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STANDARDIZED EMCS ENERGY SAVINGS CALCULATIONS

September 1982

An Investigation Conducted by
NEWCOMB & BOYD, CONSULTING ENGINEERS
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Atlanta, Georgia

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This report describes standardized methods for determining energy savings obtainable from EMCS applications programs using manual and computerized algorithms. The methods will provide reasonable approximations of savings but not detailed energy analyses of building operations.

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1.0 SUMMARY

This document is prepared in accordance with Contract N62474-81-C-9382, Task 3, from the Civil Engineering Laboratory, Port Hueneme, California. It describes standardized time-based and climate-based methods for determining energy savings obtainable from EMCS energy conservation programs utilizing manual and computerized algorithms. It is intended that these methods will provide reasonable approximations of savings and not detailed energy analyses of each building. When applicable, computer methods are recommended over manual methods to provide better accuracy. For energy conservation strategies, for which computer adgorithms exist and manual methods are unreliable, use of a computer is required. These circumstances are spelled out in Section 3 of ths report. The methods are applied to typical examples of the systems identified in the Tri-Service Design Manual for EMCS, TM 5-815-2/AFM 88-36/NAVFAC DM-4.9. Field data required for these calculations and forms which may be used in recording the field data and performing the savings calculations are included. General information about Energy Monitoring and Control Systems, descriptions of the energy conservation programs, and schematics of the typical systems may be found in the Tri-Service Design Manual referenced above. Section 5 details a hypothetical installation and completed sample forms using the manual methods discussed in this report.

2.0 FIELD SURVEY DATA

A field survey of the facility under study is required to determine what systems are present in each building being considered for EMCS connection. As-built drawings and equipment lists obtained from facility personnel need to be verified. The operation of each system and the building it serves must be determined in sufficient detail to determine which EMCS functions may be applicable to each system. These and other tasks to be performed during the field survey are listed on page 200 of the Tri-Service Design Manual for EMCS, TM 5-815-2/AFM 88-36/NAVFAC DM-4.9. Building and system survey forms which may be used in this endeavor are shown on the following two pages, in Figures 1 and 2. Blank forms are also included in Appendix A.1.

Twenty-nine typical HVAC systems to which EMCS conservation programs may be applied have been identified. System schematics and I/O summary tables for these systems may be found in the Tri-Service Design Manual for EMCS, TM 5-815-2/AFM 88-36/NAVFAC DM-4.9, pages 105 to 163.

Figure 3 lists those energy programs which may be applied to a particular system type and a page reference where the calculation method may be found. Information, specific to system type, which is required for calculation of energy savings is shown on the checklist on pages 6 to 8.

FIGURE 1

BUILDING DESCRIPTION DATA

BUILDING NUMBER: ____________________

BUILDING DESCRIPTION: ____________________

GROSS AREA (SQUARE FEET): ____________________

NUMBER OF FLOORS: ____________________

TYPE CONSTRUCTION: ____________________

____

____

APPROX. FLOOR TO FLOOR HEIGHT (FT): ____________________

GLASS TYPE: ____________________

CRITICAL AREAS: ____________________

____

____

OCCUPANCY SCHEDULE: ____________________

____

____

____

FIGURE 2

SYSTEM DESCRIPTION DATA

BUILDING NUMBER ______

SYS # ______

TYPE ______

MFGR. MOD. # ______

CAPACITY ______

HP (TYPE) ______

HP (TYPE) ______

HP (TYPE) ______

AREA SERVED ______

CONTROLS ______

NOTES: ______

SYS # ______

TYPE ______

MFGR. MOD. # ______

CAPACITY ______

HP (TYPE) ______

HP (TYPE) ______

HP (TYPE) ______

AREA SERVED ______

CONTROLS ______

NOTES: ______

SYS # ______

TYPE ______

MFGR. MOD. # ______

CAPACITY ______

HP (TYPE) ______

HP (TYPE) ______

HP (TYPE) ______

AREA SERVED ______

CONTROLS ______

NOTES: ______

SYS # ______

TYPE ______

MFGR. MOD. # ______

CAPACITY ______

HP (TYPE) ______

HP (TYPE) ______

HP (TYPE) ______

AREA SERVED ______

CONTROLS ______

NOTES: ______

FIGURE 3

ENERGY CONSERVATION PROGRAM APPLICATIONS

REFERENCE PAGE	28	34	34	38	40	40	41	36	43	45	47	48	48	49	50	51
No. HVAC System Type	S/S Schedule	Duty Cycle	Demand Limit	Vent. Recirculation	OA Enthalpy *	OA Economizer *	Night Setback	S/S Optimization	Reheat Coil Reset	Hot/Cold Deck Reset	HW OA Reset	Boiler Optimization	Chiller Optimization	Chilled Water Reset	Condenser Water Reset	Chiller Demand Limit +
1 Single Zone AHU	●	●	●	●	●	●	●	●								
2 Terminal Reheat AHU	●	●	●	●	●	●	●	●	●							
3 Variable Air Volume AHU	●	●	●	●	●	●	●	●								
4 Multi-Zone AHU	●	●	●	●	●	●	●	●		●						
5 Single Zone DX-A/C	●	●	●	●	●	●	●	●								
6 Multi-Zone DX-A/C	●	●	●	●	●	●	●	●		●						
7 Two Pipe Fan Coil Unit	●	●	●				●	●								
8 Four Pipe Fan Coil Unit	●	●	●				●	●								
9 Heating Ventilating Unit	●	●	●	●			●	●								
10 Steam Unit Heat							●									
11 Electric Unit Heater	●	●	●				●	●								
12 Hot Water Unit Heater							●									
13 Steam Radiation							●	●								
14 Electric Radiation	●	●	●				●	●								
15 Hot Water Radiation							●	●			●					
16 Steam Boiler												●				
17 Hot Water Boiler												●				
18 Direct Fired Furnace	●	●	●	●			●	●								
19 Direct Fired Boiler	●	●	●	●			●	●								
20 Steam HW Converter	●							●			●					
21 HTHW Steam Converter											●					
22 HTHW HW Converter	●							●			●					
23 Water Cooled DX Compressor	●	●	●					●							●	
24 Air Cooled DX Compressor	●	●	●					●								
25 Air Cooled Chiller	●	●	●					●					●	●		●
26 Water Cooled Chiller	●	●	●					●					●	●	●	●
27 Lighting Control	●		●													
28 Domestic HW Electric	●	●	●					●								
29 Domestic HW Gas or Oil	●							●								

*Select Economizer <u>or</u> Enthalpy
+Centrifugal Chillers only

2.1 FIELD INFORMATION CHECKLIST

All Systems

--- area being served by the system

--- required schedule of operation if different from normal building occupancy schedule

--- reliability and schedule of any existing start/stop control (manual or timeclock)

--- manufacturer's model number

Types 1 to 6 Air Handlers

--- required summer setpoint if different than 78°F

--- required winter setpoint if different than 68°F

--- required unoccupied low temperature limit if different than 55°F

--- sources of heating and cooling media

--- cfm capacity

--- percent minimum outside air

--- OA damper control and revisions necessary to convert to economizer control

--- supply and return (if any) fan horsepower

--- required unoccupied period setpoints if system cannot be shutdown

* --- reasonable reheat system reset (°F) based on coil capacity and space loads or use suggested estimates from Section 4.

\+ --- reasonable hot and cold deck resets (°F) based on coil capacities and space loads or use suggested estimates from Section 4.

\+ --- percent of system cfm passing through hot and cold decks

* Terminal Reheat AHU only

\+ Multizone AHU and DX-A/C systems only

Types 7, 8, 11, 14 Systems with no outside air

--- required summer setpoint if different than 78°F
--- required winter setpoint if different than 68°F
--- required unoccupied low temperature limit if different than 55°F
--- sources of heating and/or cooling media
--- supply fan horsepower
--- required unoccupied period setpoints is system cannot be shutdown

Types 9, 18, 19 Heating only fan units

--- required winter setpoint if different than 68°F
--- required unoccupied low temperature limit if different than 55°F
--- source of heating medium
--- cfm capacity
--- percent minimum outside air
--- OA damper control
--- supply and return (if any) fan horsepower
--- required unoccupied period setpoints if system cannot be shutdown

Types 10, 12, 13, 15 Heating Systems

--- required winter setpoint if different than 68°F
--- source of heating medium
--- required unoccupied period setpoint
* --- total maximum output of hot water radiators

* Only needed for consideration of hot water temperature reset on an independent hot water radiation loop; otherwise, it will be reset at the hot water source.

Types 16, 17 Steam or Hot Water Boiler

--- maximum capacity of each boiler
--- type of energy source (fuel)
--- conditions of operation for estimation of efficiency

Types 20, 21, 22 Converters

--- maximum heat transfer capacity of converter
--- horsepower rating of all associated pumps
--- source of steam or hot water
--- conversion efficiency (or assume 90%)

Types 23, 24, 25, 26 DX Compressors and Chillers

--- type of compressor(s)
--- horsepower of compressor motor(s) and any auxiliary pumps
--- staging control
--- refrigeration capacity (tons)
* --- entering condenser water temperature setpoint
* * --- cycling or continuously running tower fan
* * --- cold water setpoint
--- capacity control
--- double bundle condenser

* Water cooled systems only
** Chillers only

Type 27 Lighting Control

--- total KW per lighting zone

Type 28, 29 Domestic Hot Water

--- type energy source (fuel)
--- tank height and diameter
--- insulation thickness
--- hot water temperature setpoint
--- average temperature of surroundings
--- possible shutdown schedule

The savings calculations use motor horsepowers in calculation of auxiliary savings. If horsepower is not listed on the motor nameplates then calculate it based on the electrical data as follows:

$$HP = \frac{V \times A \times \sqrt{\phi} \times 0.85}{1000 \text{ watts/kw} \times 0.746 \text{ kw/hp}}$$

where,

V = voltage

A = full load or rated amperage

ϕ = number of phases

For motors 25 HP or greater, it is preferable to take field measurements of the electrical consumption.

The air handling capacity in cubic feet per minute (cfm) is required for analysis of most air handler systems. If this information cannot be determined from the equipment nameplate, catalog data or as-built mechanical plans, then assume a cfm value equal to the square feet of area being served.

3.0 DATA DEVELOPMENT

Many factors which affect the magnitude of energy savings achievable from the conservation programs are only dependent on the climate of a particular location or the building design and load characteristics. The determination of these constant factors is discussed in this section.

3.1 Climate-based factors

Before beginning the savings analysis at a particular location, those factors which are solely related to climate should be calculated. The derived values of the climate-based factors may be entered into the table shown in Figure 4, for easy reference while performing the system analyses. A blank form is also included in Appendix A.1. The page reference indicates the page in this report where a method of determining the data is outlined. If actual weather data for the facility under study is available it should be used in preference to calculated data. For example, if a base has a yearly schedule for turning central cooling equipment on May 20 and off September 30 then that time period should be used for the weeks of summer (WKS).

Several factors may be derived from weather data located in Chapter 3 of the Engineering Weather Data, NAVFAC P-89/AFM 88-29/TM 5-785. The following pages demonstrate methods for calculating each of the Climate-Based Factors using weather data for Springfield MAP, Missouri. In each case, the columns in the data tables are derived from the weather data reproduced in Figures 5 and 6, from Chapter 3, pages 3-20 and 3-21, of the Engineering Weather Data. The column letter indices in each procedure correspond to the letters on the columns in Figures 5 and 6. The Climate-Based Factors for any location in the Engineering Weather Data can be derived in a similar fashion.

FIGURE 4

CLIMATE - BASED FACTORS

LOCATION: ______________________________

SYMBOL	DESCRIPTION	PAGE REF.	VALUE	UNITS
ACWT	Average Condenser Water Temperature	16		°F
AND	Annual Number of Days for Warmup	18		Days/Yr.
AST*	Average Summer Temperature	19		°F
AWT*	Average Winter Temperature	19		°F
CFLH	Annual Equiv. Full-Load Hrs. For Cooling	20		Hrs/Yr.
HFLH	Annual Equiv. Full-Load Hrs. for Heating	22		Hrs/Yr.
HS	Hrs. of Temp. Limit Shut-off for Summer	23		Hrs/Yr
HW	Hrs. of Temp. Limit Shut-off for Winter	23		Hrs/Yr
OAH*	Average Outside Air Enthalpy	24		Btu/lb.
PRT*	Percent Run Time for Low Temp. Limit	25		%
WKS*	Weeks of Summer	27		Wks/Yr.
WKW*	Weeks of Winter	27		Wks/Yr.

* Data not necessary if computer methods are used.

SPRINGFIELD MAP MISSOURI

LAT 37 14N LONG 93 23W ELEV 1268 FT

MEAN FREQUENCY OF OCCURRENCE OF DRY BULB TEMPERATURE (DEGREES F) WITH MEAN COINCIDENT WET BULB TEMPERATURE (DEGREES F) FOR EACH DRY BULB TEMPERATURE RANGE

Temperature Range	MAY					JUNE					JULY					AUGUST					SEPTEMBER					OCTOBER				
	Obsn Hour Gp 01 to 08	09 to 16	17 to 24	Total Obsn	M C W B	01 to 08	09 to 16	17 to 24	Total Obsn	M C W B	01 to 08	09 to 16	17 to 24	Total Obsn	M C W B	01 to 08	09 to 16	17 to 24	Total Obsn	M C W B	01 to 08	09 to 16	17 to 24	Total Obsn	M C W B	01 to 08	09 to 16	17 to 24	Total Obsn	M C W B
110/114												0		0	77															
105/109												1	0	1	78															
100/104							0	0	0	73		2	0	2	76		2	0	2	74		0		0	70					
95/99							9	2	11	74	0	10	3	13	74		15	4	19	74		5	0	5	70					
90/94		1	0	1	76		23	6	29	74	0	42	13	55	75	0	40	10	50	74		14	3	17	70		1		1	66
85/89		17	3	20	70	1	45	15	61	73	2	63	26	91	74	1	64	25	90	72	0	33	9	42	70		7	0	7	67
80/84	0	41	14	55	69	8	57	31	96	71	12	59	42	113	72	7	56	42	105	71	2	42	16	60	68		24	3	27	66
75/79	3	46	24	73	66	24	41	50	115	69	41	39	65	145	71	31	39	63	133	70	6	44	32	82	66	8	32	0	40	63
70/74	18	46	46	110	64	58	32	59	149	67	54	23	63	140	69	92	21	59	172	68	32	45	53	130	65	4	41	19	64	61
65/69	47	41	54	142	61	74	20	44	138	64	69	7	29	105	65	67	8	30	105	64	64	30	55	149	63	18	36	39	93	60
60/64	71	30	49	150	58	42	8	22	72	60	21	1	6	28	60	35	2	11	48	60	54	16	35	105	58	39	35	48	122	56
55/59	47	16	29	92	53	21	3	7	31	55	7		1	8	54	10	0	3	13	55	36	6	22	64	53	45	31	39	115	52
50/54	30	7	18	55	49	10	1	3	14	51	1			1	51	4		0	4	51	27	2	12	41	49	43	22	37	102	48
45/49	21	3	8	32	44	2		0	2	46						1			1	47	13	0	3	16	45	36	11	28	75	43
40/44	8	1	1	10	40	0			0	43											3		0	3	41	32	5	18	55	39
35/39	3	0	1	4	36																0			0	38	17	2	6	25	35
30/34	1		0	1	32																					10	1	3	14	30
25/29																										2		0	2	25
20/24																										0			0	22
		144					64					31					31					99								

FIGURE 5

Sample Weather Data - Cooling Season

SPRINGFIELD MAP MISSOURI

	Temperature Range	NOVEMBER Obsn Hour Gp 01 to 08	NOVEMBER 09 to 16	NOVEMBER 17 to 24	NOVEMBER Total Obsn	NOVEMBER MCWB	DECEMBER Obsn Hour Gp 01 to 08	DECEMBER 09 to 16	DECEMBER 17 to 24	DECEMBER Total Obsn	DECEMBER MCWB	JANUARY Obsn Hour Gp 01 to 08	JANUARY 09 to 16	JANUARY 17 to 24	JANUARY Total Obsn	JANUARY MCWB	FEBRUARY Obsn Hour Gp 01 to 08	FEBRUARY 09 to 16	FEBRUARY 17 to 24	FEBRUARY Total Obsn	FEBRUARY MCWB	MARCH Obsn Hour Gp 01 to 08	MARCH 09 to 16	MARCH 17 to 24	MARCH Total Obsn	MARCH MCWB	APRIL Obsn Hour Gp 01 to 08	APRIL 09 to 16	APRIL 17 to 24	APRIL Total Obsn	APRIL MCWB	ANNUAL TOTAL Obsn Hour Gp 01 to 08	ANNUAL TOTAL 09 to 16	ANNUAL TOTAL 17 to 24	ANNUAL TOTAL Total Obsn	ANNUAL TOTAL MCWB
			40					5					8					9					35					107								
112	110/114	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
107	105/109	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
102	100/104	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
97	95/99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
92	90/94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
87	85/89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
82	80/84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
77	75/79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
72	70/74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
67	65/69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
62	60/64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
57	55/59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
52	50/54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
47	45/49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
42	40/44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	35/39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	30/34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	25/29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	20/24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	15/19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	10/14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	5/9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	0/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-3	-5/-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-8	-10/-6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
H	E																															F	C	I	K	A

SAMPLE WEATHER DATA-HEATING SEASON

Average entering condenser water temperature (ACWT):

The purpose of this procedure is to find the average entering condenser water temperature which can be obtained from a cooling tower during the cooling season at a given location. This value can then be used in the Condenser Water Temperature Reset savings calculations for any cooling tower in the same geographic location.

Using the Engineering Weather Data, compile a data table like the one below for Springfield, Missouri. Find the Mean Coincident Wet Bulb Temperatures corresponding to Temperature Ranges above 55°F. (Column A). Assume an approach temperature (the difference in temperature between the outside air wet bulb temperature and the entering condenser water temperature) of 10°F. Add this to the Mean Coincident Wet Bulb Temperatures (Column B). For normal office hours of operation consider the annual hours of occurrence during the 09 to 16 period (Column C) and perform the following calculations:

A. Mean Coincident Wet Bulb °F	B. Condenser Water Temp. (A + 10°)	C. 09 to 16 Hours of Occurrence	D. Temperature Hours (B x C)
77	87	0	0
74	84	1	84
74	84	4	336
74	84	39	3276
74	84	121	10164
72	82	232	19024
70	80	295	23600
68	78	279	21762
66	76	272	20672
62	72	228	16416
57	67	204	13668
52	62	181	11222
		1856	140224

Average condenser water temperature = ACWT

= Total of D/Total of C

= 140221/1856 = 75.6°F.

Annual number of days requiring morning warmup (AND):

Results of this procedure will be used in savings calculations for Ventilation and Recirculation and Optimum Start/Stop. Assuming the start-up time is early morning consider only those hours of occurrence 01 to 08 for temperatures below 60°F. (Column F). Derive the following information from the weather data:

E. Temperature Range °F	F. 01 to 08 Hours of Occurrence	G. Annual No. Of Days (F ÷ 8)
55/59	235	30
50/54	208	26
45/49	206	26
40/44	219	28
35/39	235	30
30/34	237	30
25/29	195	25
20/24	107	14
15/19	74	10
10/14	46	6
5/9	19	3
0/4	13	2
-5/-1	4	1
-10/-6	1	1
-11 & below	0	0
Total		232

The annual number of days that warmup is required is the total of column G: AND = 232.

Average summer temperature (AST):

Results of this procedure will be used in the savings calculations for Scheduled Start/Stop. Find the annual hours observed for time periods 01 to 08 and 17 to 24 (Columns F and I), which correspond to the mean temperature in the 5° ranges (Column H) above 75°F. Compile a table as follows:

H. Mean °F In Range	F. 01 to 08 Hours of Occurence	I. 17 to 24 Hours of Occurrence	J. Annual Summer Degree Hours (H + I) x G
112	0	0	0
107	0	0	0
102	0	0	0
97	0	9	873
92	0	32	2,944
87	4	78	7,134
82	29	151	14,760
77	105	252	27,489
TOTALS	138 hr.	522 hr.	53,200 hr°F

The average summer temperature is equal to:

$$AST = \text{Total of } J/(\text{Total of } F + \text{Total of } I)$$
$$= 53{,}200/(138 + 522) = 80.6°F$$

Average winter temperature (AWT):

Results of this procedure will be used in the savings calculations for Scheduled Start/ Stop and Ventilation/Recirculation. Find the annual total hours observed (Column K) at temperatures below 65°F (column H) and compile a data table as follows:

H. Mean °F In Range	K. Annual Total Hours	L. Annual Winter Degree Hours
62	768	47,616
57	619	35,283
52	598	31,096
47	608	28,576
42	603	25,326
37	606	22,422
32	577	18,464
27	412	11,124
22	240	5,280
17	141	2,397
12	85	1,020
7	39	273
2	21	42
-3	6	-18
-8	1	-8
TOTALS	5,324 hr/yr	228,893 °F-hr/yr

The average winter temperature is equal to:

AWT = Total of L/Total of K
= 228,893/5,324 = 43.0°F

Annual equivalent full-load hours for cooling (CFLH):

Cooling full-load hours (CFLH) will be used in savings calculations for Chiller Water Temperature Reset and and Condenser Water Temperature Reset. A value can be chosen from Table 3, p. 43.11, in the 1980 Systems ASHRAE Handbook, or the following procedure can be used to determine the value of the parameter. FInd the 2.5% Summer Design Data Dry Bulb temperature for the location under study in Chapter

1 of the Engineering Weather Data, AFM 88-29/TM 5-785/NAVFAC P-89. For Sprinfield MAP, Missouri it is 93°F. For daytime operation of the cooling systems consider the annual hours of occurence above and equal to 65°F for the 09 to 16 period (Column C), as in the example. For 24-hour operation consider the total observed annual hours of occurrence (Column K). Develop the following data table from the weather data:

H. Mean °F In Range	C. 09 to 16 Hours of Occurence	M. Degree Hours C(H-65°)
112	0	0
107	1	42
102	4	148
97	39	1,248
92	121	3,267
87	232	5,104
82	295	5,015
77	279	3,348
72	272	1,904
67	228	456
TOTAL		20,532 °F-hr.

Annual equivalent full-load hours for cooling is calculated as follows:

$$CFLH = \frac{\text{Total of M}}{\text{Cooling design temperature} - 65°}$$

$$= 20{,}532/(93°-65°) = 733 \text{ hr/yr.}$$

Annual equivalent full-load hours for heating (HFLH):

Results of this procedure will be used in savings calculations for Hot Water Outside Air Reset. Find the 97.5% Heating Design Data Dry Bulb Temperature for the location under study in Chapter 1 of the Engineering Weather Data, AFM 88-29/ TM5-785/ NAVFAC P-89. For Springfield MAP, Missouri the heating design temperature is listed as 9°F. For daytime operation of a heating system consider the annual hours of occurrence below 65°F for the 09 to 16 period; this was assumed for the example. For 24-hour operation consider the total observed annual hours of occurrence. Develop the following data table from the weather data:

H. Mean °F In Range	C. 09 to 16 Hours Of Occurence	N. Degree Hours C(65°-H)
62	204	612
57	181	1448
52	182	2366
47	191	3438
42	173	3979
37	160	4480
32	149	4917
27	92	3496
22	54	2322
17	28	1344
12	18	954
7	8	464
2	4	252
-3	1	68
-8	0	0
Total		30140 °F-hr.

Annual equivalent full-load hours for heating is calculated as follows:

$$HFLH = \frac{\text{Total of N}}{65° - \text{heating design temperature}}$$

$$= 30140/(65° - 9°) = 538 \text{ hr/yr}$$

<u>Hours for outside air temperature shutoff (HS and HW)</u>:

Results of this procedure will be used in savings calculations for Outside Air Shutoff Limit. For the heating savings consider the months during which heating auxiliaries such as hot water pumps are scheduled to operate at the facility under study and from the weather data determine the total number of hours during that period that the temperature is <u>above</u> or equal to 65°F. In a similar fashion determine the number of hours <u>below</u> the cooling season temperature limit. Cooling season shut off should only be considered for small skin-dominated buildings (low internal heat gains compared to heat transfer through walls and roof) and the temperature limit should be chosen accordingly. For the Springfield example assume the heating pumps operate November through April based on the 23.4 week winter determined on page 27. Assume the chiller for a skin-dominated building with operable windows is turned on the 15th of May and runs through September. A summer temperature limit of 75°F is used. Only the 09 to 16 time periods are considered for the example. The actual seasonal schedule for heating equipment and cooling equipment should be used when known for a facility.

Hours in summer outside temperature is below summer limit =

$$HS = 1/3\ (144) + 64 + 31 + 31 + 99 = 273 \text{ hr/yr}$$

Hours in winter outside temperature is above winter limit =

$$HW = 40 + 5 + 8 + 9 + 35 + 107 = 204 \text{ hr/yr}$$

Average outside air enthalpy (OAH):

The results of this procedure will be used in the savings calculations for Scheduled Start/Stop. For normal daytime hours of operation of the HVAC equipment consider the hours of occurrence for the time periods 01 to 08 and 17 to 24 above 75°F dry bulb temperature. Develop the following data table from the weather data:

A. Mean Coincident Wet Bulb (°F)	F. 01 to 08 Hours of Occurrence	I. 17 to 24 Hours of Occurrence	O. Degree Hours Ax(B+C)
77	0	0	0
74	0	0	0
74	0	0	0
74	0	9	666
74	0	32	2368
72	4	78	5904
70	29	151	12600
68	105	252	25276
Totals	138 hrs.	522 hrs.	45814 hrs-°F

Average wet bulb temperature =

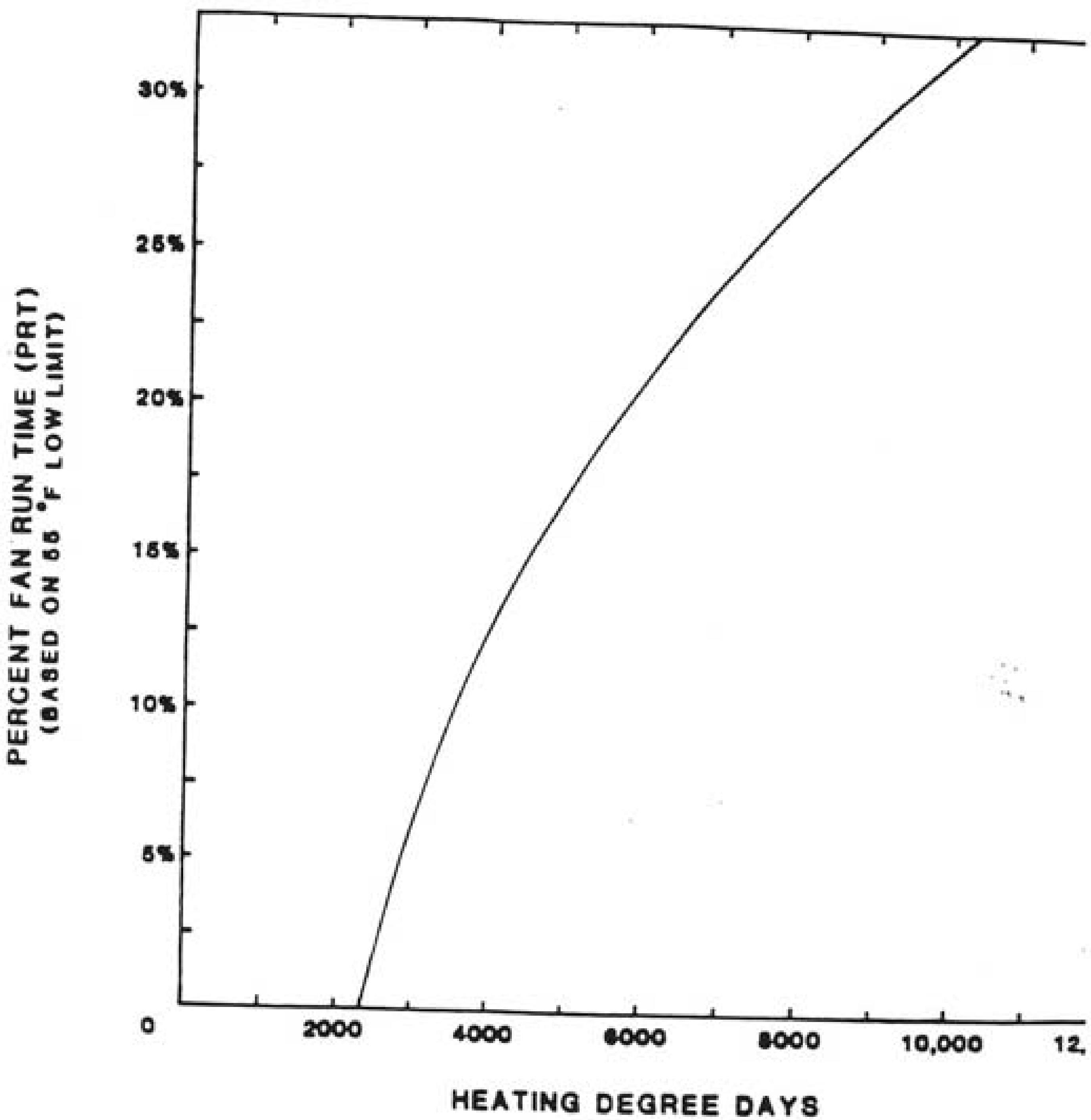
Total of O/(total of F + total of I) =

45814/(138 + 522) = 69.4°F.

The corresponding outside air enthalpy (OAH) can be obtained by consulting Appendix A.2. For this example the OAH which corresponds to 69.4°F - WB is 33.34 Btu/lb.

Percent runtime for low temperature limit (PRT):

THe percent runtime (PRT) is the percentage of scheduled off time during unoccupied periods when the fans and pumps must come back on in order to maintain a 55°F setback temperature. The determined value will be used in Scheduled Start/ Stop savings calculations. Find the annual Heating Degree Days for the location under study in Chapter 1 of Engineering Weather Data, AFM 88-29/TM 5-785/ NAVFAC P-89. The corresponding percent run time (PRT) can be found on Figure 7, page 26. For the Springfield example the number of heating degree days are 4570, and the corresponding PRT is 15%.



PERCENT FAN RUN TIME (PRT)
(BASED ON 55 °F LOW LIMIT)
30%
25%
20%
15%
10%
5%
0
2000
4000
6000
8000
10,000
12,
HEATING DEGREE DAYS

FIGURE 7

Weeks of summer (WKS) and
Weeks of winter (WKW):

Results of this procedure will be used in the savings calculations for Scheduled Start/Stop, Ventilation/Recirculation, Day/Night Setback, Reheat Coil Reset, and Hot Deck/Cold Deck Temperature Reset. Find the annual total hours observed below 55°F (Column K) and make the calculations shown below:

E. Temperature Range, °F	K. Annual Total Hours
50/54	598
45/49	608
40/44	603
35/39	606
30/34	577
25/29	412
20/24	240
15/19	141
10/14	85
5/9	39
0/4	21
-5/-1	6
-10/-6	1
Total	3937 hr/yr

The weeks of winter are equal to:

$$WKW = \frac{(\text{Total of K}) \text{ hr/yr}}{(24 \text{ hr/dy})(7 \text{ dy/wk})}$$
$$= 3937/(24)(7) = 23.4 \text{ wk/yr}$$

The weeks of summer are equal to:

$$WKS = 52 \text{ wk/yr} - WKW$$
$$= 52 - 23.4 = 28.6 \text{ wk/yr}$$

3.2 Building-specific Factors

Before beginning the savings for each system in a given building it is best to calculate those factors which are constant for that building. It is important when deriving thermal parameters of a building to take account of any proposed architectural modifications. These factors may be entered in forms like the one shown in Figure 8 for easy reference. A blank form is included in Appendix A.1. Following is a discussion of those factors and their derivations.

Building thermal transmission (BTT):

This factor is not needed if computer methods are used. The resultant answer for BTT in Btu/hr°F-ft^2 is used in the Scheduled Start/Stop and Day/Night Setback savings calculations.

$$BTT = [(Uo \times AW) + (I \times 1.08\ \text{Btu/cfm°F-hr})]/AF$$

Where,

* Uo	=	combined U-factor for all exterior surfaces (walls, windows, doors, roof) in Btu/ft^{2}hr°F
AW	=	total area of exterior surfaces in ft^2
* I	=	total infiltration for building in cfm
AF	=	total floor area of the building in ft^2

* The values for these factors may be calculated by methods discussed in ASHRAE Handbook, 1981 Fundamentals, Chapters 22 and 23.

FIGURE 8

BUILDING-SPECIFIC FACTORS

BUILDING: ____________________

* BTT = Building Thermal Transmission

= (U-factor X exterior area) + (Infiltration X 1.08)/Total Floor Area

= (______Btu/hr°F-ft² X ______ft²) + (______cfm X 1.08)/______ft²

= ______Btu/hr°F-ft²

ERT = Annual Run Time of Equipment for Morning Warmup

Heating Degree Days = ____________°F-days

Combined U-factor, Uo = ___________ Btu/hr°F-ft²

From Figure 9 or 10 : ERT = __________ hr/yr

Primary Sources of Cooling Medium

Sys. No	System Type	Systems Served	CPT

Primary Sources of Heating Medium

Sys. No	System Type	Systems Served	HEFF	HV

* Data not necessary if computer method is used.

Annual equipment runtime for morning warmup (ERT):

The equipment runtime (ERT) is the number of hours per year that a system must run in the mornings before occupancy to bring the temperature up to comfort conditions. The calculated value will be used in savings calculations for Optimum Start/Stop. Calculate the combined wall Uo factor by standard methods such as described in the ASHRAE Handbook 1981 Fundamentals, Chapter 23. Find the annual Heating Degree Days for the location under study in Chapter 1 of Engineering Weather Data, AFM 88-29/TM 5-785/NAVFAC P-89. The corresponding equipment runtime (ERT) can be found on Figure 9 or 10, page 33 or 34. For a brick building with an overall U-factor of .21 in Springfield, Missouri (HDD of 4570), the corresponding ERT from Figure 10 is 290 hours per year.

Following are factors which may sometimes be the same for all systems in a given building.

CPT = rate of energy consumption per ton of refrigeration in kw/ton or lb/ton-hr.

This figure will be the same for all air handling systems using chilled water from the same central chiller. DX units or package units will be exceptions. Use a value derived from manufacturer's catalog or nameplate data for the particular model if available; or use the approximate power inputs for compressors listed in Table 2, p. 43.10 of the ASHRAE Handbook, 1980 Systems.

For steam-driven refrigeration machines use:

steam absorption machine	-	18 lb/ton-hr
steam turbine driven machine	-	40 lb/ton-hr

HEFF = heating efficiency of the system

When calculating heating savings for boilers and domestic hot water heaters, use manufacturer's data on efficiencies if available. Typically, the seasonal efficiency of an oil or gas fired boiler and hot water heating system is between .60 and .70, and for coal fired boilers, somewhat lower. For separate domestic hot water heaters, seasonal efficiencies are about .70 for oil fired heaters, .75 for gas fired heaters, and .95 for electric water heaters.

When calculating heating savings for converters, heat exchanger effectiveness must be included. Use a factor of 0.90 combined with the efficiency of the boiler which serves the converter if actual equipment data is not available. For example, if a boiler with an efficiency of 0.65 supplies steam to a steam/hot water converter, then the total heating efficiency (HEFF) of the converter will be :65 times .90 or .585.

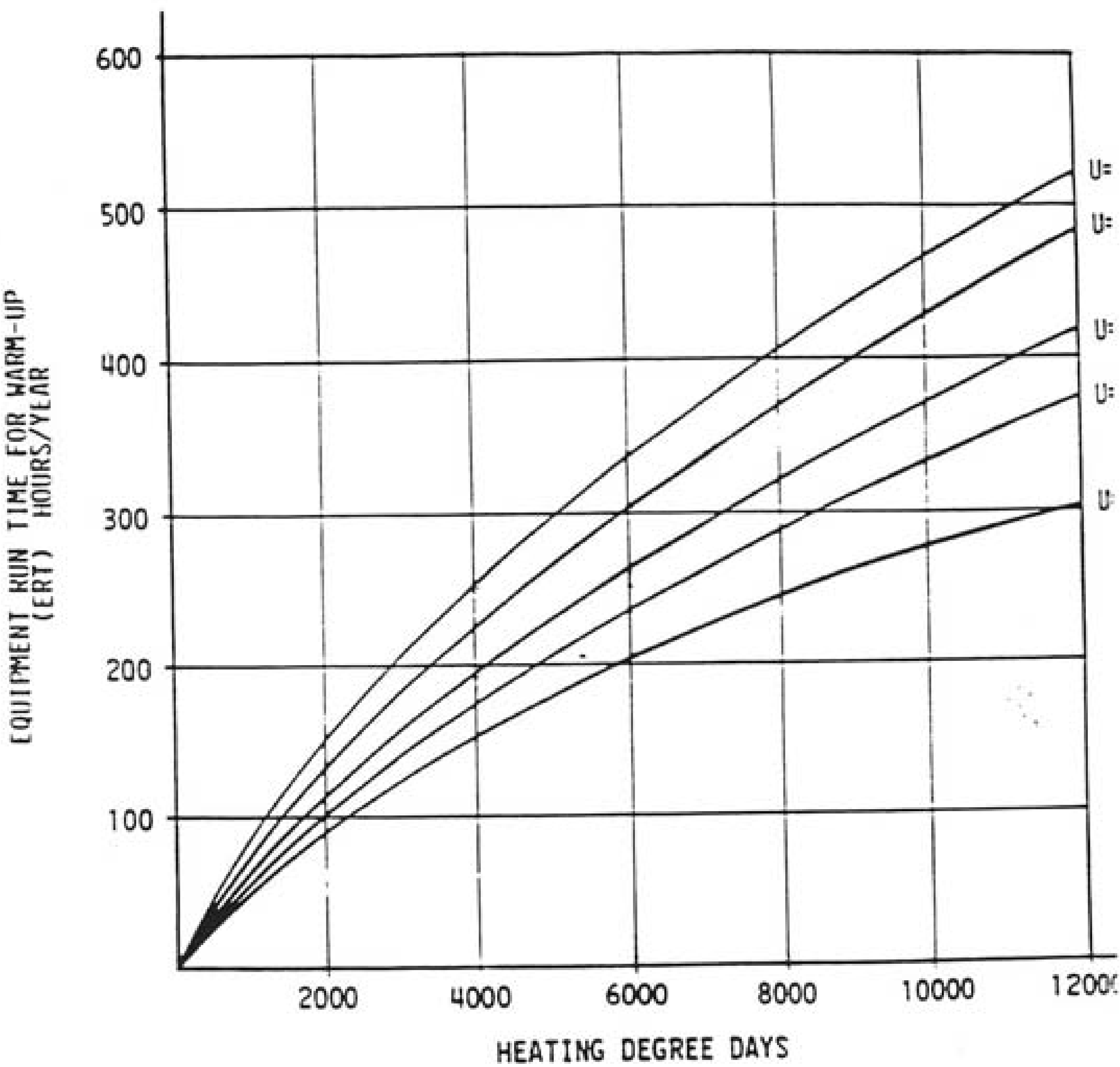
When calculating heating savings for secondary systems, the distribution losses also must be taken into account. The distribution efficiencies of hot water systems may be estimated based on the flow rate and the temperature difference between the outlet of the boiler or converter and the inlet to the air handler heating coil. If this data is not available, assume a distribution efficiency of 0.90. This must be multiplied by the boiler or converter efficiency to determine the combined heating efficiency (HEFF) of the secondary system.

For electrical resistance duct heaters assume a heating efficiency of 1.0.

HV = heating value of fuel.

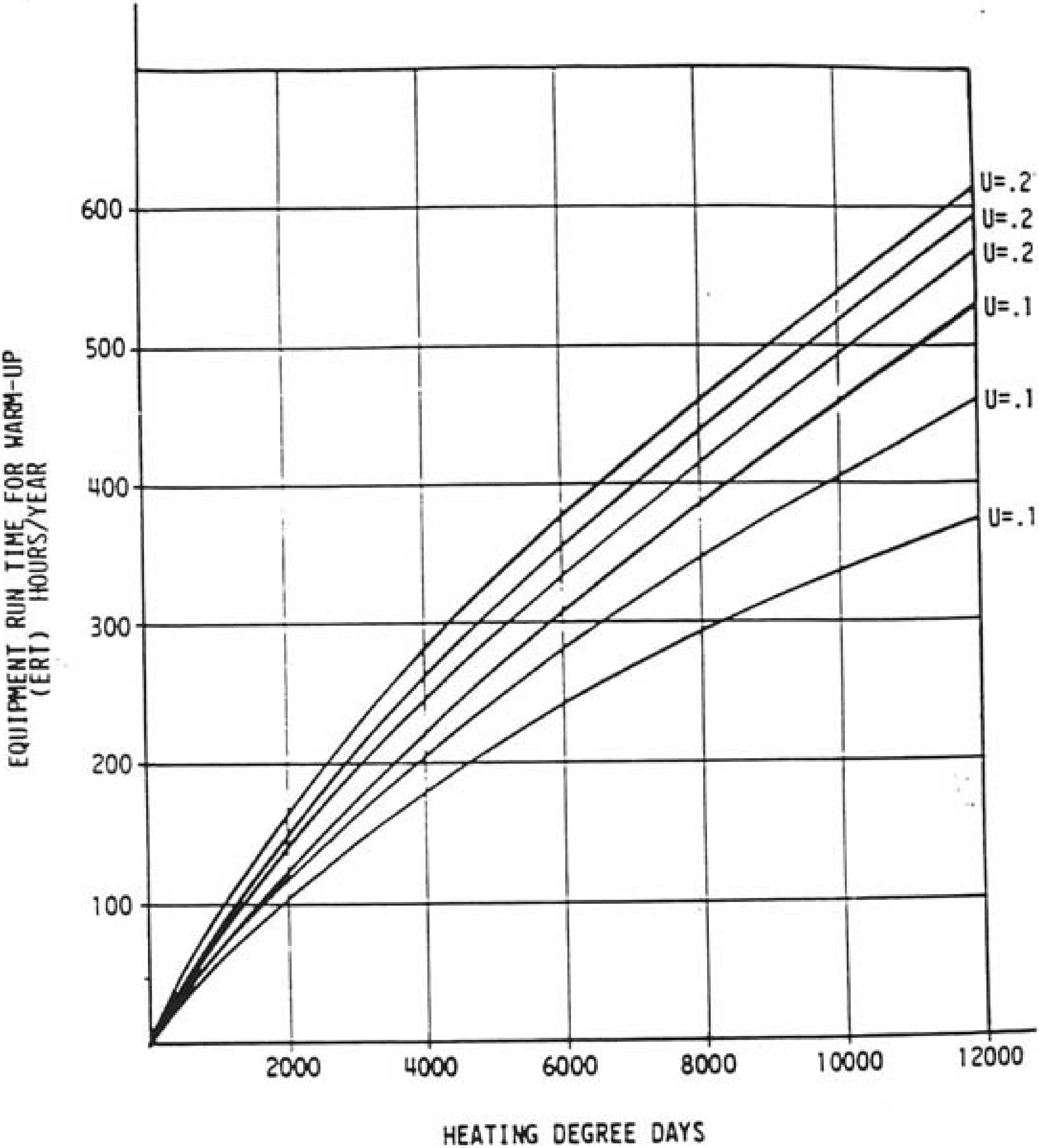
Actual heating values should be used when known; otherwise, use the following values to convert heating load in BTU's to actual fuel consumed at the building. These numbers will be used for calculating the actual amount of fuel saved in gallons, cubic feet, etc., which then will be used to determine dollar savings, based on the price per unit of fuel. Therefore, the numbers listed below for Purchased Steam and Electrical Source Fuel must be differentiated from the values for off-site generated fuel (1390 Btu/lb and 11,600 But/Kwh), which are recommended for calculation of energy to cost (E/C) ratios in Energy Conservation Investment Program (ECIP) economic analyses.

Distillate Fuel Oil..................138,700 BTU/gal
Residual Fuel Oil....................150,000 BTU/gal
Natural Gas........................1,031,000 BTU/1000 cu.ft
LPG, Propane, Butane..................95,500 BTU/gal
Bituminous Coal...................24,580,000 BTU/Short Ton
Purchased Steam........................1,060 BTU/lb
Electrical Source Fuel.................3,413 BTU/KWH



LIGHT CONSTRUCTION

FIGURE 9



HEAVY CONSTRUCTION

FIGURE 10

3.3 Miscellaneous Factors

L = load factor

This takes into account the efficiency and partial load of motors. For conservation savings estimation use 0.8 based on,

$$L = \frac{\text{partial load}}{\text{efficiency at part load}} = \frac{.68}{.85} = 0.8$$

Other values should be used if information on a particular motor indicates such.

LTL = low temperature limit in °F for shutdown periods, usually is 50°F or 55°F.

SSP = summer thermostat setpoint in °F; 78°F is recommended for normal occupancy

WSP = winter thermostat setpoint in °F; 65°F is recommended for normal occupancy

4.0 Savings Calculation Algorithms

When calculating energy savings for systems on which more than one EMCS function may be applied, care must be taken not to duplicate savings. For example, the potential cooling savings from cold/hot deck reset is affected by the operation of an economizer cycle. Therefore, it is necessary to include an economizer cycle in the computer simulation runs used for considering hot/cold deck reset savings if the economizer cycle program is also going to be used on the system. These type considerations are discussed with the savings calculations for each energy saving function.

Also, care must be taken not to calculate the same heating or cooling savings for both the secondary system and primary system serving it. For example, both an air handler and the chiller providing chilled water to the AHU coil may be considered for Scheduled Start/Stop. The cooling savings for the space being served may be calculated in the savings analysis for either system but not both.

The time event programs Scheduled Start/Stop, Day/Night Setback, Ventilation/Recirculation, and Optimum Start/Stop are closely related and the savings attributable to each is dependent on how the function is defined. An attempt has been made in the development of standard methods of determining energy savings to differentiate among these programs based on the descriptions found in Section II of the <u>Energy Monitoring and Control Systems(EMCS) Technical Manual</u>, TM 5-815-2/AFM 88-36/NAVFAC DM-4.9.

Scheduled Start/Stop may be applied to systems which can be shut down during unoccupied hours, such as chillers and air handlers serving non-critical areas. Day/Night Setback is to be applied to systems which cannot be completely shut down during unoccupied hours, but can have thermostat setpoints set back. Optimum Start/Stop calculations are applicable only in conjunction with Scheduled Start/Stop for systems having auxiliary pumps and/or fans. Some heating and cooling energy may be saved by Optimum Start/Stop applied to night setback scheduling, however, estimation of these savings would be difficult; therefore, only auxiliary savings are considered. The Ventilation and Recirculation program is applicable in conjunction with Scheduled Start/Stop or Day/Night Setback for air handlers which have or are to be retrofitted with outside air damper control.

Standard methods for calculating yearly savings from each energy conservation strategy, as they apply to individual systems, have been developed. Computer methods are recommended for better accuracy, when a building energy simulation computer program is available. The standard methods are discussed in the following pages. A master variable glossary of all the parameters used in the calculations is included in Appendix A.3.

Each equation below results in an answer with units of energy per year. In most cases, cooling savings will be in kwh per year, except where an absorption or steam turbine driven chiller is in operation. In that case, cooling savings will be in pounds of steam per year and needs to be converted to the primary fuel source units for the on-site boiler, taking boiler efficiency into consideration. Heating savings calculations will result in an answer with units of fuel consumption per year. The units could be cubic feet of natural gas per year or gallons of fuel oil per year or any other primary source of heat on the facility.

4.1 SCHEDULED START/STOP

Manual Method:

The following savings calculations for HVAC equipment assume a low temperature override to system shutdown. If no low temperature limit is desired than use the average winter temperature (AWT) in place of the low temperature limit (LTL) and let percent runtime (PRT) equal zero.

Cooling savings =

$$\frac{BTT \times AZ \times (AST-SSP) \times (168\ hr/wk - H) \times WKS \times CPT \times F}{12{,}000\ Btu/ton\text{-}hr}$$

Heating savings =

$$\frac{BTT \times AZ \times (WSP-LTL^{*}) \times (168\ hr/wk - H) \times WKW \times F}{HEFF \times HV}$$

Ventilation cooling savings =

$$[CFM \times POA \times (4.5\ lb/cfm\text{-}hr) \times (OAH-RAH) \times (168\ hr/wk - H) \times WKS \times CPT \times F]/(12{,}000\ Btu/ton\text{-}hr)$$

Ventilation heating savings =

$$[CFM \times POA \times (1.08\ Btu/cfm{}^{\circ}F\text{-}hr) \times (WSP-AWT) \times (168\ hr/wk - H) \times WKW \times F]/(HEFF \times HV)$$

Auxiliary savings =

$$HP \times L \times (0.746\ kw/hp) \times (168\ hr/wk - H) \times [WKS + (WKW \times (1-PRT)] \times F$$

Where,

AST = average summer temperature in °F (See page 19)

AWT = average winter temperature in °F (See page 19)

AZ = area of zone being served in $ft.^2$

BTT = building thermal transmission in $Btu/hr°F\text{-}ft^2$ (See page 28)

CFM = air handling capacity in ft^3/min

CPT = energy consumption per ton of refrigeration in Kw/ton or lb/ton-hr (See page 30)

F = fraction of savings attributable to EMCS (See page 42)

H = hours of operation per week (use present time clock schedule or occupied hours plus two hours each morning).

HEFF = heating efficiency of the system (total system, including converters, transmission system, boilers see page 31).

HP = motor nameplate horsepower (total of continuously running fans and pumps).

HV = heating value of fuel (in Btu/gal, Btu/kwh, etc. See page 32).

L = load factor (See page 35)

LTL = low temperature limit in °F; usually 50°F or 55°F. *Use the average winter temperature in place of LTL if AWT > LTL.

OAH = average outside air enthalpy in Btu/lb (See page 24)

POA = present percent minimum outside air expressed as a decimal

PRT = percent run time during heating season shutdown period required to maintain a low limit temperature of 55°F expressed as a decimal (See page 25). Use PRT = 0 if no low temperature limit is planned.

RAH = return air enthalpy during normal operating hours. Use 29.91 Btu/lb for 78°F and 50% humidity. For other conditions, obtain values from a psychrometric chart.

SSP	=	summer thermostat setpoint in °F
WKS	=	length of summer cooling season in weeks per year (See page 27)
WKW	=	length of winter heatng season in weeks per year (See page 27)
WSP	=	winter thermostat setpoint in °F

Computer Method:

Simulate building loads and system operation using a computerized energy analysis program. In the initial run assume that the systems run 24 hrs/day, 7 days/week. In the second run, assume that systems run only during occupied hours plus two hours in the morning for warm up or cool down. Include desired low limit temperatures when applicable. Do not include fan KW in computer runs so that the difference in results is representative only of heating and cooling energy reduction. This heating and cooling energy savings can then be proportioned on a per ft^2 basis to other similar systems serving zones with similar building loads.

Cooling Savings	=	Difference in electrical consumption of computer analysis runs.
Heating Savings	=	Difference in heating consumption of computer analysis runs.
Auxiliary Savings	=	(See manual method)

The following procedure determines the yearly savings from Scheduled Start/Stop of a domestic hot water heater.

1. Calculate tank volume and surface area:

$$V = 0.785 \times D^2 \times HT$$
$$A = (1.571 \times D^2) + (3.14 \times D \times HT)$$

2. Use Figure 11, page 43, to determine the quantity:

$$E = \frac{T - Ts}{To - Ts}$$

3. Calculate the energy savings:

DHW heating savings =
$[(A \times (To-Ts) \times LSD \times (.285\ Btu\text{-}in/ft^2hr°F/INS))$
$- (V \times 62.4\ Btu/ft^3°F \times (To-Ts) \times (1-E))] \times NSD$
$\times F/(HEFF \times HV)$

4. Repeat steps 2 and 3 for each different length of shutdown period and then total the savings.

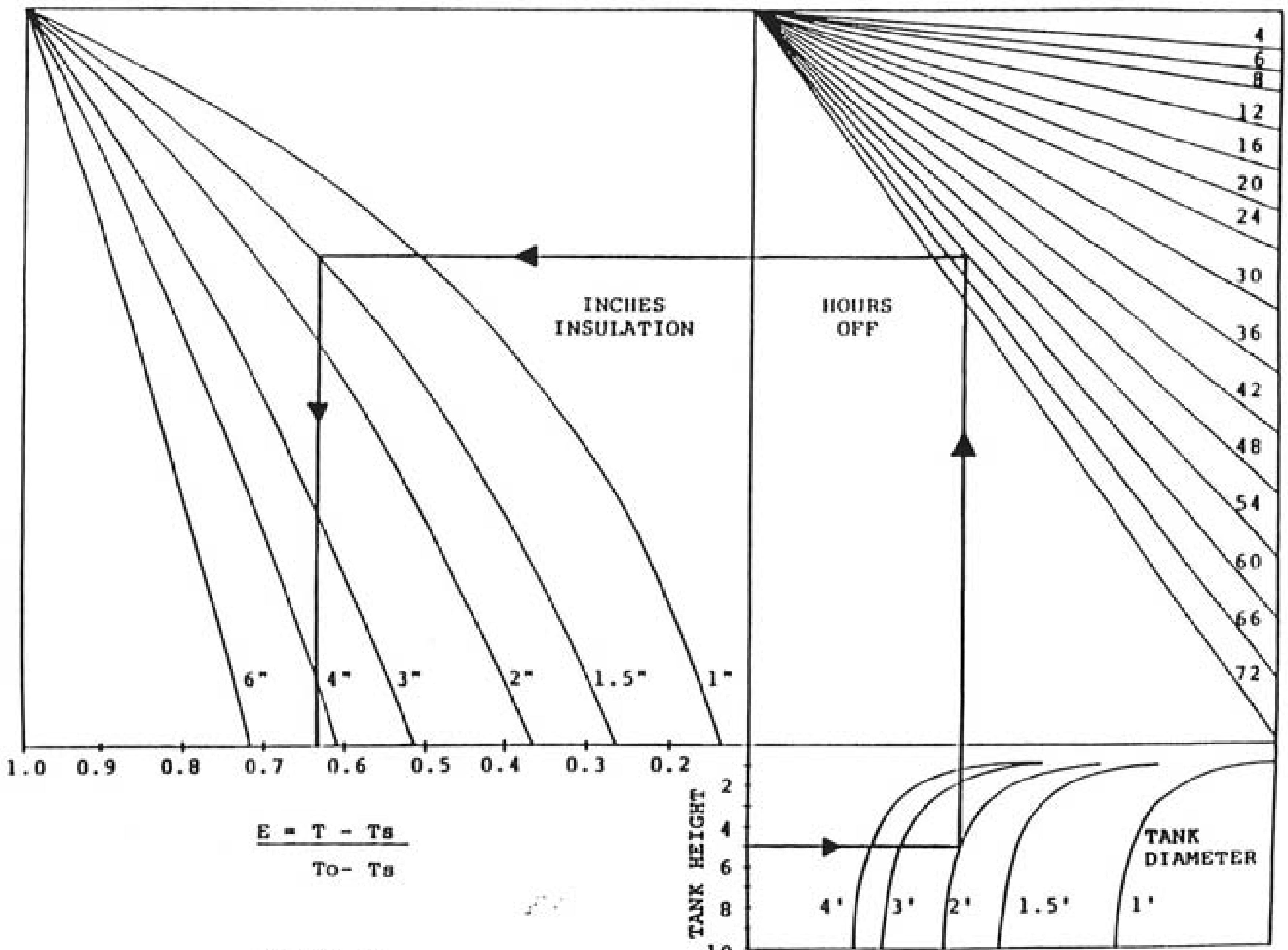
Where,

A	=	surface area of tank in ft^2
D	=	diameter of tank in ft
E	=	parameter determined from Figure 11
F	=	fraction of savings attributable to EMCS (See page 42)
HEFF	=	heating efficiency of the system (See page 31)
HT	=	height of tank in ft
HV	=	heating value of fuel in Btu/gal, Btu/kwh, etc. (See page 32)
INS	=	thickness of insulation in inches
LSD	=	length of shutdown period in hours
NSD	=	number of shutdown periods per year of a given length
T	=	water temperature at end of shutdown period in °F
To	=	hot water temperature setpoint in °F
Ts	=	average temperature of surroundings in °F
V	=	volume of tank in ft^3

If the system is currently started and stopped by a time switch or manually, full credit cannot be taken for the above savings for the EMCS. Determining what savings may be attributed to the EMCS becomes a function of the reliability of the time switch system. Time switches can be effective devices for the reduction of energy consumption; however, they have several disadvantages. They do not take into account holiday operation, seasonal changes, or daily weather variations. They are also easily tampered with, bypassed, or overridden. The pins which activate actions may slide, thus causing system operation and energy consumption at unnecessary times. They must be checked often to ensure proper operation and must be reset manually every time a power outage occurs for any appreciable time period. Manual operation is subject to human error and forgetfulness.

The EMCS is capable of performing the same operations but without most of the difficulties described, since it is not within the reach of tampering, and system operations are monitored constantly by the console operator. Therefore, the EMCS should be credited with some portion of these savings due to the increased reliability and the EMCS' ability to adjust and optimize start and stop times.

The fraction of savings attributable to the EMCS (F) shall be used to account for present timeclock or manual operation and future use of extended service capability of the system. Let F equal 1.0 if the system is presently operating around the clock and no extended service is projected. Otherwise, the value shall be between 0 and 1.0 depending on extension of operation and the reliability of the present control as determined during the field survey.



$$E = \frac{T - T_s}{T_o - T_s}$$

FIGURE 11

4.2 DUTY CYCLING

This function is applicable to electrical loads under 30 hp nameplate rating; however, the savings calculations apply only to constant loads. Duty cycling of loads which already cycle under local controls may save energy by essentially overriding the local thermostat setting, but these savings would be difficult to estimate and so are not included in the analysis. For motors above 30 hp, the savings are offset by added maintenance cost due to excessive wear on belts and bearings caused by frequent cycling.

Manual method:

Assume the system may be shut down for an average of 10 minutes per hour. The savings resulting from this function are fan or other auxiliary energy and outside air heating and cooling energy. Outside air loads are difficult to determine since they actually depend on space load conditions. If there is a net cooling load in the space, and the outside air is below 75°F, the outside air actually reduces energy consumption, which is often the case in commercial buildings during the heating season. Therefore, ventilation savings will not be credited by the manual method.

Auxiliary savings =
HP x L x 10/60 x (.746 Kw/hp) x H x (52 wk/yr)

Where,

H	=	Hours of operation per week (use number of hours of occupancy assuming duty cycling is not desirable during warmup)
HP	=	motor nameplate horsepower (total of all continuously running fans and pumps)

L = load factor (see page 35)

10/60 = fraction of time system is shut down (assumes ten minutes out of each hour)

Computer Method:

Simulate building loads and systems operation using a computerized energy analysis program capable of calculating annual energy consumption. In the initial run schedule the system to run during occupied hours plus two hours in the morning. On the second run, schedule the system to run for only 50 minutes of each hour except the first two. It is important to use accurate actual ventilation air quantities as input to the program if possible. Include dry bulb or enthalpy economizer in both runs if either exists or is to be implemented for the system by the EMCS. Do not include fan KW input in the computer runs so that the difference in results only represents heating and cooling energy reductions.

Cooling Savings	=	Difference in electrical consumption of computer analysis runs.
Heating Savings	=	Difference in heating consumption of computer analysis runs.
Auxiliary Savings	=	(See manual method)

4.3 DEMAND LIMITING

Assume by using a rotating group load shed scheme that the system can be shed 25% of time under peak load conditions.

KW Savings = HP x L x (0.746 kw/hp) x 0.25

Where,

HP = motor nameplate horsepower (total of all motors in system)

L = load factor (see page 35)

4.4 OPTIMUM START/STOP

Auxiliary savings from this function are derived by minimizing the necessary warm-up or cool-down time prior to occupancy and by shut down of the system as early as possible before the end of the occupancy period. Early shutdown is applicable only where ventilation is not critical and most of the occupants vacate the building at the scheduled time. Cooling and heating savings obtainable by keeping OA dampers closed during warm-up/cool-down times are accounted for in the Ventilation and Recirculation savings calculations. While a small amount of energy may be saved due to less run time of cycling loads (cooling tower fans or unit heaters), it is difficult to estimate and is not included in this analysis.

Warm-up Auxiliary Savings =

HP x L x (0.746 kw/hp) x ((WH x AND) - ERT) x (DAY/7 dy/wk)

* Cool-down Auxiliary Savings =

HP x L x (0.746 kw/hp) x (CH - .75 hr/dy) x (365 dy/yr - AND) x (DAY/7 dy/wk)

Where,

AND = annual number of days total that warmup is required in days per year (See page 18)

CH = present cool-down time before occupancy in hours per day. Use either the actual time presently scheduled for cool-down by an existing timeclock or 2 hours to correspond to Scheduled Start/Stop savings calculations.

DAY = equipment operation in days per week

ERT = equipment run time total required for warm up in hours per year (See page 30)

HP = motor nameplate horsepower (total of continuously running fans and pumps)

L = load factor (See page 35)

WH = present warm-up time before occupancy in hours per day. Use either the actual time presently scheduled for warmup by an existing timeclock or 2 hours to correspond to Scheduled Start/Stop savings calculations.

*This calculation assumes a 45 minute (.75 hours) cool-down time is required per day during the days of the year not requiring warmup. This is a conservative estimate; in most parts of the country, a fifteen minute purge would probably be sufficient in mild weather.

4.5 OUTSIDE AIR LIMIT SHUTOFF

Savings are derived from reduced hours of operation of auxiliary equipment and reduction of system losses (heat transfer through pipe walls, leaking steam traps, etc.). Whenever the system loss savings can be identified they should be included in the analysis. However, generally it is not possible to reasonably estimate what those losses are. Auxiliary savings are derived from the shutting off of pumps, fans, etc. The auxiliaries may be shut down whenever the outside temperature crosses limits which, according to the time of year, indicate that heating or cooling is not required. Fans which provide necessary ventilation should not be considered for these savings. Also cooling to interior zones should not be shutoff by this function.

Auxiliary Savings = HP x L x (0.746 kw/hp) x (HS + HW)

Where,

HP	=	motor nameplate horsepower (total of continuously running fans and pumps)
HS	=	hours in summer outside temperature is below summer limit in hours per year (See page 23)
HW	=	hours in winter outside temperature is above winter limit in hours per year (See page 23)
L	=	load factor

4.6 VENTILATION AND RECIRCULATION

Savings from this function are a result of control of OA dampers. All calculations assume that a 15 minute purge of ventilation air is necessary prior to occupancy.

The following calculation is applicable to systems which are shut down by the Scheduled Start/Stop function and is restricted to the period of time during warm-up or cool-down prior to occupancy. No cool-down ventilation savings is included in the analysis based on the assumption that early morning outside air adds a negligible amount to the cooling load and in fact may lessen the load through an economizer effect.

Warmup ventilation heating savings =

$$\frac{CFM \times POA \times (WSP-AWT) \times (1.08\ Btu/cfm{}^\circ F\text{-}hr) \times AND \times (WH-.25\ hr/day)}{HEFF \times HV}$$

The next two calculations are applicable to fan systems which must maintain environmental conditions but may eliminate outside air during building unoccupied periods.

Ventilation cooling savings =

$$[CFM \times POA \times (4.5\ lb/cfm\text{-}hr) \times (OAH-RAH) \times (UH-(.25\ hr/dy \times DAY)) \times WKS \times CPT]/(12{,}000\ Btu/ton\text{-}hr)$$

Ventilating heating savings =
[CFM x POA x (1.08 Btu/cfm°F-hr) x (WSP-AWT) x (UH-(.25 hr/dy x DAY)) x WKW]/(HEFF x HV)

Where,

AND = annual number of days total that warmup is required in days per year (See page 18)

AWT = average winter temperature in °F (See page 19)

CFM = air handling capacity in ft^3/min.

CPT = energy consumption per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)

DAY = equipment operation in days per week

HEFF = heating efficiency of the system (total system, including converters, transmission system, boilers. See page 31)

HV = heating value of fuel in Btu/gal, Btu/kwh, etc. (See page 32)

OAH = average outside air enthalpy in Btu/lb (See page 24)

POA = present percent minimum outside air expressed as a decimal

RAH = return air enthalpy during unoccupied hours. Use 29.91 Btu/lb for 78°F and 50% humidity. For other conditions obtain values from a psychrometric chart.

UH = unoccupied hours per week

WH = present warmup hours before occupancy each day. Use either the actual time presently scheduled for warmup by an existing timeclock or 2 hours to correspond to Scheduled Start/Stop savings calculations.

WKW = weeks of winter per year (See page 27)

WKS = length of summer cooling season in weeks per year (See page 27)

WSP = winter thermostat setpoint temperature in °F

4.7 ECONOMIZER (DRY BULB OR ENTHALPY)

Either the OA dry bulb economizer strategy or the OA enthalpy economizer strategy is applicable to air systems with outside air and exhaust air dampers. Use of a computer simulation is required for accurate determination of savings from economizer control; therefore, no manual method is discussed here. Economizer control will not be economically feasible for air handlers below about 12,000 cfm and may not be feasible for systems even as large as 300,000 cfm. More savings are obtained from economizers installed on energy inefficient systems such as reheat systems, and also in large buildings with high internal gains.

Computer Method:

Simulate building loads and system operation using a computerized building energy analysis program. In the initial run assume that no economizer is operable. In the second run, simulate savings either from a dry bulb or enthalpy economizer operation. The runs should be made assuming the system is operating the minimum number of hours necessary. Savings may be proportioned for similar systems serving zones with similar building loads on a per ft^2 basis.

Cooling Savings	=	Difference in electrical consumption of computer analysis runs.
Heating Savings	=	Should be negligible

4.8 DAY/NIGHT SETBACK

This strategy would be applied, instead of Scheduled Start/Stop, to systems with no auxiliaries such as steam radiation. It is also applicable to systems which serve critical areas with temperature, humidity, or pressure requirements that will allow a small setpoint adjustment, but the system cannot be stopped altogether. If OA dampers can be closed during the setback period, ventilation savings are possible and should be calculated under the Ventilation and Recirculation strategy.

Manual Method:

$$\text{Cooling savings} = \frac{BTT \times AZ \times SU \times (168-H) \times WKS \times CPT}{12{,}000 \text{ Btu/ton-hr}}$$

$$\text{Heating savings} = \frac{BTT \times AZ \times SD \times (168-H) \times WKW}{HEFF \times HV}$$

Where,

AZ	=	area of zone being served in ft^2
BTT	=	building thermal transmission in Btu/hr°F-ft^2 (see page 28)
CPT	=	energy consumption per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)
H	=	hours of operation per week during which the normal setpoint applies
HEFF	=	heating efficiency of the system (total system, including converters, transmission system, boilers. See page 31)
HV	=	heating value of fuel in Btu/gal, Btu/kwh etc., (see page 32)
SD	=	thermostat setdown for unoccupied periods during the heating season in °F
SU	=	thermostat setup for unoccupied periods during the cooling season in °F
WKS	=	length of summer cooling season in weeks per year (See page 27)
WKW	=	length of winter cooling season in weeks per year (See page 27)

Computer Method:

Simulate building loads and system operation using a computerized energy analysis program. In the initial run assume the systems run 24 hrs/day, 7 day/week at present heating and cooling setpoints. In the second run, assume that the systems operate under control of the setback temperatures during unoccupied hours plus one hour for warm-up or cool-down. This heating and cooling energy savings can be proportioned on a per ft^2 basis to similar systems serving zones with similar building loads and the same setback requirements.

Cooling savings = difference in electrical consumption of computer analysis runs

Heating savings = difference in heating consumption of computer analysis runs

4.9 REHEAT COIL RESET

Manual method:

A computer simulation is recommended for these savings calculations and is required for accurately determining the savings from Reheat Coil Reset, when economizer control is also applied to the system. The cooling savings with an economizer will be one-third to four-fifths of the savings without an economizer due to the reduction of mechanical cooling already obtained by the economizer control.

*Cooling savings (no economizer) =

$$\frac{H \times CFM \times (4.5\ min.lb/hr.ft^3) \times WKS \times RHR \times (0.6\ Btu/lb) \times CF}{(12{,}000\ Btu/ton\text{-}hr)}$$

** Heating savings =

$$\frac{H \times CFM \times (1.08\ Btu/cfm\text{-}hr°F) \times (52\ wk/yr) \times RHR}{HEFF \times HV}$$

Where,

CFM = air handling capacity in ft^3/min

CPT = energy consumption per ton of refrigeration (see page 30)

H = hours of operation per week (assume hours of occupancy plus one per day)

HEFF = heating efficiency of the system, (total system, including converters, transmission system, boilers. See page 31)

HV = heating value of fuel in Btu/gal, Btu/Kwh, etc. (See page 32)

RHR = reheat system cooling coil discharge reset in °F. Up to 5° or 6° is possible, dependent on the system. If a better estimate of possible reset is not available use 3°F.

WKS = length of summer cooling season in weeks per year (see page 27)

*This equation assumes a 1°F cooling coil temperature increase is equivalent to a 0.6 Btu/lb change in enthalpy.

**To account for holiday shutdown or for a system that does not operate year-round, the <u>52 wk/yr</u> term can be adjusted accordingly.

Computer method:

Simulate building loads and system operation with a computerized energy analysis program. Preferably the program used should have simulation routines for selecting the zones with the greatest cooling demand and calculating the necessary cooling coil leaving air temperature or at least the capability of a reset schedule. In order to approximate the savings from this function, run the program once using a constant cooling coil setpoint temperature and then a second time simulating variable reset based on a discriminator scheme or a reset schedule. Be sure to include economizer control when applicable.

Cooling savings	=	Difference in electrical consumption of computer analysis runs
Heating savings	=	Difference in heating consumption of computer analysis runs

4.10 HOT DECK/COLD DECK TEMPERATURE RESET

Manual Method:

A computer simulation is recommended for these savings calculations, and is required for accurately determining the savings from Hot Deck/ Cold Deck Temperature Reset when economizer control is also applied to the system. The cooling savngs with an economizer can be as little as one-fifth of the savings without an economizer due to the reduction of mechanical cooling already obtained by the economizer control.

* Cooling savings (no economizer) =

$$\frac{H \times CFM \times CD \times (4.5\ min.lb./hr.ft^3) \times WKS \times SCDR \times (0.6\ Btu/lb) \times}{(12{,}000\ Btu/ton\text{-}hr)}$$

Heating savings =

$$\frac{H \times CFM \times HD \times (1.08 \text{ min. Btu/hr ft}^3 {}^\circ F) \times (WKS \times SHDR + WKW \times WHDR)}{HEFF \times HV}$$

Where,

CD	=	fraction of total air passing through the cold deck. Assume .50 if no other information is available.
CFM	=	air handling capacity in ft^3/min
CPT	=	energy consumption per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)
H	=	required number of hours of operation per week (assume hours of occupancy plus one per day)
HD	=	fraction of total air passing through the hot deck. Assume .50 if no other information is available.
HEFF	=	heating efficiency of the system (total including converters, transmission system, boilers. (See page 31)
HV	=	heating value of fuel in Btu/gal, Btu/Kwh etc. (see page 32)
SCDR	=	summer cold deck reset in °F (The average reset is a function of the system. If an estimate is not available, use 2°F.)
SHDR	=	summer hot deck reset in °F (The average reset that will result from this function is dependent on the air handler capacity relative to the loads in the space it serves. If an estimate of the possible reset is not available use 3°F.)
WHDR	=	winter hot deck reset in °F (Again, the average reset is a function of the system. If an estimate is not available use 2°F)
WKS	=	length of summer cooling season in weeks per year (See page 27)

WKW = length of winter heating season in weeks per year (See page 27)

*This equation assumes a 1°F cold deck temperature increase is equivalent to a 0.6 BTU/lb change in enthalpy.

Computer method:

Simulate building loads and system operation with a computerized energy analysis program. The program used should have simulation routines necessary to select the zones with the greatest heating and cooling demands and then calculate the necessary hot and cold deck leaving temperatures. In order to approximate the savings from this function, run the program once using constant deck setpoint temperatures and then a second time simulating variable deck temperatures based on a discriminator control scheme. Be sure to include economizer control when applicable.

Cooling savings = Difference in electrical consumption of computer analysis runs

Heating savings = Difference in heating consumption of computer analysis runs

4.11 HOT WATER OUTSIDE AIR RESET

Boiler temperature reset saves energy by reducing heat losses through the heating system and flue gases and by providing more exact control at the end use point. This last item provides savings by reducing overheating of spaces at less than maximum loads due to control valve insensitivity in those operating ranges. Reset of hot water supply temperature from a converter produces savings similarly. No exact means of quantifying these savings is known, however experience indicates these savings should be a function of the annual equivalent full load hours of system operation and the total capacity of the system.

Heating savings = HFLH x EI x CAP/(HEFF x HV)

Where,

CAP = maximum capacity of device(s) in Btu/hour.
EI = efficiency increase expressed as a decimal. (use .01 if no better estimate is available.)
HEFF = heating efficiency of the system. (Total system, including converters, transmission system, boilers. See page 31)
HFLH = annual equivalent full load hours for heating in hr/yr (see page 22)
HV = heating vaue of fuel in Btu/gal, Btu/kwh, etc. (see page 32)

4.12 BOILER OPTIMIZATION

EMCS monitoring of boiler operation aids the maintenance personnel in keeping the boilers operating at peak efficiency.

Heating Savings = HFLH x EI x CAP/(HEFF x HV)

Where,

CAP = maximum capacity of device(s) in Btu/hour.
EI = efficiency increase expressed as a decimal. (use .01 for one boiler and .02 for multiple boilers, if no better estimate is available.)
HEFF = heating efficiency of the system. (efficiency of boiler(s). See page 31)
HFLH = annual equivalent full load hours for heating in hr/yr (See page 22)

HV = heating value of fuel in Btu/gal, Btu/kwh, etc. (See page 32)

4.13 CHILLER OPTIMIZATION

These savings are applicable only to chilled water plants with multiple chillers. The calculations assume a 1% increase in efficiency attributable to the EMCS.

Cooling savings = CPT x TON x CFLH x 0.01

CFLH = annual equivalent full-load hours for cooling in hr/yr (See page 20)

CPT = consumption of energy per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)

TON = total capacity of chilled water plant in tons

4.14 CHILLER WATER TEMPERATURE RESET

Reset of chilled water supply temperatures results in energy savings due to the increased efficiency of the refrigeration machine. Check to be sure that a chilled water controller may be applied to the particular manufacturer's chiller being considered. The savings will vary depending on the machine, the amount of reset, and the load on the equipment. The amount of reset generally ranges between 2°F and 5°F, so a conservative estimate of 2°F was used in the calculation.

Cooling Savings = TON x CPT x CFLH x 2°F x REI

Where,

CFLH = equivalent full-load hours for cooling in hours/year (See page 20)

CPT = energy consumption per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)

REI = rate of efficiency increase per °F increase of chilled water temperature.

Use for:

screw compressor machine - .024 per °F
centrifugal (elec. or turbine) machine - .017 per °F
reciprocal machine - .012 per °F
absorption machine - .006 per °F

TON = chiller capacity in tons. If chiller capacity is not available and nameplate electrical data on the chiller motor is, use the full-load KW input in place of (TON x CPT).

4.15 CONDENSER WATER TEMPERATURE RESET

Decreasing the condenser water temperature also increases the efficiency of chillers, but care must be taken not to exceed the equipments' limitations, particularly in absorption machines. The implementation of condenser water reset may result in greater fan energy consumption. If a cooling tower fan cycles on and off, the on time will be increased consuming more auxiliary energy. If it runs continuously with valve bypass control to maintain constant entering condenser water temperature and can be cycled when the EMCS function is applied, then additional auxiliary energy can be saved. An adjustment to account for these conditions has been included in the savings analysis.

The calculation procedure requires four steps:

1. Calculate the average reduction in condenser water temperature which is achievable:

   RCWT = PCWT - ACWT

2. Use Figure 12, page 61, to determine the percent efficiency increase (PEI) of the chiller based on RCWT from above.

3. Determine the adjusted efficiency increase (AEI) of the chiller:

If fan runs continuously, but will be cycled,

$$AEI = \frac{PEI + 5.5}{100}$$

If fan cycles,

$$AEI = \frac{PEI - 2.8}{100}$$

4. Calculate the cooling savings:

Cooling savings = TON x CPT x CFLH x AEI

Where,

ACWT = average condenser water temperature possible in °F (See page 16)

AEI = adjusted efficiency increase of the chiller due to condenser water reset.

CFLH = equivalent full load hours for cooling in hours/year (See page 20)

CPT = consumption of energy per ton of refrigeration in kw/ton or lb/ton-hr (See page 30)

PCWT = present condenser water temperature in °F (usually set at 85°F.)

PEI = percent efficiency increase of the chiller

TON = chiller capacity in tons. If chiller tonnage is not available for compression refrigeration machines, but nameplate electrical data is, then use the total full-load KW rating of the compressor and auxiliary motors in place of (TON x CPT).

RCWT = reduction in condenser water temperature which is achievable, in °F

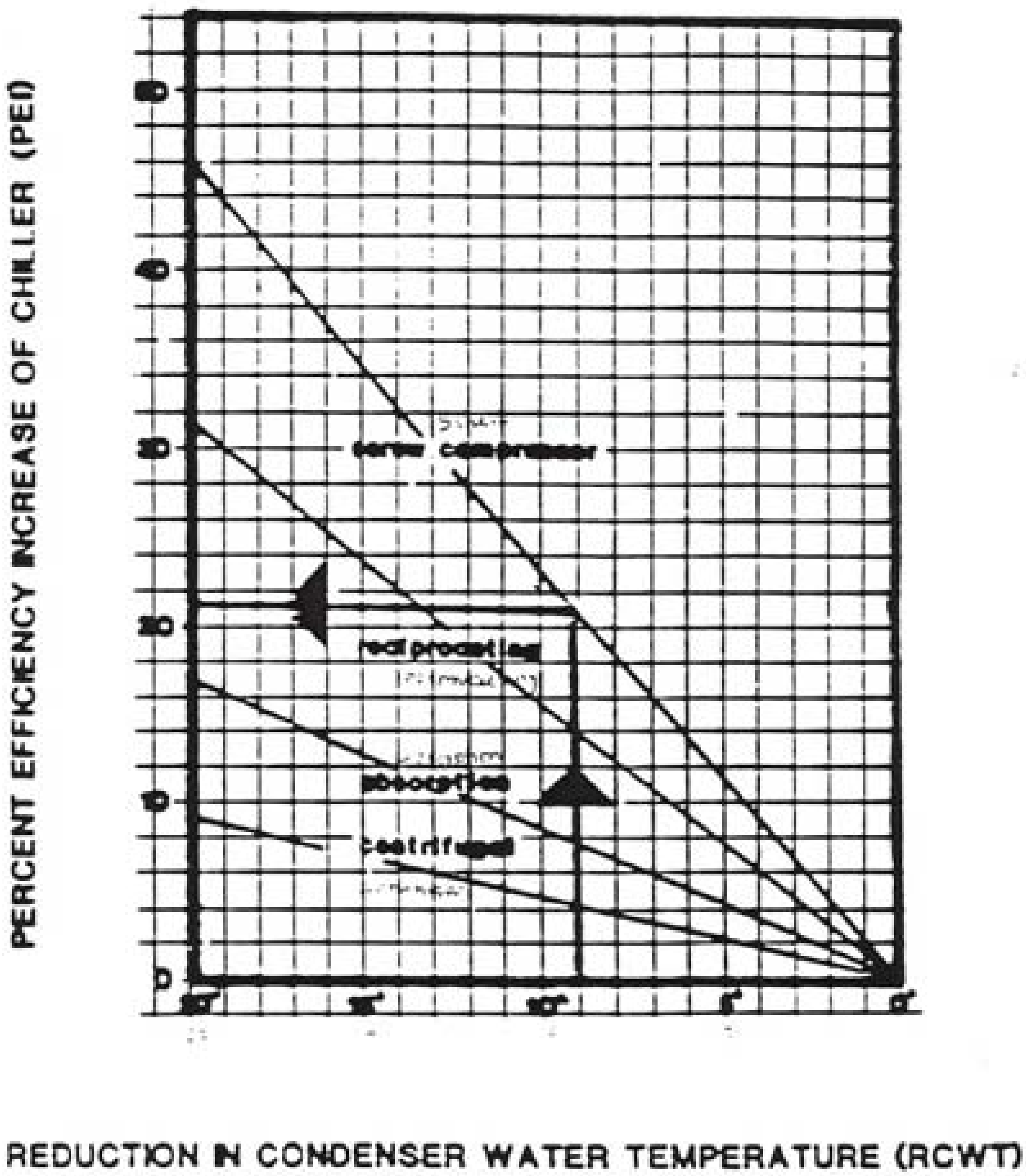

PERCENT EFFICIENCY INCREASE OF CHILLER (PEI)
REDUCTION IN CONDENSER WATER TEMPERATURE (RCWT)

FIGURE 12

4.16 CHILLER DEMAND LIMIT

These savings may be considered for centrifugal chillers that are equipped with an adjustable control system for limiting the available cooling capacity. The calculation assumes by using a rotating group load shed scheme that the chiller can be stepped down by 20% of its maximum cooling capacity 25% of the time under peak load conditions.

* KW savings = (HP/0.9) x (0.746 KW/hp) x 0.20 x 0.25

Where,

HP = motor nameplate horsepower (of compressor)

*The 0.9 factor accounts for a 90% motor efficiency.

4.17 LIGHTING CONTROL

This function is applicable to relay operated zoned lighting. The following calculation is for one zone of lighting.

Electrical savings = KW x (168 hr/wk-H) x 52 wk/yr x F

Where,

*F = fraction of savings attributable to EMCS (see page 42)
H = hours of operation per week (use hours of occupancy)
KW = total KW consumption of lights in the zone

*This factor is a subjective measure of how diligently the lights are turned off manually at the present.

4.18 RUN TIME RECORDING

By scheduling maintenance based on actual operation, assume the EMCS is able to save one man-visit per year to the system being monitored by the EMCS. Assume this man-visit is 2 hours in duration. To which systems these savings should be applied, if any, is a judgement decision based on present facility maintenance procedures.

Labor savings = 2 man-hours

4.19 SAFETY ALARM

The EMCS can save facility personnel from time spent conveying alarm information and diagnosing problems. Assume a total of 2 hours per system per year. Whether credit is taken for this savings is dependent on the individual system and on facility policies.

Labor savings = 2 man-hours

To aid in the use of the calculation methods, forms have been designed to simplify the analysis of each system. There is one form to be used for primary systems, such as boilers and chillers and one for secondary (or unitary) air distribution systems. Blank Savings Calculations and Costs forms are included in Appendix A.2.

The forms provide a simplified version of each equation used in the manual methods with blanks to be filled in with the appropriate values. The variable symbols have been inserted in the blanks of sample forms in Figures 13 and 14 on the following two pages. They can be used for reference, along with the Variable Glossary, while filling in the blank Savings Calculations and Costs Sheets.

FIGURE 11

PRIMARY SYSTEM

SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ SYSTEM NO. _____ SYSTEM TYPE ____________________

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	SAVINGS KWH	SAVINGS	SAVINGS MH	COST
Scheduled Start/Stop	Clg: ___*___ x BTT Btu/ft^{2}hr °F x AZ ft^{2}x(168 - H) x F x CPT /ton Htg: * x BTT Btu/ft^{2}hr °F x AZ ft^{2}x(168 - H) x F /(HEFFx HV) Aux: * x HP hp x (168 - H) x F					BASIC FUNCTIONS
Duty Cycling	Aux: ___*___ x ___HP___ hp x ___H___ hr					
Demand Limit	KW: ___*___ x ___HP___ hp					
Optimum Start/Stop	WU Aux: * x HP hp x((WH hr x AND) - ERT hr)x DAY days/wk CD Aux: * x HP hp x (CH hr - .75) x DAY days/wk					
OA Limit	Aux: ___*___ x ___HP___ hp x (HS + HW)					
Run Time	Labor: 2 Manhours					
HW OA Reset	Htg: HFLH hr/yr x EI x CAP Btu/hr/(HEFFx HV)					
Boiler Opt.	Htg: HFLH hr/yr x EI x CAP Btu/hr/(HEFFx HV)					
Chiller Opt.	Clg: CFLH hr/yr x CPT /ton x TON T x 0.01					
CHW Reset	Clg: CFLH hr/yr x CPT /ton x TON T x REI /°F x 2°F					
Cond. Reset	Clg: CFLH hr/yr x CPT /ton x TON T x (AEI)					
Chiller Demand	Kw: 0.0414 x HP hp					
Safety Alarms	Labor: 2 Manhours					
	TOTALS FOR SYSTEM					

*Derived constants for the specific location.

FIGURE 14
SECONDARY SYSTEM
SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ SYSTEM NO. _____ SYSTEM TYPE ______________________________

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	SAVINGS KWH	SAVINGS	SAVINGS MH	COST
Scheduled Start/Stop	Clg: * x BTT Btu/ft^2 hr°F x AZ ft^{2}x(168 - H) x F x CPT /ton Htg: * x BTT Btu/ft^{2}hr°Fx AZ ft^{2}x(168 - H) x F /(HEFF x HV) V-Clg: * x CFM cfm x POA x (168 - H) x F x CPT /ton V-Htg: * x CFM cfm x POA x (168 - H) x F /(HEFF x HV) Aux: * x HP hp x (168 - H) x F					BASIC FUNCTIONS
Duty Cycling	Aux: * x HP hp x H hr					
Demand Limit	KW: * x HP hp					
Optimum Start/Stop	WU Aux: * x HP hp x ((WH hr x AND) - ERT hr)x DAY days/wk CD Aux: * x HP hp x (CH hr - .75) x DAY days/wk					
OA Limit	Aux: * x HP hp x (HS + HW)					
Run Time	Labor: 2 Manhours					
Ventilation/ Recirculation	WU V-htg: * x CFM cfm x POA x (WH -.25)/(HEFF x HV) V-clg: * x CFM cfm x POA x((UH -(.25x DAY dy/wk)) x CPT /ton V-htg: * x CFM cfm x POA x((UH -(.25x DAY dy/wk))/(HEFF x HV)					
Economizer	(Computer simulation required. See page xx).					
Day/Night Setback	Clg: * x BTT Btu/ft^{2}hr°Fx AZ ft^{2}x SU °F x (168 - H) x CPT /ton Htg: * x BTT Btu/ft^{2}hr°Fx AZ ft^{2}x SD °F x (168 - H)/(HEFF x HV)					
Reheat Coil Reset	Clg: * x H hr/wk x CFM cfm x RHR °F x CPT /ton Htg: * x H hr/wk x CFM cfm x RHR °F/(HEFF x HV)					
Hot/Cold Deck Reset	Clg: * x H hr/wk x CFM cfm x CD x SCDR °F x CPT /ton Htg: * x H hr/wk x CFM cfm x HD x(WKS x SHDR + WKW x WHDR)/(HEFF x HV)					
Safety Alarms	Labor: 2 Manhours					
	TOTALS FOR SYSTEM					

5.0 SAMPLE CALCULATIONS

In order to demonstrate the manual analyses methods discussed in this report, sample calculations have been performed on each type of system discussed in the Tri-Service Design Manual for EMCS, TM 5-815-2/AFM 88-36/NAVFAC DM-4.9, assuming a hypothetical Navy facility located in Springfield, Missouri. It is not possible to describe completely all activities involved in an engineering design process. For this reason, this section is meant only to be used as a framework for EMCS analysis. Every military base is different, and parts of the process described herein must be adapted, added to, or ignored as the situation requires. The judgement required to make these decisions requires professional engineering personnel familiar with the mechanical and electrical systems an EMCS is to control and how that control is to be accomplished.

The buildings which comprise the hypothetical Naval Base and the systems within each building are listed below:

BUILDING NUMBER:	100
USAGE:	PUBLIC WORKS
SYSTEMS:	Electric Unit Heater Electric Radiation Multizone DX-A/C Water Cooled DX Compressor Direct Fired Boiler

BUILDING NUMBER:	200
USAGE:	BASE PERSONNEL
SYSTEMS:	HTHW/Steam Converter Heating and Ventilating Unit Single Zone DX-A/C Multizone Air Handler Air Cooled DX Compressor Domestic HW - Gas Direct Fired Furnace

BUILDING NUMBER:	300
USAGE:	BASE HEADQUARTERS
SYSTEMS:	HTHW/HW Converter Water Cooled Chiller Single Zone Air Handler 45 Two Pipe Fan Coil Units Hot Water Unit Heater Domestic HW - Electric

BUILDING NUMBER:	400
USAGE:	WAREHOUSE
SYSTEMS:	4 Steam Unit Heaters Steam Radiation Steam Boiler

BUILDING NUMBER:	500
USAGE:	ADMINISTRATION BUILDING
SYSTEMS:	Steam/HW Converter Air Cooled Chiller Terminal Reheat Air Handler Variable Air Volume AHU 15 Four Pipe Fan Coil Units Hot Water Radiation

BUILDING NUMBER:	600
USAGE:	HEATING PLANT
SYSTEMS:	3 Hot Water Boilers (High Temp.)

Completed survey forms for the hypothetical facility are included on the following pages.

The first step in the procedure is to derive the climate based factors. The location of the hypothetical Naval facility was chosen as Springfield, Missouri to correspond with the factors derived on pages 11-27 from weather data. These values and the other climate-based data have been entered in a sample form shown on page 69.

Next, the climate-based and miscellaneous factors should be substituted into the equations for calculating savings. The equations can be simplified and the constants entered onto standard Savings Calculations and Cost sheets. This process is demonstrated below for those conservation strategies which can be simplified. The Savings Calculations and Costs sheets with the simplified constants for the example are shown on pages 73 and 74.

CLIMATE - BASED FACTORS

LOCATION: ______________________________

SYMBOL	DESCRIPTION	PAGE REF.	VALUE	UNITS
ACWT	Average Condenser Water Temperature	16	75.6	°F
AND	Annual Number of Days for Warmup	18	232	Days/Yr.
AST*	Average Summer Temperature	19	80.6	°F
AWT*	Average Winter Temperature	19	43.0	°F
CFLH	Annual Equiv. Full-Load Hrs. For Cooling	20	733	Hrs/Yr.
HFLH	Annual Equiv. Full-Load Hrs. for Heating	22	538	Hrs/Yr.
HS	Hrs. of Temp. Limit Shut-off for Summer	23	273	Hrs/Yr
HW	Hrs. of Temp. Limit Shut-off for Winter	23	204	Hrs/Yr
OAH*	Average Outside Air Enthalpy	24	33.34	Btu/lb.
PRT*	Percent Run Time for Low Temp. Limit	25	15	%
WKS*	Weeks of Summer	27	23.4	Wks/Yr.
WKW*	Weeks of Winter	27	28.6	Wks/Yr.

* Data not necessary if computer methods are used.

SCHEDULED START/STOP

Clg: BTT x AZ x (80.6°F-78°F) x (168-H) x 23.4 wks/
x CPT x F/(12,000 Btu/ton-hr)
= 0.00507 x BTT x AZ x (168 - H) x CPT x F

Htg: BTT x AZ x (65°F-55°F) x (168-H) x 28.6 wks/yr
x F/(HEFF x HV)
= 286 x BTT x AZ x (168 - H) x F/(HEFF x HV)

V-clg: CFM x POA x (4.5 lb/cfm-hr) x (33.34 - 29.91 Bt
x (168 - H) x 23.4 wks/yr x CPT x F/(12,000 Btu
= .0301 x CFM x POA x (168-H) x CPT x F

V-htg: CFM x POA x (1.08 Btu/cfm°F-hr) x (65°F-43.0°F)
(168-H) x 28.6 wks/yr x CPT x F/(HEFF x HV)
= 679 x CFM x POA x (168-H) x F/(HEFF x HV)

Aux: HP x 0.8 x (0.746 Kw/hp) x (168-H) x [23.4 wks
+ (28.6 wk/yr x (1-.15))] x F
= 28.5 x HP x (168-H) x F

DUTY CYCLING

Aux: HP x 0.8 x 10/60 x (.746 Kw/hp) x H x (52 wk/
= 5.17 x HP x H

DEMAND LIMITING

KW: HP x .8 x (0.746 Kw/hp) x 0.25
= 0.149 x HP

PRIMARY STEM
SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ SYSTEM NO. _____ SYSTEM TYPE ______________________________

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	KWH		MH	COST
Scheduled Start/Stop	Clg: .00507x____Btu/ft²hr °F x____ft²x(168 - ____) x___x____/ton Htg: 286x______Btu/ft²hr °F x____ft²x(168 - ____) x___/(____x______) Aux: 28.5 x____hp x (168 - ______) x _______					BASIC FUNCTIONS ______
Duty Cycling	Aux: 5.17 x ______ hp x ______hr					
Demand Limit	KW: 0.149 x ________ hp					
Optimum Start/Stop	WU Aux: .0852 x_____ hp x((____ hr x 232) -_____hr)x ___days/wk CD Aux: 11.3 x_____ hp x (____ hr - .75) x _______ days/wk					
OA Limit	Aux: 0.597 x _______ hp x (273 - 204)					
Run Time	Labor: 2 Manhours					
HW OA Reset	Htg: 538 hr/yr x ____ x ________Btu/hr/(____x_________)					______
Boiler Opt.	Htg: 538 hr/yr x ____ x ________Btu/hr/(____x________)					______
Chiller Opt.	Clg: 733 hr/yr x ______/ton x _____T x 0.01					______
CHW Reset	Clg: 733 hr/yr x ______/ton x _____T x ______/°F x 2°F					______
Cond. Reset	Clg: 733 hr/yr x ______/ton x _____T x (______)					______
Chiller Demand	Kw: 0.0414 x_____hp					______
Safety Alarms	Labor: 2 Manhours					______
	TOTALS FOR SYSTEM					______

DAY/NIGHT SETBACK

Clg: $\dfrac{BTT \times AZ \times SU \times (168\text{-}H) \times 23.4 \text{ wks/yr} \times CPT}{12{,}000 \text{ Btu/ton-hr}}$

$= .00195 \times BTT \times AZ \times SU \times (168\text{-}H) \times CPT$

Htg: $BTT \times AZ \times SD \times (168\text{-}H) \times 28.6 \text{ wks/yr}/(HEFF \times HV)$

$= 28.6 \times BTT \times AZ \times SD \times (168\text{-}H)/(HEFF \times HV)$

REHEAT COIL RESET

Clg: $H \times CFM \times (4.5 \text{ min.lb/hr-ft}^3) \times (23.4 \text{ wks/yr}) \times RHR \times (0.6 \text{ Btu/lb}) \times CPT/(12{,}000 \text{ Btu/Ton-hr})$

$= .00526 \times H \times CFM \times RHR \times CPT$

Htg: $H \times CFM \times (1.08 \text{ Btu/crm-hr°F}) \times (52 \text{ wk/yr}) \times RHR/(HEFF \times HV)$

$= 56.16 \times H \times CFM \times RHR/(HEFF \times HV)$

HOT DECK/COLD DECK TEMPERATURE RESET

Clg: $H \times CFM \times CD \times (4.5 \text{ min.lb/hr-ft}^3) \times (23.4 \text{ wks/yr}) \times SCDR \times (0.6 \text{ Btu/lb}) \times CPT/(12{,}000 \text{ Btu/Ton-hr})$

$= .00526 \times H \times CFM \times CD \times SCDR \times CPT$

Htg: $H \times CFM \times HD \times (1.08 \text{ min.Btu/hr-ft}^3{}°F) \times (23.4 \times SHDR + 28.6 \times WHDR)/(HEFF \times HV)$

$= 1.08 \times H \times CFM \times HD \times ((23.4 \times SHDR) + (28.6 \times WHDR))/(HEFF \times HV)$

OPTIMUM START/STOP

WU Aux: HP x 0.8 x (0.746 Kw/hp) x ((WH x 232) - ERT) x (DAY/7 day/wk)

= 0.0852 x HP x ((WH x 232) - ERT) x DAY

CD Aux: HP x 0.8 x (0.746 Kw/hp) x (CH-.75 hr/day) x (365-232 day/yr) x (DAY/7 day/wk)

= 11.3 x HP x (CH-.75) x DAY

OUTSIDE AIR LIMIT SHUTOFF

Aux: HP x 0.8 x (0.746 Kw/hp) x (225 + 164)

= 0.597 x HP x (273 + 204)

VENTILATION AND RECIRCULATION

WU V-htg: CFM x POA x (65° - 43.0°) x (1.08 Btu/cfm°F-hr) x 232 days/yr x (WH-.25 hr/day)/(HEFF X HV)

= 5512 x CFM x POA x (WH-.25)/(HEFF x HV)

V-clg: CFM x POA x (4.5 lb/cfm-hr) x (33.34-29.91 Btu/lb) x (UH-(.25 hr/day x DAY)) x 23.4 wks/yr x CPT /(12,000 Btu/ton-hr)

= 0.0301 x CFM x POA x (UH-.25 x DAY) x CPT

V-htg: CFM x POA x (1.08 Btu/cfm °F-hr) x (65°-43.0°) x (UH-(.25 hr/day x DAY)) x 28.6 wks/yr/(HEFF x HV)

= 679 x CFM x POA x (UH-.25 x DAY)/(HEFF x HV)