52,700
Fan Coil	41,500	24,200	13,500	5,000	5,700	24,500	46,500
Boston, MA							
Radiant	98,000	24,100	13,500	3,400	7,200	57,200	50,700
VAV	65,000	20,100	13,500	1,100	5,400	37,200	39,500
Fan Coil	40,100	23,000	13,500	5,000	4,500	24,000	34,400
Tampa, FL							
Radiant	19,900	31,100	13,500	3,400	14,200	10,300	168,000
VAV	17,400	25,800	13,500	1,300	10,900	9,000	130,000
Fan Coil	5,900	26,600	13,500	5,000	8,100	3,500	89,100
Phoenix, AZ							
Radiant	32,900	29,400	13,500	3,400	12,500	17,700	111,000
VAV	22,400	24,900	13,500	1,400	10,000	12,000	88,300
Fan Coil	10,000	26,200	13,500	5,000	7,700	6,000	77,700

----

* Each room faces a different compass point (N, E, S, and W)

Table 2.3 Summary of Heating and Cooling Loads Data for Four Rooms

Location / System	Total Heating (kBtu)	Peak Heating (kBtuh)	Heating Cap. (kBtuh)	Oper. Ratio --	Total Cooling (kBtu)	Peak Cooling (kBtuh)	Cooling Cap. (kBtuh)	Oper. Ratio --
Dayton, OH								
Radiant	56,500	45.6	50	.129	63,200	40.2	44	.266
VAV	36,100	31.0	35	.150	52,700	34.5	40	.257
Fan Coil	24,500	26.0	30	.277	46,500	31.8	36	.284
Boston, MA								
Radiant	57,200	38.8	44	.148	50,700	38.8	44	.225
VAV	37,200	26.3	30	.162	39,500	30.9	35	.233
Fan Coil	24,000	20.1	24	.222	34,400	26.1	30	.235
Tampa, FL								
Radiant	10,300	20.9	25	.047	168,000	44.3	48	.409
VAV	9,000	11.5	14	.113	130,000	34.6	38	.404
Fan Coil	3,500	12.3	15	.176	89,100	29.7	34	.340
Phoenix, AZ								
Radiant	17,700	21.8	26	.078	111,000	43.6	48	.286
VAV	12,000	12.6	15	.125	88,300	35.0	40	.280
Fan Coil	6,000	12.9	15	.213	77,700	28.9	33	.326

3. Economic Analysis

The energy requirements shown in Table 2.2 for each of the three HVAC systems evaluated in Section 2 were divided by 4.0 to represent the average purchased energy requirements of a typical 320 sq ft patient room in each of four locations (Dayton, Boston, Tampa, and Phoenix). These purchased energy requirements are shown in Table 3.1. First cost and annual operating cost for each HVAC system type, as provided by the VA, are shown in Table 3.2. Energy cost projections (per million Btu) were provided by the U.S. Department of Energy (DOE), based on average prices for the DOE region in which each facility is located. These price projections and corresponding present worth factors (20 years, seven percent discount rate) are shown in Table 3.3.

These data were then evaluated using the NBS Federal Building Life-Cycle Cost (FBLCC) [7] program to determine the 20-year life-cycle cost of each system in each location. The results of these economic analyses are summarized in Table 3.4. The FBLCC report for each system in each location is included in Appendix A, while the actual input data used to run these analyses are included in Appendix B.

Of the three system types, the radiant panel systems have the highest total life-cycle costs (LCC) in all four locations. This is due almost entirely to the relatively high energy usage of the radiant panel systems. That is, their present-value energy costs are approximately 50 percent higher than the most energy efficient of the three systems in each of the four locations. While the first cost of the radiant panel systems is only slightly higher than that of the VAV system, and its operating and maintenance (O&M) cost is considerably less than either the VAV or fan coil systems, its higher energy cost dominates this analysis. As a result, the radiant panel systems do not appear to be economical on a life-cycle cost basis given the referenced data.

The FBLCC analysis of the remaining two systems shows that the VAV system has a first cost that is approximately 15 percent higher ($550) than that of the fan coil system, but has present-value O&M-related savings ($530) which offset this first cost premium almost entirely. As a result, any significant life-cycle cost advantage of one over the other is due primarily to a reduction in life-cycle energy costs. In Dayton and Boston the VAV systems have a slight energy cost advantage, but a 5 percent increase in either first cost or energy usage, or a 33 percent increase in O&M costs, would negate this advantage. In Tampa the fan coil system has a slight energy advantage, but a 5 percent increase in first cost or energy usage, or 10 percent increase in O&M costs, would negate this advantage. In Phoenix, the energy cost, and thus the life-cycle cost, of both systems are virtually identical.

The relative advantage, if any, of one of these two systems over the other from an energy cost standpoint is largely attributable to climate, their relative energy requirements for space heating and cooling, and relative prices of gas and electricity. The fan coil system uses less gas but uses more electricity than the VAV system in all four locations. In the Dayton, Boston, and Phoenix facilities, the savings in gas are two to three times greater than the increase in electricity usage on a purchased Btu basis, while in Tampa the savings in gas are approximately four times the increase in electricity usage. (See Table 3.1.) However, because the cost of electricity is approximately three times greater than the cost of natural gas (per million

Btu on a present-value basis), only in Tampa are present-value energy costs actually reduced by the fan coil system.

Since neither the VAV nor the fan coil system has a clear LCC advantage in any of these four locations, both should be considered as potential candidates for new VA facilities. Energy simulations and cost data specific to the actual design and operation of a new VA facility will be required to select one over the other from an economic standpoint.

Table 3.1
Annual Purchased Energy per 320 sq ft Room
(million Btu)

	GAS	ELECTRICITY*
Dayton		
Radiant	24.30	9.73
VAV	15.95	6.74
Fan Coil	10.38	9.13
Boston		
Radiant	24.50	9.04
VAV	16.25	5.63
Fan Coil	10.03	8.11
Tampa		
Radiant	4.98	15.02
VAV	4.35	10.49
Fan Coil	1.48	11.18
Phoenix		
Radiant	8.23	13.57
VAV	5.60	9.73
Fan Coil	2.50	10.83

Source: Table 2.2
*Does not include scheduled electricity constant.

Table 3.2
HVAC System Costs per 320 sq ft Room**

	First Cost	Annual O&M Cost
Radiant	$4065	$28
VAV	$4000	$40
Fan Coil	$3450	$90

**Source: Telephone communication, Tom Louie, VA

Table 3.3
DOE Energy Prices Projections* and Present Worth Factors**
(Million Btu delivered)

	DOE REGION	Natural Gas 1987 Price	Natural Gas UPW Factor	Electricity 1987 Price	Electricity UPW Factor
Dayton	5	$4.72	14.58	$22.63	9.24
Boston	1	6.10	14.05	29.07	9.75
Tampa	4	4.73	14.89	19.38	9.12
Phoenix	9	5.64	12.06	21.12	9.41

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*Source: Communication: Energy Information Administration, US Department of Energy.

** 7% discount rate, 20 years, DoE energy price escalation rates by region.

Table 3.4
FBLCC ANALYSIS OF THREE VA HVAC SYSTEMS

City/ System Type	First Cost	Present Value Energy Cost	Present Value O&M	Present Value Total LCC	LCC Rank
Dayton/					
Radiant	$4065	$3707	$297	$8068	3
VAV	4000	2507	424	6931	1
Fan Coil	3450	2623	953	7027	2
Boston/					
Radiant	$4065	$4661	$297	$9023	3
VAV	4000	2988	424	7412	1
Fan Coil	3450	3157	953	7561	2
Tampa/					
Radiant	$4065	$3006	$297	$7368	3
VAV	4000	2163	424	6586	2
Fan Coil	3450	2081	953	6484	1
Phoenix/					
Radiant	$4065	$3255	$297	$7617	3
VAV	4000	2315	424	6739	2
Fan Coil	3450	2325	953	6728	1

4. Summary

Thermal and economic analyses were performed for three different types of heating, ventilating, and cooling systems for a patient room in a typical VA patient facility in each of four locations. Radiant panel, variable air volume (VAV), and fan coil systems were simulated. Under the specific operating conditions simulated, the radiant panel system required significantly more energy than the other systems. This was primarily due to an increased outdoor air requirement for the radiant panel system. The VAV and fan coil systems had similar total energy requirements but different proportions of electric and gas energy. These energy requirements figured significantly into the system life cycle costs, with the VAV or fan coil system having the lowest life cycle cost depending on the relative costs of electricity and gas in the different locations. These results indicate that energy simulations and cost data specific to the actual design and operation of a new VA facility will be required to select one system over the other from an economic standpoint.

5. References

[1] "BLAST 3.0 User's Manual", BLAST Support Office, University of Illinois, Urbana IL, April 1986.

[2] ASHRAE Handbook - 1984 Systems, ASHRAE, Atlanta GA, 1984, pg 8.6.

[3] Wray, W.O., "A Simple Procedure for Assessing Thermal Comfort in Passive Solar Heated Buildings", Los Alamos Scientific Laboratory Report LA-UR-80-550, Los Alamos NM, 1980.

[4] Walton, G.N., "Algorithms for Calculating Radiation View Factors Between Plane Convex Polygons With Obstructions", NBS Interagency Report NBSIR 86-3463, National Bureau of Standards, Gaithersburg, MD 20899, October 1986.

[5] Dougall, R.S., Rudoy, W., & Cirka, C., "PEP User's Manual (Version 3.0)", Veterans Administration, Washington DC, June 1979.

[6] Crow, L.W., "Development of Hourly Data for Weather Year for Energy Calculations (WYEC)", ASHRAE Journal, Vol. 23, NO. 10, October 1981.

[7] Petersen, S. R., A User's Guide to the FBLCC Computer Program, Tech Note 1222, United States Department of Commerce, National Bureau of Standards, Gaithersburg, MD 20899, May 1986.

Appendix A

F B L C C   A N A L Y S E S

Table A-1 FBLCC ANALYSIS: DAYTON, RADIANT PANEL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: RADIANT
RUN DATE:07-08-1987 17:01:54
BLDG. CHAR. FILE NAME: VADRAD1.BCF, LAST MODIFIED 05-16-1987 10:28:51
LCC OUTPUT FILE NAME: VADRAD1.LCC, CREATED 05-16-1987 10:32:23
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 5

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,065
TOTAL PROJECT COST (ACTUAL)	$4,065
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,065

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	24.3	$4.72	$0	14.58	$1672
ELECTRICITY	9.7	$22.63	$0	9.24	$2034

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: RADIANT RUN DATE: 07-08-1987/17:01:54

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,065	$384
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$297	$28
ENERGY COSTS	$3,707	$350
SUBTOTAL	$4,003	$378
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$8,068	$762

Table A-2 FBLCC ANALYSIS: DAYTON, VARIABLE AIR VOLUME

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: VAV
RUN DATE:07-09-1987 09:07:13
BLDG. CHAR. FILE NAME: VADVAV1.BCF, LAST MODIFIED 05-16-1987 10:30:26
LCC OUTPUT FILE NAME: VADVAV1.LCC, CREATED 05-16-1987 10:32:55
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 5

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,000
TOTAL PROJECT COST (ACTUAL)	$4,000
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,000

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	16.0	$4.72	$0	14.58	$1098
ELECTRICITY	6.7	$22.63	$0	9.24	$1409

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: VAV RUN DATE: 07-09-1987/09:07:13

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,000	$378
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$424	$40
ENERGY COSTS	$2,507	$237
SUBTOTAL	$2,931	$277
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$6,931	$654

Table A-3 FBLCC ANALYSIS: DAYTON, FAN COIL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: FAN COIL
RUN DATE:07-09-1987 09:07:25
BLDG. CHAR. FILE NAME: VADFC1.BCF, LAST MODIFIED 05-16-1987 10:31:59
LCC OUTPUT FILE NAME: VADFC1.LCC, CREATED 05-16-1987 10:33:18
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 5

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$3,450
TOTAL PROJECT COST (ACTUAL)	$3,450
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$3,450

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	10.4	$4.72	$0	14.58	$714
ELECTRICITY	9.1	$22.63	$0	9.24	$1909

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: FAN COIL RUN DATE: 07-09-1987/09:07:25

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$3,450	$326
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$953	$90
ENERGY COSTS	$2,623	$248
SUBTOTAL	$3,577	$338
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$7,027	$663

Table A-4 FBLCC ANALYSIS: BOSTON, RADIANT PANEL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: RADIANT
RUN DATE:07-09-1987 09:07:33
BLDG. CHAR. FILE NAME: VABRAD1.BCF, LAST MODIFIED 05-16-1987 10:53:28
LCC OUTPUT FILE NAME: VABRAD1.LCC, CREATED 05-16-1987 11:04:25
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 1

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,065
TOTAL PROJECT COST (ACTUAL)	$4,065
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,065

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	24.5	$6.10	$0	14.05	$2100
ELECTRICITY	9.0	$29.07	$0	9.75	$2561

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: RADIANT RUN DATE: 07-09-1987/09:07:33

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,065	$384
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$297	$28
ENERGY COSTS	$4,661	$440
SUBTOTAL	$4,958	$468
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$9,023	$852

Table A-5 FBLCC ANALYSIS: BOSTON, VARIABLE AIR VOLUME

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: VAV
RUN DATE:07-09-1987 09:07:44
BLDG. CHAR. FILE NAME: VABVAV1.BCF, LAST MODIFIED 05-16-1987 10:55:10
LCC OUTPUT FILE NAME: VABVAV1.LCC, CREATED 05-16-1987 11:04:44
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 1

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,000
TOTAL PROJECT COST (ACTUAL)	$4,000
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,000

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	16.3	$6.10	$0	14.05	$1393
ELECTRICITY	5.6	$29.07	$0	9.75	$1595

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: VAV RUN DATE: 07-09-1987/09:07:44

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,000	$378
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$424	$40
ENERGY COSTS	$2,988	$282
SUBTOTAL	$3,412	$322
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$7,412	$700

Table A-6 FBLCC ANALYSIS: BOSTON, FAN COIL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: FAN COIL
RUN DATE:07-09-1987 09:07:54
BLDG. CHAR. FILE NAME: VABFC1.BCF, LAST MODIFIED 05-16-1987 10:56:31
LCC OUTPUT FILE NAME: VABFC1.LCC, CREATED 05-16-1987 11:05:02
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 1

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$3,450
TOTAL PROJECT COST (ACTUAL)	$3,450
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$3,450

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	10.0	$6.10	$0	14.05	$860
ELECTRICITY	8.1	$29.07	$0	9.75	$2298

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: FAN COIL RUN DATE: 07-09-1987/09:07:54

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$3,450	$326
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$953	$90
ENERGY COSTS	$3,157	$298
SUBTOTAL	$4,111	$388
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$7,561	$714

Table A-7 FBLCC ANALYSIS: TAMPA, RADIANT PANEL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: RADIANT
RUN DATE:07-09-1987 09:08:01
BLDG. CHAR. FILE NAME: VATRAD1.BCF, LAST MODIFIED 05-16-1987 10:59:49
LCC OUTPUT FILE NAME: VATRAD1.LCC, CREATED 05-16-1987 11:05:17
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 4

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,065
TOTAL PROJECT COST (ACTUAL)	$4,065
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,065

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	5.0	$4.73	$0	14.89	$351
ELECTRICITY	15.0	$19.38	$0	9.12	$2655

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: RADIANT RUN DATE: 07-09-1987/09:08:01

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,065	$384
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$297	$28
ENERGY COSTS	$3,006	$284
SUBTOTAL	$3,303	$312
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$7,368	$695

Table A-8 FBLCC ANALYSIS: TAMPA, VARIABLE AIR VOLUME

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: VAV
RUN DATE:07-09-1987 09:08:14
BLDG. CHAR. FILE NAME: VATVAV1.BCF, LAST MODIFIED 05-16-1987 11:00:40
LCC OUTPUT FILE NAME: VATVAV1.LCC, CREATED 05-16-1987 11:05:31
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 4

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,000
TOTAL PROJECT COST (ACTUAL)	$4,000
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,000

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	4.4	$4.73	$0	14.89	$306
ELECTRICITY	10.5	$19.38	$0	9.12	$1856

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: VAV RUN DATE: 07-09-1987/09:08:14

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,000	$378
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$424	$40
ENERGY COSTS	$2,163	$204
SUBTOTAL	$2,586	$244
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$6,586	$622

Table A-9 FBLCC ANALYSIS: TAMPA, FAN COIL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: FAN COIL
RUN DATE:07-09-1987 09:08:26
BLDG. CHAR. FILE NAME: VATFC1.BCF, LAST MODIFIED 05-16-1987 11:01:23
LCC OUTPUT FILE NAME: VATFC1.LCC, CREATED 05-16-1987 11:05:48
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 4

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$3,450
TOTAL PROJECT COST (ACTUAL)	$3,450
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$3,450

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	1.5	$4.73	$0	14.89	$104
ELECTRICITY	11.2	$19.38	$0	9.12	$1976

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: FAN COIL RUN DATE: 07-09-1987/09:08:26

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$3,450	$326
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$953	$90
ENERGY COSTS	$2,081	$196
SUBTOTAL	$3,034	$286
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$6,484	$612

Table A-10 FBLCC ANALYSIS: PHOENIX, RADIANT PANEL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: RADIANT
RUN DATE:07-09-1987 09:08:34
BLDG. CHAR. FILE NAME: VAPRAD1.BCF, LAST MODIFIED 05-16-1987 11:02:30
LCC OUTPUT FILE NAME: VAPRAD1.LCC, CREATED 05-16-1987 11:06:05
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 9

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,065
TOTAL PROJECT COST (ACTUAL)	$4,065
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,065

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	8.2	$5.64	$0	12.06	$560
ELECTRICITY	13.6	$21.12	$0	9.41	$2695

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: RADIANT RUN DATE: 07-09-1987/09:08:34

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,065	$384
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$297	$28
ENERGY COSTS	$3,255	$307
SUBTOTAL	$3,552	$335
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$7,617	$719

Table A-11 FBLCC ANALYSIS: PHOENIX, VARIABLE AIR VOLUME

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: VAV
RUN DATE:07-09-1987 09:08:40
BLDG. CHAR. FILE NAME: VAPVAV1.BCF, LAST MODIFIED 05-16-1987 11:03:14
LCC OUTPUT FILE NAME: VAPVAV1.LCC, CREATED 05-16-1987 11:06:21
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 9

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$4,000
TOTAL PROJECT COST (ACTUAL)	$4,000
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$4,000

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	5.6	$5.64	$0	12.06	$381
ELECTRICITY	9.7	$21.12	$0	9.41	$1934

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: VAV RUN DATE: 07-09-1987/09:08:40

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$4,000	$378
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$424	$40
ENERGY COSTS	$2,315	$219
SUBTOTAL	$2,739	$259
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$6,739	$636

Table A-12 FBLCC ANALYSIS: PHOENIX, FAN COIL

PART I - INITIAL ASSUMPTIONS AND COST DATA

PROJECT NAME: FAN COIL
RUN DATE:07-09-1987 09:08:48
BLDG. CHAR. FILE NAME: VAPFC1.BCF, LAST MODIFIED 05-16-1987 11:03:56
LCC OUTPUT FILE NAME: VAPFC1.LCC, CREATED 05-16-1987 11:06:35
LCC ANALYSIS TYPE: NBS HANDBOOK 135
STUDY PERIOD: 20 YEARS (1987 TO 2007)
DISCOUNT RATE: 7.0%
BUILDING TYPE: COMMERCIAL
DOE REGION: 9

INITIAL CAPITAL COMPONENT COSTS (NOT DISCOUNTED)

	TOTAL COST
TOTAL FOR HVAC	$3,450
TOTAL PROJECT COST (ACTUAL)	$3,450
LESS FEDERAL CONSERVATION CREDIT(a)	$0
TOTAL ADJUSTED PROJECT COST	$3,450

ENERGY-RELATED COSTS

ENERGY TYPE	MMBTU/ YEAR	PRICE ($/MMBTU)	DEMAND COST	UPW* FACTOR	TOTAL P.V. COST
NATURAL GAS	2.5	$5.64	$0	12.06	$170
ELECTRICITY	10.8	$21.12	$0	9.41	$2154

(a) TO REFLECT 10% FIRST COST ADJUSTMENT RULE IN NBS HANDBOOK 135.

PART II - LIFE-CYCLE COST ANALYSIS: DISCOUNT RATE = 7.0%

PROJECT NAME: FAN COIL RUN DATE: 07-09-1987/09:08:48

	PRESENT VALUE (1987 DOLLARS)	ANNUAL VALUE (1987 DOLLARS)
A. INITIAL INVESTMENT REQUIREMENTS	$3,450	$326
B. OPERATING, MAINTENANCE & RELATED COSTS:		
ANNUALLY RECURRING COSTS (NON-ENERGY)	$953	$90
ENERGY COSTS	$2,325	$219
SUBTOTAL	$3,278	$309
D. LESS: REMAINING VALUE AT END OF STUDY PERIOD	$0	$0
E. TOTAL LIFE-CYCLE PROJECT COST	$6,728	$635

APPENDIX B

BUILDING CHARACTERISTICS FILES

Table B-1 BCF: Dayton, Radiant Panel

BUILDING CHARACTERISTICS FILE

FILE NAME: VADRAD1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:28:51

PROJECT TITLE: RADIANT

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 5

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4065
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $28
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-1 BCF: Dayton, Radiant Panel (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 24.3 MILLION BTU
PRICE PER MILLION BTU = $4.72
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-1.31%	1997	3.22%
1988	2.44%	1998	3.93%
1989	3.46%	1999	4.57%
1990	4.39%	2000	0.00%
1991	7.82%	2001	0.00%
1992	5.76%	2002	0.00%
1993	7.03%	2003	0.00%
1994	6.40%	2004	0.00%
1995	5.40%	2005	0.00%
1996	4.54%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 9.7 MILLION BTU
PRICE PER MILLION BTU =$22.63
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-0.09%	1997	-0.89%
1988	-2.93%	1998	2.86%
1989	-2.50%	1999	-1.03%
1990	-3.38%	2000	0.00%
1991	-4.60%	2001	0.00%
1992	-3.98%	2002	0.00%
1993	-1.85%	2003	0.00%
1994	-0.44%	2004	0.00%
1995	0.17%	2005	0.00%
1996	0.39%	2006	0.00%

Table B-2 BCF: Dayton, Variable Air Volume

BUILDING CHARACTERISTICS FILE

FILE NAME: VADVAV1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:30:26

PROJECT TITLE: VAV

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 5

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4000
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $40
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-2 BCF: Dayton, Variable Air Volume (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 16.0 MILLION BTU
PRICE PER MILLION BTU = $4.72
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-1.31%	1997	3.22%
1988	2.44%	1998	3.93%
1989	3.46%	1999	4.57%
1990	4.39%	2000	0.00%
1991	7.82%	2001	0.00%
1992	5.76%	2002	0.00%
1993	7.03%	2003	0.00%
1994	6.40%	2004	0.00%
1995	5.40%	2005	0.00%
1996	4.54%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 6.7 MILLION BTU
PRICE PER MILLION BTU =$22.63
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-0.09%	1997	-0.89%
1988	-2.93%	1998	2.86%
1989	-2.50%	1999	-1.03%
1990	-3.38%	2000	0.00%
1991	-4.60%	2001	0.00%
1992	-3.98%	2002	0.00%
1993	-1.85%	2003	0.00%
1994	-0.44%	2004	0.00%
1995	0.17%	2005	0.00%
1996	0.39%	2006	0.00%

Table B-3 BCF: Dayton, Fan Coil

BUILDING CHARACTERISTICS FILE

FILE NAME: VADFC1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:31:59

PROJECT TITLE: FAN COIL

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 5

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	3450
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $90
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 10.4 MILLION BTU
PRICE PER MILLION BTU = $4.72
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-1.31%	1997	3.22%
1988	2.44%	1998	3.93%
1989	3.46%	1999	4.57%
1990	4.39%	2000	0.00%
1991	7.82%	2001	0.00%
1992	5.76%	2002	0.00%
1993	7.03%	2003	0.00%
1994	6.40%	2004	0.00%
1995	5.40%	2005	0.00%
1996	4.54%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 9.1 MILLION BTU
PRICE PER MILLION BTU =$22.63
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-0.09%	1997	-0.89%
1988	-2.93%	1998	2.86%
1989	-2.50%	1999	-1.03%
1990	-3.38%	2000	0.00%
1991	-4.60%	2001	0.00%
1992	-3.98%	2002	0.00%
1993	-1.85%	2003	0.00%
1994	-0.44%	2004	0.00%
1995	0.17%	2005	0.00%
1996	0.39%	2006	0.00%

Table B-4 BCF: Boston, Radiant Panel

BUILDING CHARACTERISTICS FILE

FILE NAME: VABRAD1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:53:28

PROJECT TITLE: RADIANT

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 1

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4065
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $28
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 24.5 MILLION BTU
PRICE PER MILLION BTU = $6.10
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	2.55%
1988	6.27%	1998	2.83%
1989	3.03%	1999	4.18%
1990	2.48%	2000	0.00%
1991	5.89%	2001	0.00%
1992	5.56%	2002	0.00%
1993	3.11%	2003	0.00%
1994	5.24%	2004	0.00%
1995	3.49%	2005	0.00%
1996	3.73%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 9.0 MILLION BTU
PRICE PER MILLION BTU =$29.07
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	3.06%	1997	-0.57%
1988	-2.14%	1998	1.73%
1989	-2.89%	1999	1.17%
1990	-2.98%	2000	0.00%
1991	-4.00%	2001	0.00%
1992	-2.57%	2002	0.00%
1993	-0.60%	2003	0.00%
1994	-0.36%	2004	0.00%
1995	-1.01%	2005	0.00%
1996	-0.33%	2006	0.00%

Table B-5 BCF: Boston, Variable Air Volume

BUILDING CHARACTERISTICS FILE

FILE NAME: VABVAV1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:55:10

PROJECT TITLE: VAV

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 1

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4000
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $40
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-5 BCF: Boston, Variable Air Volume (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 16.3 MILLION BTU
PRICE PER MILLION BTU = $6.10
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	2.55%
1988	6.27%	1998	2.83%
1989	3.03%	1999	4.18%
1990	2.48%	2000	0.00%
1991	5.89%	2001	0.00%
1992	5.56%	2002	0.00%
1993	3.11%	2003	0.00%
1994	5.24%	2004	0.00%
1995	3.49%	2005	0.00%
1996	3.73%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 5.6 MILLION BTU
PRICE PER MILLION BTU =$29.07
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	3.06%	1997	-0.57%
1988	-2.14%	1998	1.73%
1989	-2.89%	1999	1.17%
1990	-2.98%	2000	0.00%
1991	-4.00%	2001	0.00%
1992	-2.57%	2002	0.00%
1993	-0.60%	2003	0.00%
1994	-0.36%	2004	0.00%
1995	-1.01%	2005	0.00%
1996	-0.33%	2006	0.00%

BUILDING CHARACTERISTICS FILE

FILE NAME: VABFC1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:56:31

PROJECT TITLE: FAN COIL

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 1

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	3450
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $90
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-6 BCF: Boston, Fan Coil (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 10.0 MILLION BTU
PRICE PER MILLION BTU = $6.10
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	2.55%
1988	6.27%	1998	2.83%
1989	3.03%	1999	4.18%
1990	2.48%	2000	0.00%
1991	5.89%	2001	0.00%
1992	5.56%	2002	0.00%
1993	3.11%	2003	0.00%
1994	5.24%	2004	0.00%
1995	3.49%	2005	0.00%
1996	3.73%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 8.1 MILLION BTU
PRICE PER MILLION BTU =$29.07
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	3.06%	1997	-0.57%
1988	-2.14%	1998	1.73%
1989	-2.89%	1999	1.17%
1990	-2.98%	2000	0.00%
1991	-4.00%	2001	0.00%
1992	-2.57%	2002	0.00%
1993	-0.60%	2003	0.00%
1994	-0.36%	2004	0.00%
1995	-1.01%	2005	0.00%
1996	-0.33%	2006	0.00%

Table B-7 BCF: Tampa, Radiant Panel

BUILDING CHARACTERISTICS FILE

FILE NAME: VATRAD1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 10:59:49

PROJECT TITLE: RADIANT

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 4

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4065
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $28
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 5.0 MILLION BTU
PRICE PER MILLION BTU = $4.73
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	3.41%
1988	1.97%	1998	4.08%
1989	3.64%	1999	5.82%
1990	3.51%	2000	0.00%
1991	7.78%	2001	0.00%
1992	5.74%	2002	0.00%
1993	6.83%	2003	0.00%
1994	7.54%	2004	0.00%
1995	6.25%	2005	0.00%
1996	5.31%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 15.0 MILLION BTU
PRICE PER MILLION BTU =$19.38
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.58%	1997	-0.33%
1988	-2.07%	1998	0.13%
1989	-1.37%	1999	0.52%
1990	-2.14%	2000	0.00%
1991	-3.01%	2001	0.00%
1992	-3.17%	2002	0.00%
1993	-1.20%	2003	0.00%
1994	-1.53%	2004	0.00%
1995	-0.84%	2005	0.00%
1996	0.07%	2006	0.00%

Table B-8 BCF: Tampa, Variable Air Volume

BUILDING CHARACTERISTICS FILE

FILE NAME: VATVAV1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 11:00:40

PROJECT TITLE: VAV

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 4

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4000
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $40
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 4.4 MILLION BTU
PRICE PER MILLION BTU = $4.73
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	3.41%
1988	1.97%	1998	4.08%
1989	3.64%	1999	5.82%
1990	3.51%	2000	0.00%
1991	7.78%	2001	0.00%
1992	5.74%	2002	0.00%
1993	6.83%	2003	0.00%
1994	7.54%	2004	0.00%
1995	6.25%	2005	0.00%
1996	5.31%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 10.5 MILLION BTU
PRICE PER MILLION BTU =$19.38
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.58%	1997	-0.33%
1988	-2.07%	1998	0.13%
1989	-1.37%	1999	0.52%
1990	-2.14%	2000	0.00%
1991	-3.01%	2001	0.00%
1992	-3.17%	2002	0.00%
1993	-1.20%	2003	0.00%
1994	-1.53%	2004	0.00%
1995	-0.84%	2005	0.00%
1996	0.07%	2006	0.00%

Table B-9 BCF: Tampa, Fan Coil

BUILDING CHARACTERISTICS FILE

FILE NAME: VATFC1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 11:01:23

PROJECT TITLE: FAN COIL

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 4

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	3450
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $90
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 1.5 MILLION BTU
PRICE PER MILLION BTU = $4.73
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	0.00%	1997	3.41%
1988	1.97%	1998	4.08%
1989	3.64%	1999	5.82%
1990	3.51%	2000	0.00%
1991	7.78%	2001	0.00%
1992	5.74%	2002	0.00%
1993	6.83%	2003	0.00%
1994	7.54%	2004	0.00%
1995	6.25%	2005	0.00%
1996	5.31%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 11.2 MILLION BTU
PRICE PER MILLION BTU =$19.38
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.58%	1997	-0.33%
1988	-2.07%	1998	0.13%
1989	-1.37%	1999	0.52%
1990	-2.14%	2000	0.00%
1991	-3.01%	2001	0.00%
1992	-3.17%	2002	0.00%
1993	-1.20%	2003	0.00%
1994	-1.53%	2004	0.00%
1995	-0.84%	2005	0.00%
1996	0.07%	2006	0.00%

Table B-10 BCF: Phoenix, Radiant Panel

BUILDING CHARACTERISTICS FILE

FILE NAME: VAPRAD1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 11:02:30

PROJECT TITLE: RADIANT

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 9

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4065
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $28
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-10 BCF: Phoenix, Radiant Panel (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 8.2 MILLION BTU
PRICE PER MILLION BTU = $5.64
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.21%	1997	2.37%
1988	-0.76%	1998	5.20%
1989	0.77%	1999	1.51%
1990	1.34%	2000	0.00%
1991	3.40%	2001	0.00%
1992	3.47%	2002	0.00%
1993	4.94%	2003	0.00%
1994	5.21%	2004	0.00%
1995	4.47%	2005	0.00%
1996	3.36%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 13.6 MILLION BTU
PRICE PER MILLION BTU =$21.12
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-2.01%	1997	0.91%
1988	-3.20%	1998	1.75%
1989	-3.25%	1999	0.50%
1990	-2.61%	2000	0.00%
1991	-3.89%	2001	0.00%
1992	-2.39%	2002	0.00%
1993	0.35%	2003	0.00%
1994	0.76%	2004	0.00%
1995	0.52%	2005	0.00%
1996	0.57%	2006	0.00%

Table B-11 BCF: Phoenix, Variable Air Volume

BUILDING CHARACTERISTICS FILE

FILE NAME: VAPVAV1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 11:03:14

PROJECT TITLE: VAV

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 9

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	4000
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $40
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

Table B-11 BCF: Phoenix, Variable Air Volume (continued)

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 5.6 MILLION BTU
PRICE PER MILLION BTU = $5.64
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.21%	1997	2.37%
1988	-0.76%	1998	5.20%
1989	0.77%	1999	1.51%
1990	1.34%	2000	0.00%
1991	3.40%	2001	0.00%
1992	3.47%	2002	0.00%
1993	4.94%	2003	0.00%
1994	5.21%	2004	0.00%
1995	4.47%	2005	0.00%
1996	3.36%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 9.7 MILLION BTU
PRICE PER MILLION BTU =$21.12
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-2.01%	1997	0.91%
1988	-3.20%	1998	1.75%
1989	-3.25%	1999	0.50%
1990	-2.61%	2000	0.00%
1991	-3.89%	2001	0.00%
1992	-2.39%	2002	0.00%
1993	0.35%	2003	0.00%
1994	0.76%	2004	0.00%
1995	0.52%	2005	0.00%
1996	0.57%	2006	0.00%

Table B-12 BCF: Phoenix, Fan Coil

BUILDING CHARACTERISTICS FILE

FILE NAME: VAPFC1(.BCF)
FILE LAST MODIFIED ON 05-16-1987 11:03:56

PROJECT TITLE: FAN COIL

BASIC LCC ANALYSIS ASSUMPTIONS:

ANALYSIS TYPE: NBS HANDBOOK 135
BASE DATE FOR LCC ANALYSIS: 1987
STUDY PERIOD: 20 YEARS
OCCUPANCY DATE: 1987
DISCOUNT RATE (REAL) = 7.00%
BUILDING TYPE = 2 COMMERCIAL
DOE REGION = 9

CAPITAL COMPONENT AND REPLACEMENT COST DATA:

NUMBER OF CAPITAL COMPONENTS: 1
CAPITAL COMPONENT DATA:

COMPONENT NAME	HVAC
INITIAL COMPONENT COST	3450
INIT. CONSERVATION-RELATED COST	0
EXPECTED COMPONENT LIFE(YRS)	20
AVG PRICE ESC RT DURING CONST.	0.00%
AVG PRICE ESC RT DURING OCC.	0.00%
RESALE VALUE FACTOR	0.00%
NUMBER OF REPLACEMENTS	0

NO REPLACEMENTS TO ANY CAPITAL COMPONENTS

OPERATING AND MAINTENANCE COST DATA:

ANNUAL RECURRING O AND M COST = $90
ANNUAL RATE OF INCREASE FOR A.R.C. = 0.00%
NUMBER OF NON-ANNUAL RECURRING O AND M COSTS = 0
ANNUAL RATE OF INCREASE FOR N.A.R.C. COSTS = 0.00%

ENERGY COST DATA:

NUMBER OF ENERGY TYPES = 2

ENERGY TYPE NO. 1 = NATURAL GAS
AVG ANNUAL CONSUMPTION = 2.5 MILLION BTU
PRICE PER MILLION BTU = $5.64
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-4.21%	1997	2.37%
1988	-0.76%	1998	5.20%
1989	0.77%	1999	1.51%
1990	1.34%	2000	0.00%
1991	3.40%	2001	0.00%
1992	3.47%	2002	0.00%
1993	4.94%	2003	0.00%
1994	5.21%	2004	0.00%
1995	4.47%	2005	0.00%
1996	3.36%	2006	0.00%

ENERGY TYPE NO. 2 = ELECTRICITY
AVG ANNUAL CONSUMPTION = 10.8 MILLION BTU
PRICE PER MILLION BTU =$21.12
ANNUAL DEMAND (AND/OR OTHER CHARGE) = $0
ESCALATION RATE METHOD = 2

YEAR	RATE	YEAR	RATE
1987	-2.01%	1997	0.91%
1988	-3.20%	1998	1.75%
1989	-3.25%	1999	0.50%
1990	-2.61%	2000	0.00%
1991	-3.89%	2001	0.00%
1992	-2.39%	2002	0.00%
1993	0.35%	2003	0.00%
1994	0.76%	2004	0.00%
1995	0.52%	2005	0.00%
1996	0.57%	2006	0.00%

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5. AUTHOR(S)

George N. Walton and Stephen R. Petersen

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Thermal and economic analyses were performed for three different types of heating, ventilating, and cooling systems for a patient room in a typical VA patient facility in each of four locations. Thermal analysis was done with the U.S. Army's Building Loads Analysis and System Thermodynamics (BLAST) energy analysis program. Radiant Panel, variable air volume (VAV), and fan coil systems were simulated. Some subroutines were developed and added to the BLAST program in order to simulate the radiant panel system. The predicted energy requirements, energy cost projections, and system costs were then evaluated using the NBS Federal Building Life-Cycle Cost (FBLCC) program to determine the 20-year life-cycle cost of each system in each location.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

building design; building economics; energy analysis; HVAC systems; life-cycle cost analysis; thermal analysis

13. AVAILABILITY

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