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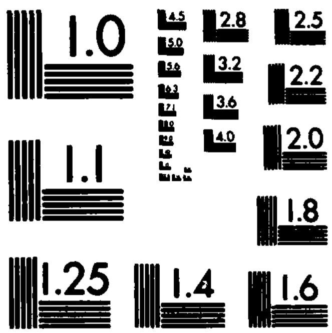

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CR 83.037

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
NAVY ENERGY & NATURAL RESOURCES
R&D OFFICE
NAVAL FACILITIES ENGINEERING COMMAND

SELECTION AND IMPLEMENTATION OF SINGLE BUILDING EMCS

August 1983

An Investigation Conducted by
STAN AND ASSOCIATES, INC.
1205 Third National Building
Dayton, Ohio

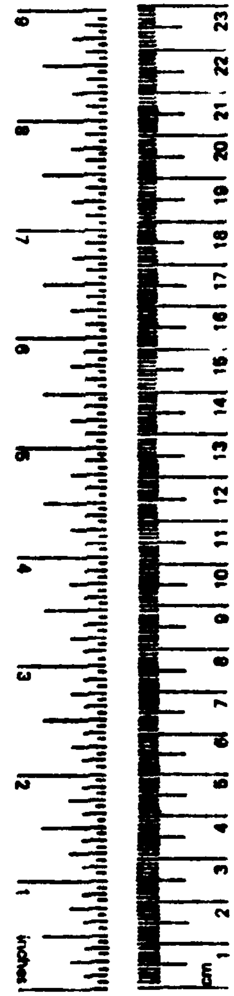
N68305-3018-7940

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

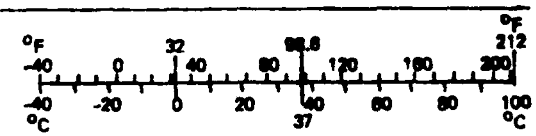
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the selection and implementation of single-building ~~EMCS, systems~~. The process is examined in three phases. The initial phase examines the selection of candidate buildings based on metered utility data, examination of building operation, examination of building systems and controls, and measured data. The second phase examines the capability of time clocks, duty cyclers, demand limiters,

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) programmable controllers, micro EMCS and small EMCS. The functions performed by each are examined. Alternatives to EMCS are presented. An example calculation compares time clock control, time clock control with control enhancement, and small EMCS control of a typical air handling unit. The third phase examines the installation of equipment emphasizing interface techniques for efficient installation and operation. A summary of the analysis steps follows.

This report was prepared as an account of work sponsored by an agency of the United States Government. Reference to any specific commercial product by trademark, manufacturer, or in any other manner does not constitute or imply its endorsement or recommendation by either the United States Government or the author of this report. The devices mentioned are intended to be representative of the various control devices currently being marketed and are not necessarily better than any competing product.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

This report is a guide to identify single buildings which are good candidates for energy management. Several topics will be discussed.

While there is no single best measure of what constitutes a good energy management candidate or an "energy wasteful" building, several factors are good indicators. Chapter 2 discusses analysis of utility billings to assess current usage and equipment loading. Where utility company metering of a building is not available, analysis of opportunities is done by calculation. The calculation phase provides useful information on building "tuning" as well. In assessing energy management potential, a consideration of existing automatic control systems is necessary. Finally, the use of computer simulation techniques for establishing a data base is presented, along with other measuring and monitoring techniques.

Chapter 3 presents a discussion of single building energy controllers. Six types are discussed; time clocks and microprocessor based thermostats, demand limiters and duty cyclers, programmable controllers, micro EMCS, and small EMCS. Typical application programs are presented. A discussion of implementation of these programs for the six types of controllers follows. Information on available micro and small EMCS is presented, including typical applications, building size ranges, utility bill ranges, available application programs, hardware, and other parameters. An example of calculating payback follows. Chapter Four presents typical interface techniques between EMCS systems and standard control systems. Chiller control is presented, as well as boiler control. Details on air handling unit interface are presented on a subsystem approach.

Chapter Five summarizes results and draws conclusions on use of the data and techniques presented.

This report is intended for use with other Navy publications. They are CR 82.028 "Controlling Energy Consumption in Single Buildings," CR 83.030 "Standardized EMCS Energy Savings Calculations," TM 5-815-2/AFM 88-36/ NAVFAC DM-4.9 "Energy Monitoring and Control Systems (EMCS)," and CR* 83.008 "EMCS Cost Estimating Data." These publications should be referenced for other information on the topics presented in this report.

*CR stands for Contractor Reports that have been prepared for NCEL. They can be obtained by contacting the Naval Civil Engineering Laboratory, Code L07, Port Hueneme, CA 93043

CHAPTER 2

SELECTING APPROPRIATE BUILDINGS

A properly applied EMCS system has the potential to reduce energy consumption in almost any building. When considering the savings and assessing the economic viability of installing EMCS, either the total savings potential can be considered, or the percentage of existing energy consumption. For example, a large building may have the potential to save 500,000 KWH of a total annual use of 5,000,000 KWH. This is 10 percent of the total. A smaller building may have the potential to save 250,000 KWH of a total annual use of 1,250,000 KWH. This is 20 percent of the total. Which project should be pursued? Possibly both, but if only one project could be completed, the large building would have the greatest monetary impact, while the smaller building saves the most percentage wise. The answer of course is in considering the cost to design and install the EMCS in each case, which would allow economic analysis to dictate the choice.

This chapter will consider several methods for selecting appropriate buildings for EMCS implementation. There is no one single factor which clearly indicates which building to pursue. The selection process involves analysis of utility data where available, analysis of the use of the building, the heating, ventilating, and air conditioning systems, and the controls which operate these systems at part load. The utility data will indicate overall consumption and show yearly trends. The analysis of heating, ventilating, and air conditioning systems, and controls, will indicate both what can be done, and what control interface will be required. These factors will be discussed in detail in a later chapter.

This chapter will consider three main areas. The analysis of utility billings will be discussed. The analysis of building potential by calculation will next be presented, to identify both EMCS potential and "tuning" requirements of the building. Finally, the use of computer simulation techniques and data gathering equipment will be presented.

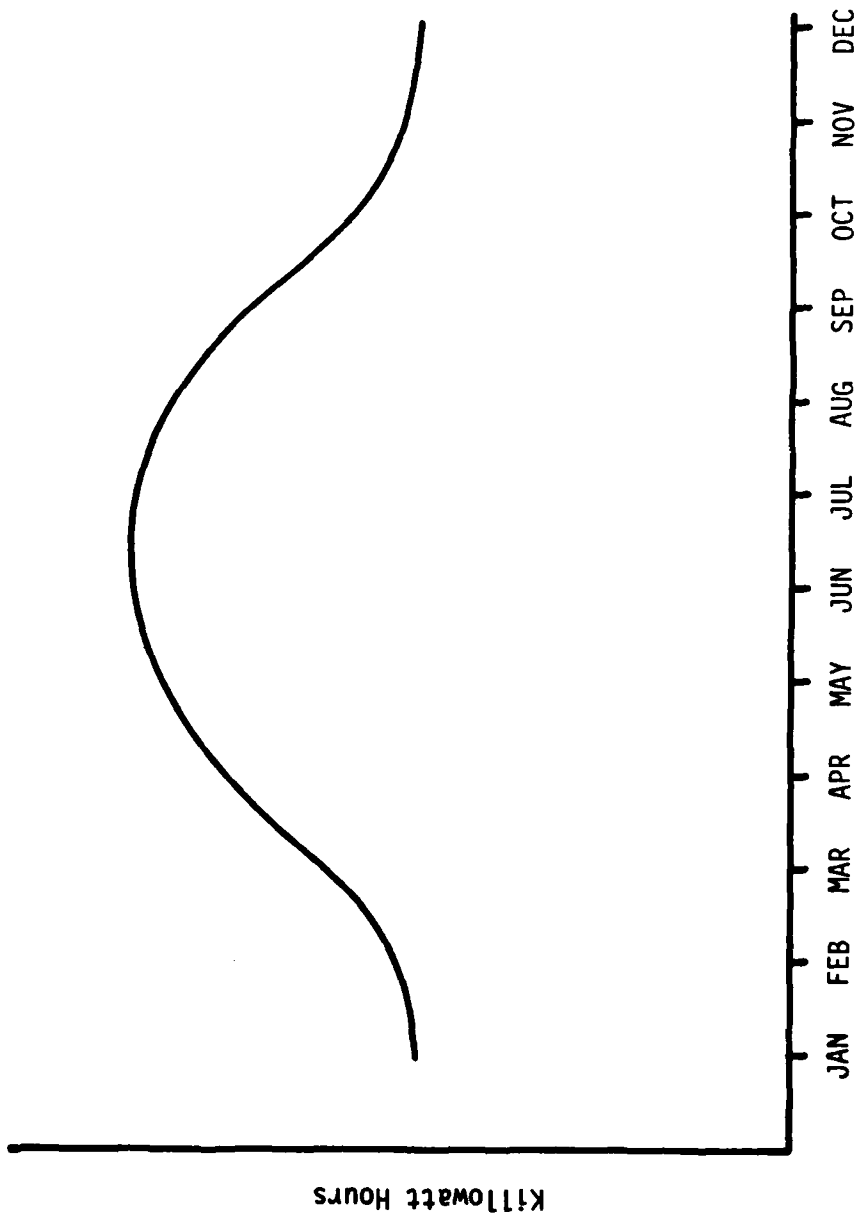
IDENTIFICATION OF ENERGY WASTEFUL BUILDINGS

There is no perfect indicator of an energy wasteful building. All buildings "waste" energy to some extent, some much more than others. The identification phase examines the potential for energy savings, and will consider analysis of metered utility data and its impact.

METERED UTILITY DATA

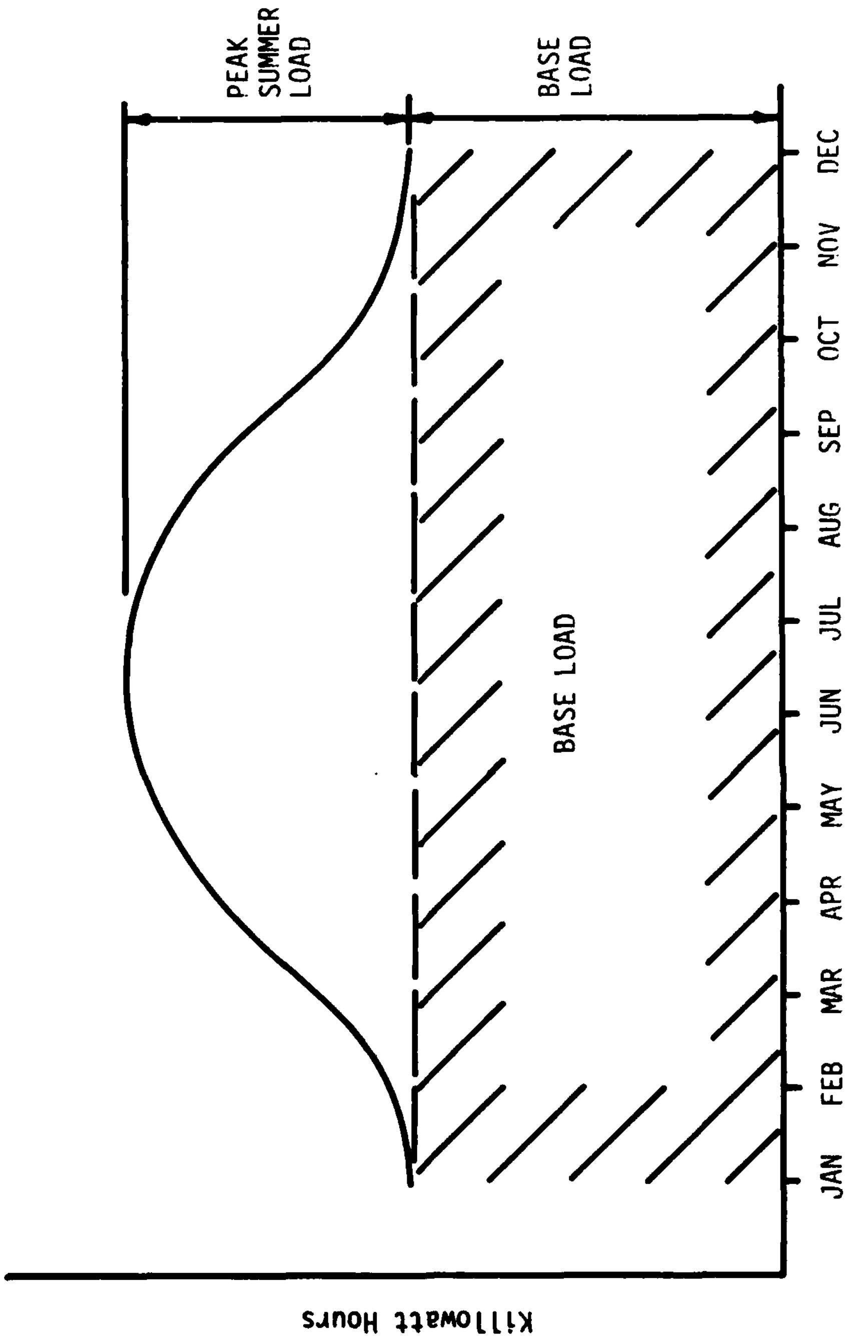
Many engineers consider metered utility data to be a good source of information on energy use trends. Consider three typical quantities, electric usage, electric demand, and natural gas usage. (The natural gas usage will typify heating energy use. If oil or some other fuel is used to provide heating, the evaluation of data would be similar.)

Electric Usage: The typical electric usage trend for a calender year is shown in Figure 1. The trend increases from a winter low typically to a summer peak. The low yearly value is called the base loading (See Figure 2). This represents the electric usage from loads which are not effected by the weather. Good examples are lighting, equipment, exhaust and supply fans. If changes have been made in the building schedule which would effect total hours of lighting, or equipment use, the data is no longer valid. Similarly, if energy conservation measures have been taken to reduce electric loads (such as reducing lighting) since the utility bills were gathered, that data will not be correct. The curves normally increase from spring to a peak summer value. The increase in usage normally results from air conditioning loads. These loads come from compressors, condenser fans, chillers, cooling towers, pumps, and other cooling equipment loads. The air conditioning supply fans in air handling units normally run year round. If this is not the case, and instead the fans are cycled on for summer cooling only, then they too are included in the increased summer usage. The key values to pull from the yearly metered utility data, are the monthly usage figures. For all cooling months, the net power used for cooling is the



Typical Yearly Electric Usage

Figure 1



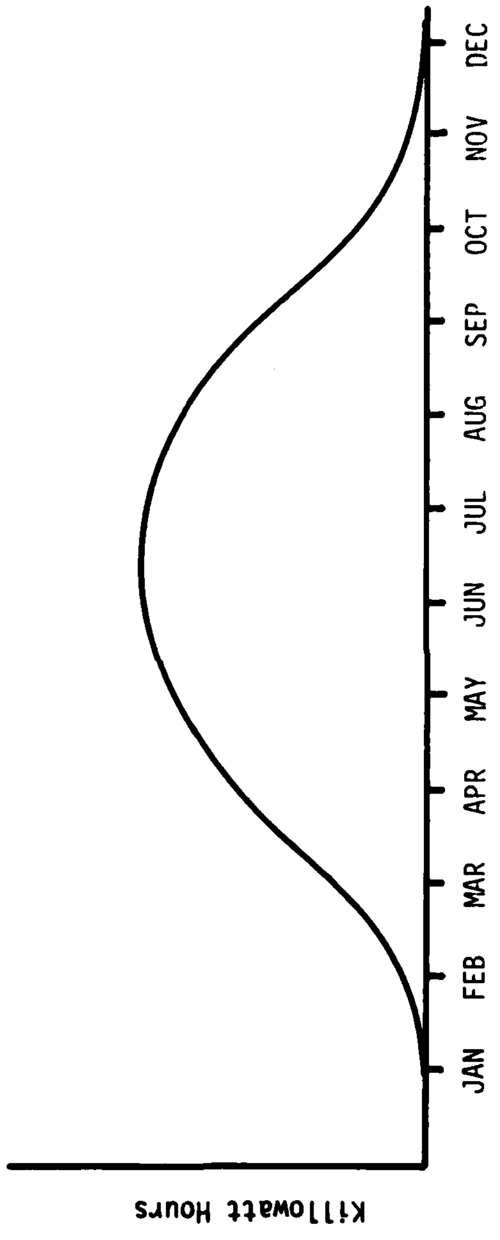
Base and Peak Summer Electric Usage

Figure 2

difference between the peak monthly loads and the yearly base case value. The resulting differences are plotted in Figure 3.

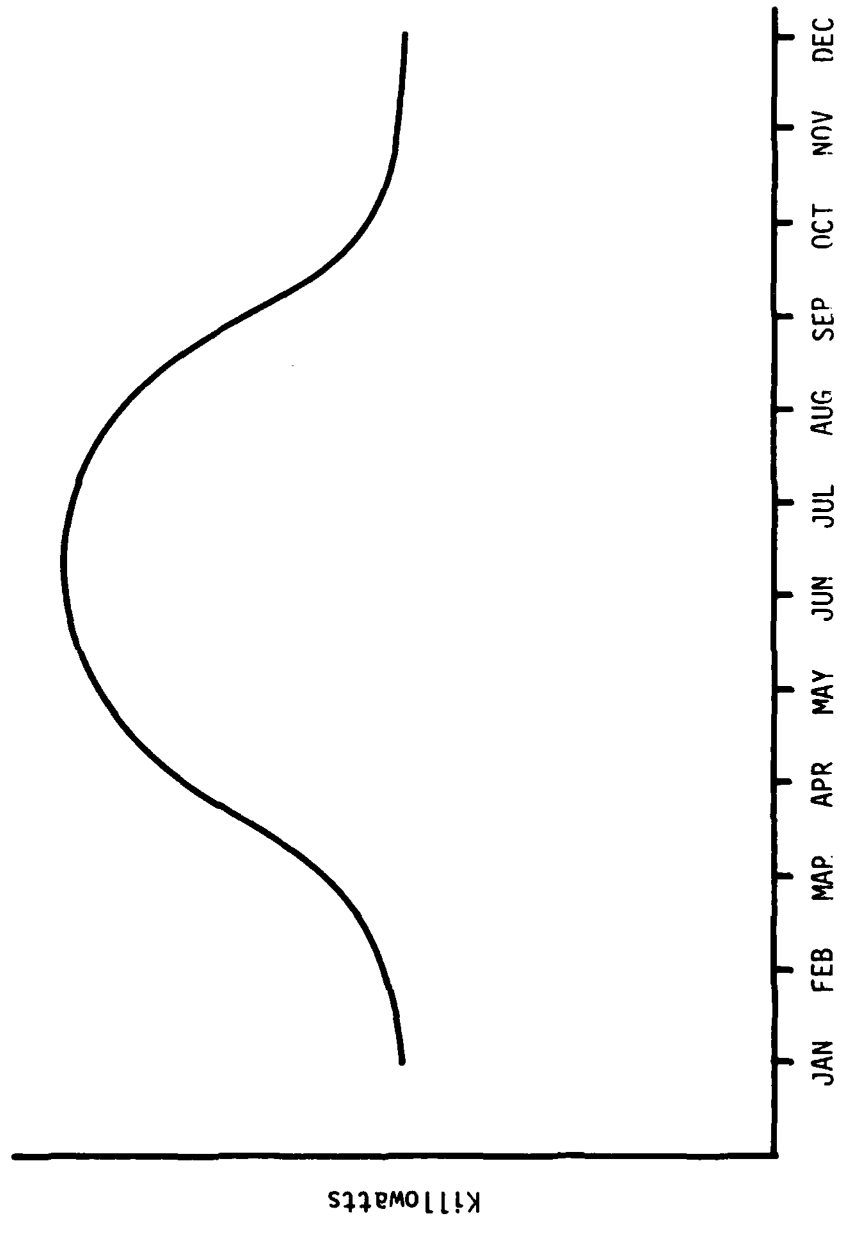
This figure yields some useful results in identifying building "waste". Compare the electric use for cooling with weather data gathered during the same period. If the outside temperature for a given month was below 55 degrees (a typical cooling coil discharge temperature), the cooling in most cases should not have been energized. If a significant power consumption is noted for any of these months, a problem with controls or installed systems is likely. (Not all systems respond to outside air temperature. Systems which have adequate outside air intake capacity can normally take advantage of a control concept called "economy of cooling", or often called "economizer control". These systems should use no mechanical cooling below 55 degrees, and should use a reduced amount of energy from mechanical cooling between 55 and 75 degrees. This function can be controlled by the EMCS. The application will be discussed in a later chapter.) The electric usage plotted in Figure 3 physically represents the number of hours of equipment operation during each month, multiplied by the average load over a given time interval. This time interval could be the load each hour, or a daily, weekly, or monthly average. The load, expressed in kilowatts, or KW, multiplied by hours, gives the common kilowatt-hours, or KWH. This information is useful, and will be discussed further in an example to follow.

Electric Demand: The typical electric demand trend for a calender year is shown in Figure 4. The trend again varies



Net Cooling Electric Consumption

Figure 3

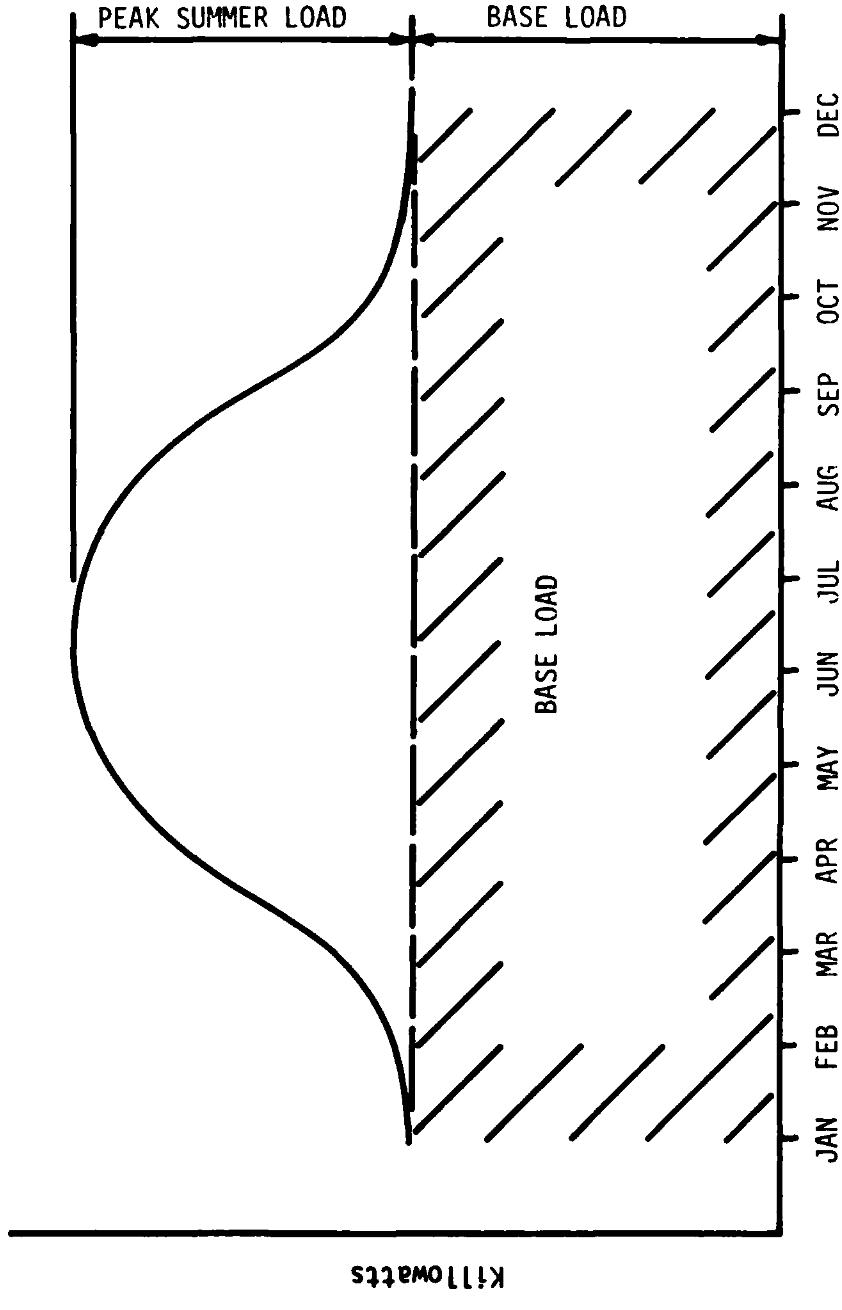


Typical Yearly Electric Demand

Figure 4

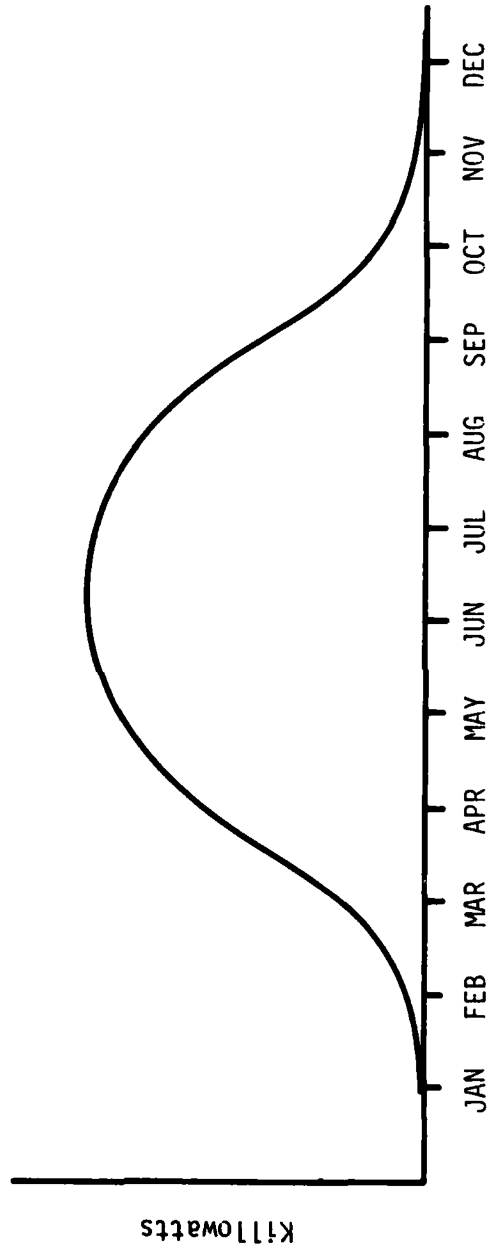
from a winter low to a summer high. In obtaining this data, it is very important to obtain the actual metered demand, not the billed demand. Many utilities have a rate provision called a ratchet clause. The general technique is to take the highest electric demand for the previous eleven months, and apply a percentage factor to arrive at a minimum billing demand. For example, if the maximum demand over the past eleven months was 1000 KW, a 75 percent ratchet clause multiplies 1000 by 0.75, giving 750 KW. By this type of rate structure, the monthly demand quantity for billing purposes would be 750 KW, or the actual metered demand, whichever is greater. The impact of the ratchet clause will be important later as estimates of savings are discussed. The importance here is to determine if data for electric demand is the actual or billed KW. The billed KW may include this ratchet amount, and in this case the metered data will be misleading.

The lowest yearly value is again the base loading. The highest summer value represents the peak summer load (see Figure 5). The demand increases during the summer months for the same reasons as the electric usage. Cooling equipment such as compressors, condenser fans, chillers, cooling towers, chilled water pumps and other devices operate during this period, and possibly cycling air handling unit loads. Subtracting the base load amount from each of the monthly electric demand values gives the peak load from heating, ventilating, and air conditioning equipment for that month. The results are shown in Figure 6. The results will be interpreted to give details on potential for EMCS installation.



Base and Peak Summer Electric Demand

Figure 5



Net Cooling Electric Demand

Figure 6

Consider an example for a hospital. The cooling plant consists of three centrifugal chillers rated at 420 tons each. The chillers are served by a three cell cooling tower with three 25 horsepower motors, operating at 17.5 brake horsepower, and two condenser pumps operating at 34 brake horsepower. The chilled water pumps operate year round serving a two pipe system, and are part of the base load. The total connected load from these components is then

Chillers: 3 at 312 KW (Full Load) =	936 KW
Tower Fans: 3 at 17.5 KW =	52 KW
Condenser Pumps: 2 at 34 KW =	68 KW
Total Connected Load	1056 KW

The monthly base load for the facility was 960,680 KWH. The chilled water plant operates in April through November. Table 1 shows the month, KWH for the month, and the difference between this consumption and the base load.

Table 1

Sample Electric Usage Data - Hospital

Month	KWH	Difference	Days	% Load
April	1108000	147320	30	19.4
May	1226000	265320	31	33.8
June	1362000	401320	30	52.8
July	1477000	516320	31	65.7
August	1563000	602320	31	76.7
September	1422000	461320	30	60.7
October	1315000	354320	31	45.1
November	1220000	259320	30	34.1

To next determine the average loading of the cooling plant we take the monthly difference and divide by load and hours to give the average load:

$$\text{Cooling Plant Load} = \frac{\text{Difference}}{\text{Total Load} \times \text{Days} \times \text{hours/day}} \times 100$$

For July for example

$$\text{Cooling Plant Load} = \frac{516320}{1056 \text{ KW} \times 31 \text{ days} \times 24 \text{ hrs/day}} \times 100$$

Cooling Plant Load (Average) = 65.7 percent

The results are also summarized in Table 1.

In very general terms, equipment operating at *part load* is less efficient than equipment operated at full load. The average load demonstrated in the table is from 19.4 percent to 76.7 percent. This indicates potential for improvement exists. The second indication is that the plant operates below full load in most cases based on these averages. This indicates that excess capacity is present for recovery from night shutdown, or demand limiting activities, which will enhance the ability to utilize EMCS.

The electric demand figures can also be analyzed to evaluate peak monthly loading. For the same location, Table 2 lists demand values for three months, from a base load electric demand of 2420 KW. The difference column again subtracts the base load from the metered electric demand to give the difference. If the difference is compared to the total connected load of 1056 KW, the cooling plant peak loading can be estimated.

Table 2

Sample Electric Demand Data

Month	KW	Difference	Max Load %
April	2657	237	22.4
May	3040	620	58.7
June	3056	636	60.2
July	3391	917	92.0
August	3397	977	92.5
September	3370	950	90.0
October	3083	663	62.8
November	3137	717	67.9

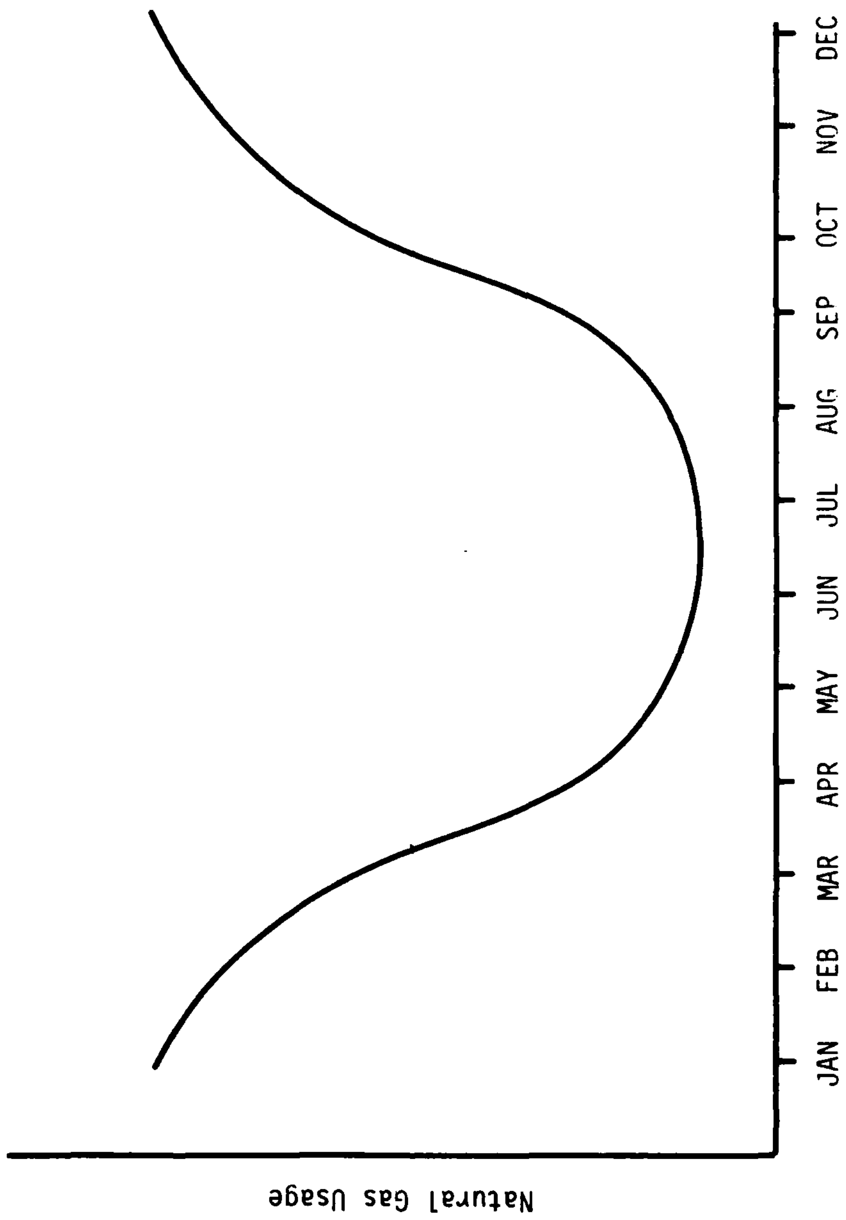
For example for July

Max % Load = (971 X 100) / 1056 = 92.0%

This indicates that the plant operates at 92.0 percent capacity (peak) in July, with an average loading from Table 1 of 65.7 percent.

The results here indicate that the peak plant loading is near full capacity for short durations. Again, the potential of the plant to recover is good in spring and fall, but based on peak loads, the capability to recover is less during the peak time of summer months. A further examination of demand would consider the daily or hourly trends. In the installation examined here, the peak loads occur during late afternoon, from 3:00 to 5:00 P.M. The impact of the maximum percent loading will be discussed in a later chapter.

Natural Gas: A typical trend for the use of heating fuels such as natural gas is shown in Figure 7. The trend is opposite to that experienced on electric usage. In this case the "base load" occurs in the summer months. The base load is a result of hot water loads, kitchen loads, other process loads, and in some cases, loads related to the heating, ventilating, and air conditioning systems. (A description of reheat systems, which use heating energy simultaneously with cooling, and thermodynamically similar systems of dual duct and multizone, follows.) The peak winter load typically occurs in December through February. The peak is normally directly attributed to heating plant loads, which are a function of demands placed on the system due to cold, windy weather. The analysis of heating data can again give average loading of the heating plant as done in Table 1 for electric loads related to cooling. The total connected heating equipment load and energy consumption must be converted to common units for comparison. For example a 100 horsepower boiler equates to 3,347,200 Btu per hour. 1000 CCF of natural gas equates to approximately 103,000,000 Btu. Conversion constants are included in the Appendix. Be careful to account for efficiencies of boilers and other devices. In considering the energy efficiency, or wastefulness of buildings, the concept of Btu per degree days is often used. Two cautions are required when using degree day analysis. First, the degree day concept was based on residential construction of the 1950's, where heating was



Typical Yearly Electric Natural Gas Usage

Figure 7

required below 65 degrees. It followed that as temperature dropped below 65 degrees, the amount of heating fuel required increased linearly as temperature dropped. The degree days for any single day are calculated by adding the day's high and low temperature and dividing by two (i.e., the average of the high and low) and subtracting this from 65 degrees. If the result is a positive number, it is a degree day of heating. For example, a day with a high of 66 and a low of 34 degrees has an average of 50 degrees. 65 degrees minus 50 degrees then gives 15 degree days of heating requirement. The problem today is that due to both higher internal loads, and better constructed buildings, most commercial buildings do not require heat at 65 degrees. The temperature where buildings require no heating or cooling is called the balance point, and for most commercial type buildings this is from 45 to 55 degrees. (CAUTION! This number varies widely by building and should be determined by calculation.) This 45 to 55 degree range of course does not match the 65 degree base of standard degree days. A second concern is the comparison of heating bills to degree days in late spring and early fall. A day with a low of 40 degrees and a high of 76 degrees may require heating of outside air and the building during more than half of the day. The "degree days" of this day are only 7, which would show a very large Btu per degree day, indicating high energy use which is not a true representation. Based on actual metered data for a building on purchased steam (bought in units of M-lbs, or 1000 pounds), a sample of this follows in Table 3.

Table 3

Energy Use Per Degree Day

Month	M-lbs Steam	Btu $\times 10^6$	Degree Days	Btu per Degree Day $\times 10^6$
Jan	10095	14032	1265	11.1
Feb	9775	13587	1080	12.6
Mar	9621	13373	791	16.9
Apr	6559	9117	504	18.1
May	3549	4933	33	149.5
Jun	4021	5589	10	558.9
Jul	3606	5012	0	
Aug	3158	4390	0	
Sep	3511	4880	57	85.6
Oct	3916	5443	238	22.9
Nov	7428	10325	574	18.0
Dec	7324	10180	608	16.7

As it stands above, what conclusions can be drawn from these results? Considering the Btu per degree day column, the use appears to vary widely; but the definite trend is the lowest use during the most severe weather. Is this likely? Probably not, but based on this type of metered data, the results cannot be further refined. The data is useful however. It serves as a base for comparison with manual calculations. If you are trying to calculate the before and after energy use of a building being considered for EMCS, the energy consumption indicated forms a good foundation for judgement. For example, if your calculations predicted a use of 15000 x 10^6 Btu in January, you would likely conclude that your results were acceptable. If your calculations indicated 7000 or 28000 x 10^6 Btu, another look at your results would probably be warranted.

Conclusions: Metered utility data is useful if properly applied. The most important concern is the full understanding of how a building was utilized during the period of months included in the measured data. If the use has changed, hours of operation changed, or significant energy conservation measures have been taken, the data should be reviewed. Metered electric data is most useful in determining base loads, and in calculating average and peak plant loadings, which may impact the available EMCS strategies. Considering yearly kilowatt-hours per square foot is useful in comparing buildings only if utilization is similar (i.e., comparing an 8 to 5 office building to a 24 hour use manufacturing facility is of course not a valid comparison). If kilowatt hours per square foot are high, indications of a greater savings potential may be concluded. While it has been shown that heating energy use in Btu per degree day yields inconsistent results, the quantity still serves to identify more "wasteful" buildings when like buildings in like climates are compared.

The use of measured utility data is meaningful only if properly applied and interpreted. It should not be the only data source on which to base your savings calculations. The use of measured data can be summed up with two words: use caution.

ANALYSIS BY CALCULATION

The most viable backup to measured utility data is analysis by calculation. This is supported in some cases by measurements of simple data. In almost every case, the building being considered for EMCS is not being used as originally conceived and designed. In the design phase, the mechanical engineer who designed the heating, ventilating and air conditioning system was forced to make many design assumptions. For example, consider the engineer looking at a blank floor plan of a 20 foot by 30 foot office area. The amount of cooling supplied is based on external factors such as wall, window, and roof construction, and internal factors such as lights, people, and equipment. The external factors are normally indicated on the architectural plans, however, actual construction often varies from the "ideal" shown on the drawings. The hardest quantity to estimate is air leakage or "infiltration" into an area. The internal loads are based on experience and probable use only, forcing the engineer to guess at how many people will occupy the office, and what lighting will be utilized. While the lighting is often times easy to determine from the electrical plans, the people and equipment are only estimates. The result is a calculated cooling load based on estimates, which dictates the necessary supply air temperature and air volume. The probability is very high that the area being considered is not being used as originally designed. In this phase of EMCS evaluation, the actual loads must be determined. EMCS control of a building which is not operating efficiently to start with, will only lead to comfort complaints and probably dissatisfaction. The steps in this tuning process (discussed here under Analysis by Calculation, and normally implemented prior to EMCS installation) are very basic:

Step 1) Determine actual loads. The building being considered should be thoroughly examined for actual installed loads. A complete walk-through study of the building should be made, examining actual construction, and noting actual numbers of people in each area, actual lighting, and installed equipment. This information should be used to perform a complete load estimate by room, by zone, and by each separate heating, ventilating, and air conditioning system. The net result should be the air flow required at each outlet to meet actual loads. Performing a study such as this can be done with standard load estimating techniques as developed by the Carrier Corporation, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), or others. The other viable alternative today is the use of microprocessor based computer load estimating programs. This tool enables rapid calculation of loads. The time requirement, including the building walk-through is approximately 24 hours for a 100 zone building. A sample of the results is shown in Figure 8.

The results are significant in that they provide the foundation for the analysis of EMCS potential, and provide valuable information for energy conservation measures. For example, in Figure 8 the total sensible load for the room is 40,727 Btuh. Of this the roof load is 9,136 Btuh, or 22.4 percent. This compares to the total wall load of 727 Btuh, or 1.8 percent. This of course indicates a much greater potential exists for saving energy through roof measures

Figure 8

Sample Load Calculation

Carrier E20-II Load Estimating Program

SAMPLE CALCULATION
May 5, 1983

WARREN *OHIO LAT = 41 ALT = 900
CONST= 130W/40R/130B ID= 74/40 : 73
WALL COLOR: DARK ROOF COLOR: DARK
- SER# 21207821.5

	D.B.TEMP	TOTAL TONS	RSH TONS	C.F.M.
1. JUN AT 9 A.M.	73.4	2.71	2.39	1,449
2. JUL AT 9 A.M.	76.4	2.81	2.49	1,509
3. SEP AT 10 A.M.	73.2	2.64	2.33	1,409
4. OCT AT 2 P.M.	72.0	2.69	2.37	1,436
5. SEP AT 3 P.M.	83.2	3.31	2.95	1,788
6. JUL AT 4 P.M.	88.0	3.79	3.39	2,057
7. JUN AT 4 P.M.	85.0	3.69	3.30	2,002

ZONE HEATING--> = 28,897 W/INFIL= 28,897 C.F.M = 1,194

INPUTS

	CEILING	PARTITION	FLOOR	SKYLIGHT
TRANSMISSION FACT.	0.00	0.00	1.00	0.80
TEMP DIFF HEATING	0	0	0	73
TEMP DIFF COOLING	0	0	0	14

FLOURESCENT LIGHTS - Y SOLAR FACTOR SKYLIGHT = 0.45

OVERHANGS AND/OR REVEALS PRESENT (FT)

		TYPE 1	TYPE 2	TYPE 3
HEIGHT OF OVERHANG	-	0.17	0.00	0.00
DEPTH OF OVERHANG	-	0.67	0.00	0.00
HEIGHT OF WINDOW	-	8.00	0.00	0.00
DEPTH OF REVEAL	-	0.67	0.00	0.00
NUMBER FLOORS	-	1.00	1.00	1.00

EFFECTIVE AVERAGES FOR ZONE LOADS OR OP-COST :

EXPOSURE:	N.	NE	E.	SE	S.	SW	W.	NW
WALL TRANS. FACTORS	0.00	0.00	0.00	0.00	0.12	0.00	0.12	0.00
GLASS TRANS FACTORS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLASS SOLAR FACTORS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROOF TRANS. FACTOR = 0.15 SKYLIGHT TRANS. FACTOR = 0.80

OUTPUTS

NUMBER OF PEOPLE	=	8	SENSIBLE PEOPLE LOAD	=	1,960
TOTAL LIGHTS	=	3,840	LIGHTING LOAD	=	16,382
OTHER ELECTRICAL	=	1,680	OTHER ELECTRICAL	=	5,734
TOTAL GLASS AREA	=	0	TOTAL GLASS SOLAR	=	0
TOTAL GLASS AREA	=	0	TOTAL GLASS TRANS.	=	0
SKYLIGHT AREA	=	0	TOTAL SKYLIGHT SOLAR	=	0
SKYLIGHT AREA	=	0	TOTAL SKYLIGHT TRANS	=	0
-					
S. TYPE 1 WALL AREA	=	149	S. TYPE 1 WALL LOAD	=	187
W. TYPE 1 WALL AREA	=	500	W. TYPE 1 WALL LOAD	=	540
TOTAL WALL AREA	=	649	TOTAL WALL TRANS.	=	727
PARTITION AREA	=	0	TOTAL PART. TRANS	=	0
CEILING AREA	=	0	TOTAL CEILING TRANS	=	0
FLOOR AREA	=	0	TOTAL FLOOR TRANS	=	0
AREA OF ROOF	=	1,680	ROOF LOAD	=	9,136

Figure 8

Sample Load Calculation

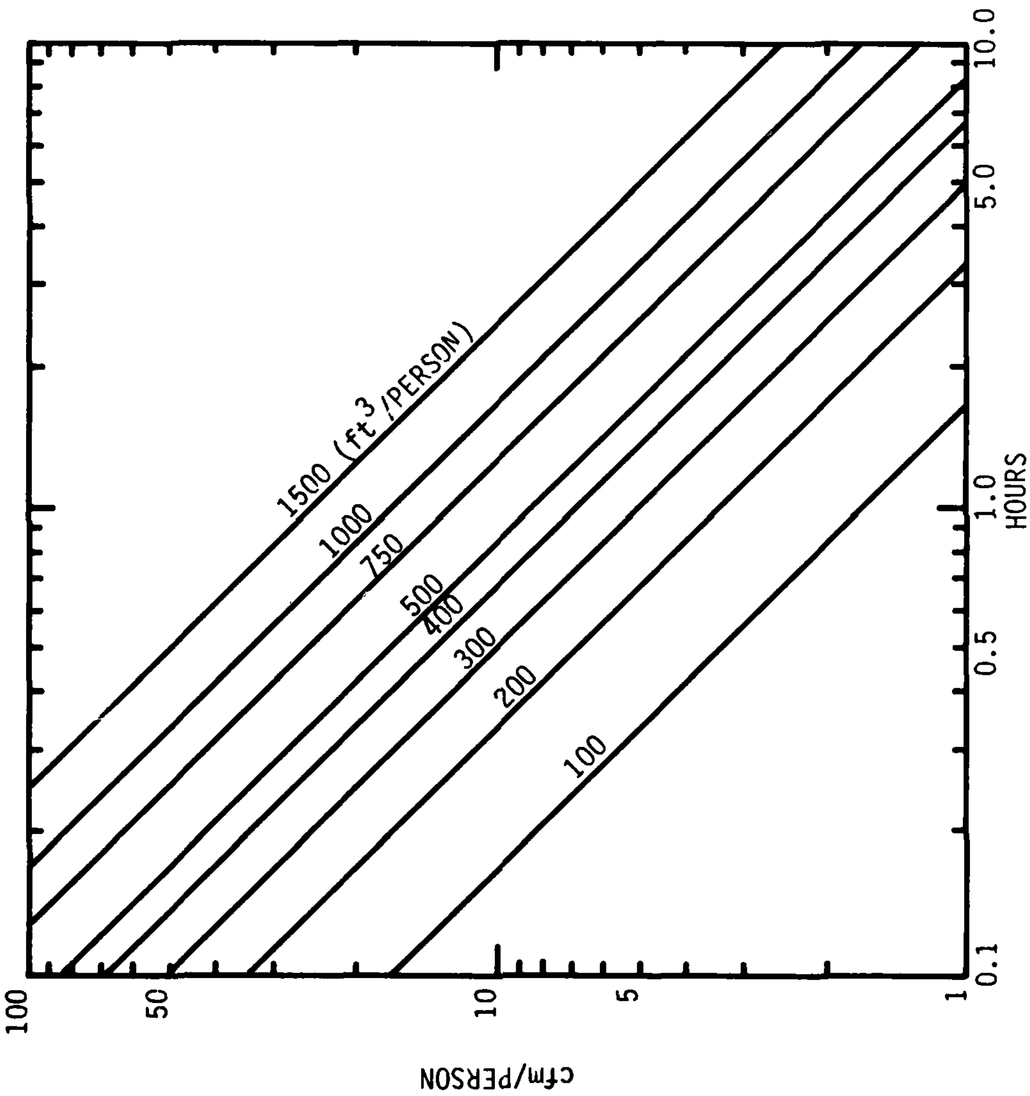
```
-
SAFETY FACTOR    =        20%  SAFETY B.T.U.S        =    6,788
EVAP FAN H.P.    =       1.00  FAN HEAT GAIN - BT    =    3,070
MISC SENSIBLE    =          0  MISC. SENSIBLE        =        0
VENTILATION CFM =           0  O. A.SENSIBLE LOAD    =        0
MISC. LATENT     =          0  MISC. LATENT          =        0
NUMBER OF PEOPLE=           8  PEOPLE LATENT LOAD    =    1,640
VENTILATION CFM =           0  O.A.  LATENT LOAD     =        0
TOTAL CFM-STD AIR=      2,057   TOTAL LATENT LOAD     =    1,640
-
ROOM SENSIBLE    =     40,727  ROOM LAT. LOAD        =    1,640
     **********************************************
                        SAMPLE CALCULATION
--> GRAND TOTAL LOAD =    45,437 BTU'S  OR      3.79 TONS <--
                LOAD RUN FOR  # 6.  JUL AT  4 P.M.
AREA (SQ FT)       =    1,680  SQ. FT PER TON     =         444
TOTAL CFM-STD AIR =     2,057  CFM PER SQ FT      =        1.22
                         HEATING LOAD
PARTITION LOAD     =        0  CEILING LOAD       =           0
VENTILATION LOAD  =         0  ROOF HEATING LOAD =       18,396
FLOOR HEATING LOAD=         0  SKYLIGHT LOAD      =           0
GLASS HEATING LOAD=         0  WALL HEATING LOAD =        5,685
SLAB HEATING LOAD =         0  INFIL HEAT LOAD    =           0
WARM UP LOAD       =    4,816  H LOAD WITH VENT   =      28,897

                 COIL SELECTION PARAMETERS
DB TEMP ENT EVAP    =   75.4   TOT SENSIBLE LOAD   =     43,797
WB TEMP ENT EVAP    =   62.9   TOT COIL LOAD       =     45,437
SPECIFIED ROOM RH   =    40%   RESULTING ROOM RH   =        52%
TERM AIR TEMP   = 56.00 / 95  DEGREES ROTATED = 0
T. ST. EVAP FAN =  1.70            NON-CEILING RETURN
BLDG.   'U' FACTOR=  0.14     CARRIER DEFAULTS
-------------------------------------------------------------
```

than wall measures. The information presented also allows a designer to look at the analysis at any time in the future, and determine what has changed, and what requirements are necessary to "tune" the building. The important result for EMCS potential is the total air flow or CFM required to meet the actual installed loads. If the air flow is currently too low, comfort complaints probably exist already, and complaints will likely increase when EMCS control is added. Similarly, if air flow is too high, the installed heating, ventilating, and air conditioning system is likely compensating for the excess in some way, which normally increases energy consumption. The importance of this step cannot be stressed enough.

Step 2) Sum air flow requirements. For the area served by the heating, ventilating, and air conditioning system, the air flows are summed. This total air flow is required in EMCS savings calculations. In most cases, the total air flow required differs from the installed capacity.

Step 3) Determine ventilation requirements. Based on the results of the walk-through study, the minimum required ventilation rate should be calculated. The current industry reference is ASHRAE publication 62-1981, "Ventilation for Acceptable Indoor Air Quality". The standard is based on requirements for occupancy only - greater ventilation amounts may be required to meet exhaust air flow requirements. Table 3 from the standard is reproduced in the Appendix. The actual time requirement for this ventilation should be determined based on building use. Be specific. If an area is occupied from 8:00 to 12:00, and 1:00 P.M. to 5:00 P.M., normally only 8 hours of ventilation should be used. Where indoor contaminants are from people only, the ventilation can actually lag occupancy time. The "Maximum Permissible Ventilation Lag Time" from ASHRAE publication 62-1981 is reproduced in Figure 9. In the example load calculation of Figure 8, there were 8 people, 22,680 cubic feet in the room, and 15 cfm per person ventilation. From Figure 9, the ventilation may lag the 8:00 A.M. and 1:00 P.M. occupancy times by approximately 2 hours. Thus actual ventilation is required only from 10:00 A.M. to noon, and 3:00 P.M. to 5:00 P.M. If this ventilation from outside air now runs continuously, the ventilation time can be reduced by 83 percent. The key to this analysis step is to 1) determine actual ventilation requirements, and 2) calculate minimum ventilation times.

Step 4) Determine what exists. After determining what is needed, you must ascertain what the existing conditions are. Normally this requires a measurement of air flow at each supply and return outlet, and the measurement of static pressures at the air handling unit. The outside air amount being used for ventilation should be measured, both at normal settings and at a full closed signal to the outside air dampers from the controls. The full closed position will indicate how much air leaks through the dampers. A typical leakage for old dampers is 15 to 25 percent. If the goal of the EMCS is in part to close outside air dampers when the building is unoccupied, the results may be minimal if the leakage is high, and damper repair, retrofit, or replacement may be warranted. If calculations show that only 8 percent outside air is required when occupied, and the dampers leak 15 percent when full closed, energy is wasted for heating and cooling.



Maximum Permissible Ventilation Lag Time

Figure 9

ASHRAE STANDARD 62-1981

If measurements of air flow in the building indicate that more air is required in an area, the impact should be considered carefully. As air flow in a duct run is increased, the static pressure required at the supply fan goes up, and so does the power requirement. For example, in the multizone system which serves the area detailed in Figure 8, the air flow required was 18,695 cfm, and the existing air flow was 13,052 cfm, with the current motor pulling 7.6 brake horsepower. To increase the cfm will require a larger motor to develop 22.3 brake horsepower. If motor loads must be increased, this should be recognized in evaluating metered utility data from past billings, or in savings calculations.

In some cases it may be next to impossible to calculate loads in a room. For example, rooms filled with electrical equipment are difficult to analyze. Nameplate data normally gives power at full loading, and not normal operating conditions. If it is difficult to calculate the heat gain, calculate the heat being removed. From psychrometrics,

$$Q = 1.1 \text{ CFM } (t_{out} - t_{in})$$

Where Q = heat gain in Btuh

1.1 = Constant

CFM = Total air flow into room

t_{out} = Temperature of air leaving the room, degrees F

t_{in} = Temperature at cooling air supply, degree F

For example, a room with a measured air flow of 4,000 cfm has a supply temperature of 55 degrees, and 79.5 degrees leaving temperature. The equipment load is thus 107,800 Btuh. Be sure to account for external loads if present.

When measuring air flows, it is often necessary in multizone and dual duct systems to measure volume with all controls set for full cooling, and secondly with all controls set for full heating. This will identify variations in total air flow as air is diverted through heating and cooling coils which are typically sized differently.

Conclusions: The calculation of loads and associated air volumes for total supply and ventilation is a powerful tool in evaluating wasteful buildings. The results provide detailed information on "tuning" requirements for the existing building, which can be done with the EMCS implementation. In general, systems with excess heating, cooling, and air flow capacity offer substantial potential for cost effective EMCS control. Systems with large excesses of ventilation air offer good EMCS potential. Buildings which have large time varying ventilation loads are good candidates for EMCS control. Buildings which have systems designed and operated very close to actual building requirements offer less potential for EMCS.

ANALYSIS OF CONTROLS

In the chapter "Guidelines for Efficient Installation" which follows, several types of control systems will be introduced, and the possibilities for EMCS interface and local control modifications will be discussed. The controls applied to heating, ventilating, and air conditioning systems vary by the system type. Basic air handling unit system types are classified as:

1) All-Air Systems
2) Air-Water Systems
3) All-Water Systems
4) Multiple Unit or Unitary Systems

While other types exist, these four general catagories include most equipment which will be encountered. A brief discussion of each class of system is in order, with typical control characteristics and operation.

All-Air Systems: An all-air system is an air handling unit and associated supply and return duct and equipment, which is designed to provide all sensible and latent cooling, and in some cases heating, and humidification, in air supplied by the system. No additional cooling is required in the area being served, and the heating where installed is the primary heat source. These systems are designed to meet cooling and heating loads under peak load conditions (and are often oversized for various reasons). This peak load condition normally occurs for only a few hours every year, and typically 97 percent of the hours of system operation are at part load. When the systems are at part load, there are three basic choices of how to control capacity. The first is on-off control.

For commercial systems on-off control is normally unsatisfactory. The first objection is that ventilation is discontinued, causing odors and a "stuffy" feeling in the building. Second, as the system is cycled on-off the noise level at the supply outlets goes from 30-40 db to none. The higher noise level is common and normally not objectionable, but the cycling of the noise on and off is objectionable. The third main objection is the start and stop of the fan motor. Large horsepower motors (over 10 hp) are not normally cycled due to excessive belt wear and substantially decreased motor life.

The second basic technique for control is to vary the temperature of the air being supplied. In all-air systems, air is normally supplied at 15 to 25 degrees below the room temperature. A normal value for a room maintained at 78 degrees, is a 58 degree supply, at full or peak load. To prevent overcooling, the air supply temperature is raised as the load drops. For example, if the load is 75 percent of maximum, the air is supplied 15 degrees cooler than the room, at 63 degrees (75 percent of the original 20 degrees below room temperature). As load drops to 50 percent, the temperature is increased to 73 degrees, and so on. The change in supply air temperature is accomplished through pneumatic or electronic automatic temperature controls. The opposite holds true for heating. The supply temperature to the room is typically 25 to 40 degrees above the room temperature. The supply temperature is decreased as the need for heating decreases. There are two types of all-air systems which provide this control:

A) Single-Path Systems
B) Dual-Path Systems

The single path systems contain main heating and cooling coils in series, with heating coils located either in the air handling unit or in the supply ducts to the zones. Temperature control is provided by either modulating the cooling coil (through varying flow to a chilled water coil or cycling stages of mechanical refrigeration), or maintaining a constant temperature leaving the cooling coil and "reheating" the supply air to prevent overcooling of the areas served by the system. The dual path systems contain main heating and cooling coils in parallel. For capacity control, the warm and cool air streams are mixed to give the desired temperature at the supply to the room.

The third basic technique for capacity control is by leaving temperature constant, and varying the volume of the air being supplied. At full load, the maximum air flow is delivered. At 75 percent call for cooling, 75 percent of the air is delivered, and so on. The advantage of this system is substantially reduced fan horsepower and minimal simultaneous heating and cooling.

In evaluation of controls, which must be related to systems, controls which allow simultaneous heating and cooling normally indicate wasteful practices. Normally variable air volume systems are much more efficient in this regard.

All-air systems normally are connected to an outside air intake section. When the outside air is cool enough, it can be introduced directly for "free cooling". These sections are often controlled by the dry bulb temperature. The return and outside air is blended to give a mixture normally around 55 degrees. Above 55 to 65 degrees, the outside air is normally reduced to minimums for ventilation. While this is normal, it is no longer the "state-of-the-art" and EMCS can refine this control substantially. If the temperature of the mixture is not changed based on the actual demand for cooling by the system, and the change to minimum outside air made based on the enthalpy of the outside and return air, then the system offers substantial potential for EMCS control.

Air-Water Systems: Air-water systems provide space conditioning through the use of both air and water sources that are distributed to terminal units throughout buildings. Normally these systems are used throughout buildings with a large number of zones, where humidity control is less important. They are found in hospitals, hotels, schools, and many other locations. These systems can either heat, cool, or both simultaneously depending on the original design of the supply piping. While all-air systems are normally larger with typical supply fans ranging from 5 to 200 horsepower, air-water systems are characterized by many smaller units - usually one per room - of fractional horsepower if any. Each unit is controlled individually. EMCS control of the many smaller units is as effective as the larger systems, however, the costs associated with control of air-water systems often makes EMCS installation too expensive. The central plants which provide hot and chilled water to these units are good EMCS candidates, as well as the primary air handling units.

All-Water Systems: All-water systems accomplish heating and cooling by distributing hot and chilled water from a central plant to individual room units. These units contain either a single coil for heating or cooling, but not both simultaneously, or both a heating and a cooling coil, which offer either heating or cooling on demand. The units are controlled by individual room controls, and typically have fractional horsepower motors. As was the case for air-water systems, energy saving opportunities are good but often cost prohibitive, while the control heating and cooling plants offer good potential for savings.

Multiple Unit or Unitary Systems: These systems are characterized by equipment ranging from through-the-wall and window air conditioners to heat pumps, and each typically contains all equipment for a complete refrigeration cycle. These pieces of equipment are often small and uneconomical to control with EMCS. The best control technique is to simply turn off when not in use.

Conclusions: The current method of control of air handling units will strongly dictate the potential for savings with EMCS. Poorly or simply controlled units offer significant potential. Often times units with very complex control systems can be improved with EMCS. Systems which offer the highest potential are those with simultaneous heating and cooling, those which operate 24 hours per day when not needed, or those which operate basically five days per week from 8:00 A.M. to 5:00 P.M. or a similar schedule, with poor night time control.

The identification of energy wasteful buildings is thus a three pronged attack. The analysis of metered utility data is always valuable, but not always available. The seasonal trends of electric use are a strong indication of cooling energy consumption and peak utilization. They can be used as a comparison tool between facilities in like areas. The very nature of the billing structure, i.e., high demand charges, can enhance the economic viability of an energy management system. The study of spring and fall electric consumption, when temperatures are moderate, can indicate waste. Careful consideration should be given to the source of the yearly "base loads" and "peak loads", why these loads occur when they do, and what can be done to reduce the loads through EMCS. A similar evaluation of heating fuel usage can yield good results. Again, what are the components of the base load and peak load, and what can be done to reduce these loads. While metered utility data is often used, apply caution: the conditions which occurred when the monthly usage and peak demand were measured will never occur again. Numerous weather related variables impact these values. Utilization of the building greatly impacts the values. The results are not repeatable.

In analysis by calculation, a concerted effort is made to determine whether systems are performing at the optimum. This certainly is more time involved than examining a set of utility bills, but is a necessary first step before EMCS installation. EMCS control of systems that are not operating as well as possible is inviting doom from the outset of the project. The results of the analysis form the data base for evaluation.

The examination of controls is necessary to complete the evaluation. This will be a good indicator of potential for improved control, and/or EMCS to improve energy efficiency.

Many cases will arise where utility billings are not available. To compare facilities in this case requires a computation of energy use or metering/monitoring of the building. The information gained in the "Analysis by Calculation" and "Analysis of Controls" provides the input for calculation. The techniques used today range from the large scale computer energy calculation programs, to microprocessor computer energy calculation programs, to manual calculations.

Manual calculations can be done with reasonable accuracy using such guides as the "Standardized EMCS Energy Saving Calculations", calculating energy use before and after EMCS strategies are incorporated. These techniques account for equipment operation in heating, ventilating, and air conditioning, but not internal building equipment or lighting loads. Calculation of building peak demand is not possible, but changes (reductions) in electric demand can be calculated.

Energy calculation programs for desk top microcomputers are used widely today. A building must be examined system by system with these programs. Results are stated to be within 15 percent of actual usage (which is highly dependant on accurate input and a full understanding of how the programs model systems and part load performance). Normally, the analysis is based on bin weather data, and monthly electric demands are not predicted. An average cost per unit of fuel is used to estimate energy costs per year. A typical analysis of an average building (50,000 square feet, 12 systems) takes from two to five days depending on complexity.

Large scale computer simulation programs are also available. They require extensive input which increases both data gathering time and analysis time substantially. The resulting cost is much greater for a slight, if any, improvement in results. In a recent study by NASA, results for the Carrier Corporation E20-II Operating Cost Analysis Program (Microprocessor run) were within 10 percent of those calculated by DOE-II, a large scale simulation program. The large scale simulation program can, however, provide electric demand data which is desirable for the consideration of several EMCS application programs.

For single buildings, the use of microcomputer programs is recommended for analysis of both "base case" energy use and energy conservation alternatives, including EMCS. A sample follows for a typical building.

Figure 10 reproduces input data for a hospital building in Minneapolis, Minnesota. The input was obtained using a load calculation program as presented in Figure 8. Figure 11 is a "Base Case" analysis result for a constant volume reheat system, which indicated an annual energy cost of $123,393 for the system as now operated. In Figure 12, the system was considered with EMCS control of outside air economizer

Figure 10

** INPUT SUMMARY ***

```
LOCATION          : MINNEAPOLIS    ,MINNESOTA
OUTDOOR DESIGN    :  92 F. DB/ 39.0103 BTU/LB (SUMMER)
                  : -16 F. (WINTER)
INDOOR DESIGN     :  75 F./ 50 %RH (COOLING)
BLDG. WEIGHT      : MED.-HVY.
OCCUPIED SCHED. : 24 HRS.

OTAL COND. SPACE AREA ( 38388 )
INTER. COND. SPACE AREA ( 32630 )
INDOOR OCC. HTG. DES. TEMP. ( 73 )
INDOOR UNOCC. HTG. DES. TEMP. ( 73 )
VARIABLE OR CONSTANT VOLUME AIR SYSTEM <V OR C> (C)
OUTDOOR DB TEMP. @ KNOWN LOAD ( 91 )
INDOOR DB TEMP. @ KNOWN LOAD ( 75 )
UNOCC. CFM/SQ.FT. INFILTRATION ( 0 )


*** BLOCK LOADS ****** LOSSES SHOWN AS (-) BTUH ***
TRANSMISSION    BTUH  ( 33229 )
GLASS SOLAR     BTUH  ( 75422 )
O.A. SENSIBLE   BTUH  ( 119715 )
PEOPLE SENS.    BTUH  ( 70805 )
LITES & EQUIP.  BTUH  ( 351185 )
OTHER SENS.    BTUH  ( 174394 )
O.A. LATENT    BTUH  ( 158092 )
PEOPLE LATENT   BTUH  ( 59245 )
OTHER LATENT    BTUH  ( 0 )
OCC. S.A. CFM @  91 F. OUTSIDE ( 28377 )

*** INTERIOR ONLY ****** LOSSES SHOWN AS (-) BTUH ***
TRANSMISSION    BTUH  ( 0 )
GLASS SOLAR     BTUH  ( 0 )
O.A. SENSIBLE   BTUH  ( 101758 )
PEOPLE SENS.    BTUH  ( 60184.6 )
LITES & EQUIP.  BTUH  ( 298509 )
OTHER SENS.    BTUH  ( 148236 )
O.A. LATENT    BTUH  ( 134379 )
PEOPLE LATENT   BTUH  ( 50358.6 )
OTHER LATENT    BTUH  ( 0 )
OCC. S.A. CFM @  91 F. OUTSIDE ( 24120.6 )
```

FUEL COSTS: $0.05 per KWH ELECTRICITY
$0.50 per THERM NATURAL GAS

Figure 11

PROJECT NAME : SAMPLE OPERATING COST (38388 SQ.FT., 85 % INT.)

SER# 21120821.6	PERIMETER	INTERIOR	OPER.$/YR.
	*********	********	**********
COOLING PLANT :	CENTRIFUGAL	<---------	$ 39173.90
MAX.LD.TONS :	89.50	<---------	
NOM. TONS :	95.00	<---------	
NOM. KW :	104.50	<---------	
STM. RATE :	0.00	<---------	
MIN.% UNL. :	0.00	<---------	
LAYOUT :	1 SERIES UNITS	<---------	
SA/CW RESET :	NO	<---------	
ECONOMIZER :	NONE	<---------	
ECON. LEAK %:	0.00	<---------	
PULLDOWN CYC:	NO	<---------	
HEAT SINK :	CLG. TOWER	<---------	
HEATING PLANT :	COMBUSTION	<---------	$ 10885.50
HT. SOURCE :	NAT. GAS	<---------	
MAX.LD.MBH :	1073.96	<---------	
NOM. MBH :	1200.00	<---------	
NOM. KW :	0.00	<---------	
NOM. % EFF. :	80.00	<---------	
CONTROLS :	MODULATING	<---------	
WARMUP CYC. :	NO	<---------	
AUX. PLANT :	NONE	<---------	
AUX. FUEL :	NONE	<---------	
AUX. MBH :	0.00	<---------	
AUX. % EFF. :	0.00	<---------	
AUX. CONTROL:	NONE	<---------	
SUPPLY FAN :	BI OR AIRFOIL	<---------	$ 18895.80
CONTROL :	NONE	<---------	
DES. CFM :	28377.00	<---------	
IN.WG. TSP :	7.00	<---------	
HTG. DUTY :	YES	<---------	
RETURN FAN :	AXIAL	<---------	$ 5130.89
CONTROL :	PITCH	<---------	
DES. CFM :	21575.00	<---------	
IN.WG. TSP :	2.50	<---------	
HTG. DUTY :	YES	<---------	
AUX. MOTOR :			$ 4225.25
CW PUMP BHP :	1.69	<---------	
HW PUMP BHP :	0.89	<---------	
TW PUMP BHP :	2.64	<---------	
OW PUMP BHP :	0.00	<---------	
TWR FAN :	6.71	<---------	
VENT. RECLAIM :			$ 0.00
CLG MBH @95F:	0.00	0.00	
HTG MBH @ OF:	0.00	0.00	
MTR. BHP :	0.00	<---------	
COOLING TERM. :	CV TERM.REHEAT	CV TERM.REHEAT	
HEATING TERM. :	SAME AS CLG.	SAME AS CLG.	

HVAC OPCOST/YR:			$ 78311.30
LITES&MISC.EL.:			$ 45081.60

TOT.OPCOST/YR.:			$123393.00

Figure 12

PROJECT NAME : SAMPLE EMCS CONTROL (38388 SQ.FT., 85 % INT.)

SER# 21120821.6	PERIMETER *********	INTERIOR *********	OPER.$/YR. **********
COOLING PLANT :	CENTRIFUGAL	<---------	$ 4722.79
MAX.LD.TONS :	89.50	<---------	
NOM. TONS :	95.00	<---------	
NOM. KW :	104.50	<---------	
STM. RATE :	0.00	<---------	
MIN.% UNL. :	0.00	<---------	
LAYOUT :	1 SERIES UNITS	<---------	
SA/CW RESET :	YES	<---------	
ECONOMIZER :	ENTH.+REFR.	<---------	
ECON. LEAK %:	5.00	<---------	
PULLDOWN CYC:	NO	<---------	
HEAT SINK :	CLG. TOWER	<---------	
HEATING PLANT :	COMBUSTION	<---------	$ 6786.25
HT. SOURCE :	NAT. GAS	<---------	
MAX.LD.MBH :	1073.96	<---------	
NOM. MBH :	1200.00	<---------	
NOM. KW :	0.00	<---------	
NOM. % EFF. :	80.00	<---------	
CONTROLS :	MODULATING	<---------	
WARMUP CYC. :	NO	<---------	
AUX. PLANT :	NONE	<---------	
AUX. FUEL :	NONE	<---------	
AUX. MBH :	0.00	<---------	
AUX. % EFF. :	0.00	<---------	
AUX. CONTROL:	NONE	<---------	
SUPPLY FAN :	BI OR AIRFOIL	<---------	$ 18895.80
CONTROL :	NONE	<---------	
DES. CFM :	28377.00	<---------	
IN.WG. TSP :	7.00	<---------	
HTG. DUTY :	YES	<---------	
RETURN FAN :	AXIAL	<---------	$ 5130.89
CONTROL :	PITCH	<---------	
DES. CFM :	21575.00	<---------	
IN.WG. TSP :	2.50	<---------	
HTG. DUTY :	YES	<---------	
AUX. MOTOR :			$ 1100.28
CW PUMP BHP :	1.69	<---------	
HW PUMP BHP :	0.89	<---------	
TW PUMP BHP :	2.64	<---------	
OW PUMP BHP :	0.00	<---------	
TWR FAN :	6.71	<---------	
VENT. RECLAIM :			$ 0.00
CLG MBH @95F:	0.00	0.00	
HTG MBH @ 0F:	0.00	0.00	
MTR. BHP :	0.00	<---------	
COOLING TERM. :	CV TERM.REHEAT	CV TERM.REHEAT	
HEATING TERM. :	SAME AS CLG.	SAME AS CLG.	

HVAC OPCOST/YR:			$ 36636.00
LITES&MISC.EL.:			$ 45081.60

TOT.OPCOST/YR.:			$ 81717.60

through enthalpy changeover, and supply air reset based on zone of greatest demand. With economizer control, the use of cooling energy was reduced from $39,174 to $4,723, and through reset of the cooling temperature, the heating energy cost was reduced from $10,885 to $6,786. Auxiliary motor power consumption dropped as well. The technique is useful in evaluating (quickly) the energy saving potential through EMCS control, but the technique used to model the energy use must be thoroughly understood.

OBTAINING BUILDING ENERGY CONSUMPTION DATA

Where metered utility data is not available, an alternative to computer simulation programs is to measure building energy consumption. In typical buildings there are two types of loads which occur. The first is "constant loads" which can easily be measured or calculated once, and which do not vary (except when turned off). The second is "time varying loads" which include equipment not used constantly. This section will address the treatment of each of these loads and the measurements of each.

Constant Loads: Constant Loads are those which are not time varying, other than when turned off. Examples in a typical building are lights, and constant speed motors such as exhaust fans and supply fans.

Lighting loads are in most cases easy to calculate. For example, a four tube fluorescent light fixture with standard 40 watt tubes will pull 200 watts of power including standard ballast. Similarly, a two tube fixture pulls approximately 100 watts. Other lamps are typically stamped with the wattage. To calculate these loads a simple count is required which details the number of fixtures of each type and wattage. A second alternative is to remove the cover from the lighting distribution panel and measure the amperage directly. The resulting load is obtained by standard calculations (to be presented later in this section.) Thus lighting loads are easily calculated or measured. Occasionally other loads will be added to the lighting circuit so it is necessary to verify that you are actually measuring the power consumption in question - panels are often mismarked as well.

Other constant loads are fan and pump motors. Many supply fans operate continuously, as do many pumps, shut down seasonally or daily during unoccupied hours. Each of these devices is required to have a separate disconnect or starter. To use the nameplate data of a fan or pump motor for calculation of EMCS potential is incorrect and will normally lead to an overestimate of savings potential. Since motors come in nominal sizes only, such as 3, 5, 7.5, 10 horsepower and so on, the engineer must always select the "next size" motor to meet a given load. For example, if a fan requires 8 brake horsepower, a 10 horsepower motor will be used, as the next lowest size, 7 1/2 horsepower would be inadequate. Because the motor is not at full load, the nameplate amperage is not the amount of power drawn. The nameplate data is used to determine the motors efficiency and power factor. To calculate the motors efficiency and power factor the following equation is utilized:

HP = (Voltage) x (Amps) x (Power Factor) x (Efficiency)/(746 watts/hp)

For three phase motors:

HP = (Voltage) x (Amps) x (Power Factor) x (Efficiency) x (1.73)/(746 watts/hp)

where HP = Horsepower

Voltage = the measured circuit voltage
Amps = the amperage reading or nameplate data (use the average of the three readings where they differ)
Power Factor = Motor rated power factor
Efficiency = rated motor efficiency
1.73 = square root of 3
746 = conversion constant

For example, a 10 hp motor has nameplate data which indicates 3 phase 208 volt power, at 27 amps per phase. Thus:

10 = (208 volts) x (27 amps) x (Power Factor) x (Efficiency) x (1.73)/(746 watts/hp)

Which gives

(Power Factor) x (Efficiency) = 0.77

An actual amperage reading on this motor gave a 21.0 amps reading for each leg, which gives

hp = (208 volt) x (21 amps) x (0.77) x (1.73)/ (746 watts/hp)

hp = 7.8

By removing the conversion constant from the denominator of the equation, the answer is the watts of power, in this case 5819, or 5.8 kilowatts. It should be noted here that using the nameplate data only, would have indicated a motor load of 7.5 kilowatts, which is 29 percent above the actual, thus all savings potential calculations would have been incorrect. Motor loads like fans and pumps will be constant unless they are part of a variable speed application, where they should then be treated as time varying loads.

In a similar fashion, any load in a building may be measured. While every load could be measured and documented, results will be used in EMCS calculations for only a limited number of devices. For example if EMCS control of lighting is being considered, then the lighting load must be determined. If the on-off control of a fan is proposed, then its power consumption must be determined. Your EMCS is likely not to control coffee pots and typewriters, so measuring these loads would be unnecessary. The general rule which applies here as well as in the case of time varying loads is if you have no plans to control the load, gathering data on that device will not help your EMCS evaluation. A listing of typical available equipment for measuring amperage is included in the appendix.

Time Varying Loads: There are many loads which vary with time of day and time of year. On a daily cycle, loads from office and manufacturing type equipment will fluctuate widely around use schedules. In general the EMCS will not control these loads. Air conditioning equipment such as compressors and chillers have widely varying daily loads, with a seasonal variation as well. Other electrical loads such as kitchens (where electric) have wide daily variations.

There are two choices in measuring time varying loads. The first is to monitor each on a short term basis. For example record loads for a 24 hour period. While this of course does not give the annual use, it does give a good indication of the impact on daily building electric usage and demand. Where loads vary with day of the week, a typical week day may be selected, and a typical weekend day. Assuming that a load operates consistently throughout the year, the measured values would be useful in determining yearly impact as well.

The second choice is to monitor time varying loads on a yearly or continuous basis. Consider a chilled water plant. The loads will definitely vary with time of day. Starting at midnight loads will be low (if the building is occupied) due to lower nighttime temperatures and decreased activity in most cases from daytime schedules. Loads normally increase between 7:30 and 9:00 due to warmer temperatures, solar gains on buildings, and increased use of the building by people and equipment. As the daily temperature and solar radiation increase during the day, the cooling system is normally under peak load from 3:00 to 5:00 P.M. The loads then drop into the evening hours. Several recording type devices are available which will either plot or compute power consumption on paper tapes. Due to the large amounts of data, reduction is often very time consuming. To make a valid determination of loads, the conditions of the load must also be known. How was the building used that day? How many people were present? Was all lighting and equipment in use? What were the outside temperatures? What type of cloud cover or haze was present? These are all valid questions, however, even if all the answers could be listed for each recording period, the data reduction would be near impossible. The data can be used to develop monthly total of kilowatt-hours and maximum electric demand for either a total building, or any branch circuit to groups of equipment, or even individual pieces of equipment. The data then should be interpreted in a manner similar to yearly utility billings. The maximum loading for the cooling season is usually the primary interest.

The discussion thusfar has been centered around electricity, but there are other sources of energy use as well. For heating of buildings hot water and steam are two common sources. The usage of the end product, i.e., hot water or steam, is not the measured quantity of interest, but rather how much fuel is required to produce this output. In almost all cases, natural gas is metered as it enters a site. If individual meters on buildings are not installed and long term data is required, the submetering at each building is the easiest solution. The reading of data is best accomplished manually, with reading frequency as desired. Flow meters are also available which have an output which can be sent to a strip chart recorder or EMCS, or various types of totalizing devices. If the fuel used is not measured or the boiler as a heating device serves several buildings, then steam flow to individual buildings or areas can be measured and recorded.

Five types of devices are normally used to measure steam flow. They are:

1) Orifice Plate
2) Venturi Tube
3) Pitot Tube, Averaging Pitot Tubes
4) Turbine Meter
5) Vortex Shedder

All of these meters are momentum type meters, that is, the meter makes use of the kinetic energy available in fluid.

The first three types (orifice plate, venturi tube, pitot tube) are so called "head" meters. They require a loss of head (pressure drop) to affect measurement. In general, "head" meters convert velocity head to a corresponding pressure head. This class of meters are inherently non-linear and have a limited flow range.

The other two types (turbine meter, vortex shedders) are sub-classed as velocity meters, that is, the meter monitors fluid velocity directly. Ideally this class of meters does not extract flow energy to operate. However, due to mechanical losses of the meter, some energy from the steam is required which may limit performance.

Orifice Plates are by far the most common type of primary element found in steam metering service. Orifice plates are simply a restriction, which when placed in line creates a difference in pressure, which is sensed by a secondary element (differential pressure cell). From this the flow rate is determined inferentially. The main advantage of orifice plates is their low cost and ability to accommodate a wide range of flows. However, this type of meter has a low turndown of only 4:1, and accuracies of +- 1.5% of full scale which must be considered as restrictive performance parameters. A significant head loss, hence energy loss, is also a drawback.

Venturi tube meters create a pressure drop by virtue of their construction (geometrically configured pipe reduction, then expansion within a tube). The venturi meters chief attributes are a small head loss, high velocity measurement capabilities, ability to handle upset conditions (slug, annular flow) without detriment to the meter. Again being a head type meter they have inherently low turndown (5:1), and resulting accuracy of +- 1.5% full scale.

Averaging Pitot Tube - The front "holes" of the average pitot tube sense the average impact pressure of the fluid and the rear "hole" senses the low pressure (see Figure 13). The differential pressure cell located in the head of the meter transmits the differential pressure signal. This unique construction improves the accuracy (+- 1% of full scale) of the head meter, however, turndown is still limited (3.5:1). In saturated steam the lower "hole" tends to plug with condensate rendering meaningless readings. In low pressure gas application, the differential pressure becomes very low. The resultant low signal obtained requires extraordinary sensitivity of the associated electronics.

Turbine Meters make use of the kinetic energy available in the flow stream to turn a turbine rotor. As the device rotates a signal is created through the use of a magnetic

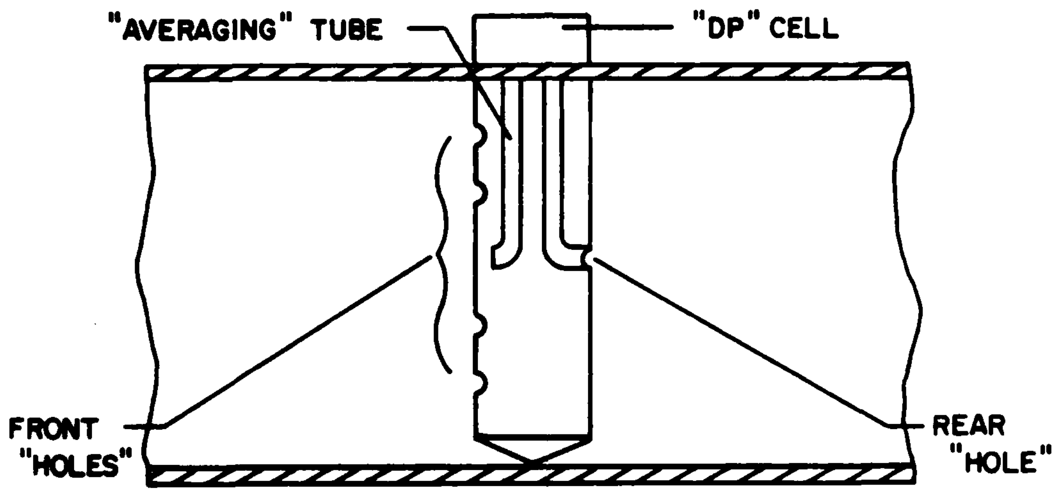


Figure 13

pickup device. The speed of the rotor, therefor, is directly proportional to the flow rate. The hallmarks of the turbine meter are the wide turndown (10:1 minimum, up to 40:1), excellent accuracy (+- 1% of reading) and repeatability (+- .25%). The major limitation on the turbine meter is the rotor bearing life.

Vortex Shedder Meters detect vortices which are created by an obstruction in the flow stream. The vortex formation is proportional to the rate of flow. These vortices are detected by an extremely sensitive strain gage imbeded in the obstruction, magnetic pickup, or ultra-sonic detector. These types of meters offer excellent turndown (15:1) and accuracies (+- 1%). Major drawbacks are the low levels of detection (typically millivolts) upon which this meter operates making it extremely sensitive to noise (pipe vibration, excess electrical noise). The meter is also Reynolds Number limited and cavitation limited. Flow irregularities, such as swirl, due to piping configuration are difficult if not impossible to measure with this device. All devices must be installed correctly, and require either long straight runs of pipe before and after the devices for accurate readings. Devices installed improperly provide totally meaningless data. A summary of performance, mechanical characteristics, and relative cost for the devices discussed is included in Table 4.

Conclusions: Several types of metering are available. The rule of application is don't measure or monitor data that will not be used. Stacks of data are of little value if they are not completely utilized. When using data, be sure that the conditions in the building when the data was

	ORIFICE	VENTURI	ANNUBAR	TURBINE	VORTEX
Performance					
Accuracy	1.5% f.s.*	1.5% f.s.*	1% f.s. +	1% reading +	1.5% reading *
Turndown	4:1 *	5:1 *	3.5:1 +	10:1 minimum +	15:1 *
Linearity	NL	NL	NL	Excellent	Satisfactory
Mechanical Characteristics					
Insertion compatible	NO	NO	YES	YES	YES
Pressure drop	Poor	Good	Satisfactory	Excellent	Satisfactory
Failure mode	Soft	Soft	Soft	Hard	Soft/Hard
Cost					
Initial	Medium	Medium	Medium	Medium	High
Installation	High	Medium	Low	Low	High
Maintenance	Low	Low	Low	Low	Low

* Chemical Engineering, Dec. 18, 1978

\+ Manufacturers Specifications

f.s. - full scale

NL - Non-linear

Table 4

Flow Measurement Devices

gathered are clearly understood. Measured data described in this section, like utility billing data, will seldom if ever be repeatable. This is due to both weather and utilization of the buildings. Finally, long term metering in the name of gathering "base case" data can be self defeating. A full year of data is the minimum in this case, requiring substantial amounts of equipment and manpower. In the year required to obtain data, and the follow-on time for data reduction, a two year payback EMCS could have been justified, designed, installed, and made operational. Measure, record, and reduce long term data only when absolutely necessary.

CHAPTER 3

SELECTING SINGLE BUILDING ENERGY CONTROLLERS

This chapter will address the six basic types of energy controllers for single buildings. The six types are:

1) Time Clocks
2) Microprocessor Based Thermostats
3) Demand Limiters and Duty Cyclers
4) Programmable Controllers
5) Micro EMCS
6) Small EMCS

Each type of controller performs specific functions related to energy management or conservation. The capabilities vary widely, increasing from basic on-off control with time clocks to very sophisticated control with the small EMCS. There are several basic applications for energy management which are described as follows.

Scheduled start/stop.

The scheduled start/stop program consists of starting and stopping equipment based on the time of day and day of week. Scheduled start/stop is the simplest of all EMS functions to implement. This program provides potential for energy conservation by turning off equipment or systems during unoccupied hours. In addition to sending a start/stop command, it is important, although not mandatory, to have a feedback signal indicating the status (on-off or open-closed) of the controlled equipment. The feedback signal verifies that the command has been carried out and provides the EMS operator with an alarm when the equipment fails or is locally started or stopped.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Day of week.
- (b) Time of day.
- (c) Equipment schedules.
- (d) Equipment status.
- (e) Equipment constraints.

(2) Program outputs.

- (a) Start signal.
- (b) Stop signal.

Application notes. The scheduled start/stop program operates in conjunction with optimum start/stop, day/night setback, ventilation/recirculation, and lighting control programs.

Optimum start/stop.

The scheduled start/stop program described can be refined by automatically adjusting the equipment operating schedule in accordance with space temperature and outside air (OA) temperature and humidity. HVAC systems are normally restarted prior to occupancy to cool down or heat up the space on a fixed schedule independent of OA and space conditions. The optimum start/stop program automatically starts and stops the system on a sliding schedule. The program will automatically evaluate the thermal inertia of the structure, the capacity of the HVAC system to either increase or reduce space temperatures, and OA conditions. This accurately determines the minimum time of HVAC system operation needed to satisfy the space environmental requirements at the start of the occupied cycle, and determines the earliest time for stopping equipment at the day's end.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Day of week.

(b) Time of day.
(c) Equipment schedules.
(d) Equipment status.
(e) Building occupancy schedule.
(f) Space temperature(s).
(g) Building thermal inertial profile.
(h) HVAC system capacity.
(i) OA temperature.
(j) OA relative humidity.
(k) Required space temperature at occupancy.
(l) Predictor/corrector program.
(m) Equipment constraints.

(2) Program outputs
(a) Start time.
(b) Stop time.

Application notes. The optimum start/stop program operates in conjunction with the scheduled start/stop program, day/night setback, and ventilation/recirculation programs.

Duty cycling.

Duty cycling is defined as the shutting down of equipment for predetermined short periods of time during normal operating hours. This function is normally only applicable to HVAC systems. Duty cycling operation is based on the presumption that HVAC systems seldom operate at peak design conditions. If the system is shut off for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during the shutdown period. Although the interruption does not reduce the energy required for space heating or cooling, it does reduce energy input to auxiliary loads such as fans and pumps. Duty cycling also reduces outside air heating and cooling loads since the outside air intake damper is closed (under local loop control) while an air handling unit is off.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Day of Week.
- (b) Time of day.
- (c) Equipment schedules.
- (d) Equipment status.
- (e) Space temperature.
- (f) Maximum temperature during occupied periods.
- (g) Equipment maximum on time.
- (h) Equipment maximum off time.
- (i) Equipment on-off cycle interval.
- (j) Equipment priority level.
- (k) Control from higher priority demand limiting program.
- (l) Equipment constraints.

(2) Program outputs.

- (a) Start signal.

(b) Stop signal.

Application notes. (1) The duty cycling program is used in conjunction with demand limiting, schedule start/stop, and optimum start/stop programs. (2) Duty cycling is not advisable for variable capacity loads such as variable volume fans, chillers, or variable capacity pumps.

Demand Limiting.

Demand Limiting consists of shedding electrical loads to prevent exceeding an electrical demand peak value (target). This prevents an increase in electrical rates where demand oriented rate schedules apply. Peak demand contract values are established by the utility company using fixed demand intervals, sliding window intervals, and time of day schedules. Many complex schemes exist for reducing peak demand billings; however, all schemes continuously monitor power demand and calculate the rate of change of the demand value in order to predict future peak demand. When the predicted peak exceeds present limits, predetermined scheduled electrical loads are shut off on a prescheduled priority basis to reduce the connected load before the peak is exceeded.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Day of week.
(b) Time of day.
(c) Equipment schedules.
(d) Equipment status.
(e) Peak demand limit target.
(f) Equipment priority schedule.
(g) Length of demand period.
(h) Predictor-corrector program.
(i) Start of demand interval.
(j) Equipment constraints.

(2) Program outputs.

(a) Load shedding strategy category selection.
(b) Preemptory signal to duty cycling program.

Application notes. (1) The demand limiting program is used in conjunction with the duty cycling program to prevent any one load from being cycled on or off during the wrong time interval or an excessive number of times. (2) The demand limiting program is also used in conjunction with scheduled start/stop and optimum start/stop programs.

Day/night setback.

The energy required for heating or cooling during unoccupied hours can be reduced by lowering the heating space temperature setpoint or raising the cooling space temperature setpoint. This applies only to facilities that do not operate 24 hours a day. Space temperature can be reduced from the normal 65 F winter inside design temperature to a 50 F or 55 F space temperature during the unoccupied hours. In space that require air conditioning during unoccupied hours, the normal temperature setting can be reset upwards to a temperature that is compatible with the space special requirements. OA dampers for the HVAC system are closed when the equipment operates during the unoccupied periods in order to avoid imposing additional OA thermal loads.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Day of week.
(b) Time of day.
(c) Equipment schedules.
(d) Equipment status.
(e) Minimum and maximum space temperature during unoccupied periods.
(f) Equipment constraints.

(2) Program outputs.

(a) Day/night control signal.
(b) Close OA dampers control signal.

Application notes. (1) The day/night setback program operates in conjunction with the scheduled start/stop and optimum start/stop programs. (2) Space temperature sensors must be located to preclude freezing during the night setback period.

Economizer.

The utilization of an all outside air dry bulb economizer cycle in air conditioning systems can be a cost effective conservation measure, depending on climatic conditions and the type of mechanical systems. The dry bulb economizer cycle utilizes outside air to reduce the building's cooling requirements when the outside air dry bulb temperature is less than the required mixed air temperature. The changeover temperature at which outside air is used for cooling is based on the outside air dry bulb temperature (enthalpy changeover point is determined by the total air heat content.) When the outside air dry bulb temperature is above the changeover temperature, the outside air dampers, return air dampers, and relief air dampers are positioned to provide minimum required outside air. When the outside air dry bulb temperature is below the changeover temperature, the outside air, return air and exhaust air dampers are positioned to maintain the required mixed air temperature.

Software I/O requirement. The software requirements are:

(1) Program inputs.

(a) Changeover dry bulb temperature.
(b) OA dry bulb temperature.
(c) Return air dry bulb temperature.
(d) OA intake damper position.
(e) Equipment constraints.

(2) Program outputs. Automatic/minimum outside air damper control signal.

Application notes. This program cannot be used where humidity control is required, or when the enthalpy program is selected.

Enthalpy.

The utilization of an outside air enthalpy program can be a cost effective energy conservation measure, depending on climatic conditions and the type of mechanical system. The enthalpy cycle utilizes outside air to meet the building's cooling requirements when the enthalpy (total heat content) of the outside air is less than that of the return air. When the outside air enthalpy is less than the return air enthalpy, the outside air and return air dampers are allowed to modulate to admit sufficient outside air to minimize cooling requirements. When the outside air enthalpy is greater than the return air enthalpy the outside air dampers, return air dampers, and relief air dampers are positioned to provide minimum required outside air.

Software I/O requirements. The software requirements consist of the following:

(1) Program inputs.

- (a) Return air dry bulb temperature.
- (b) Return air relative humidity.
- (c) Outside air dry bulb temperature.
- (d) Outside air relative humidity.
- (e) Equipment constraints.

(2) Program outputs. Automatic/minimum outside air damper control signal.

Application notes. The enthalpy program cannot be used when the economizer program is selected.

Ventilation and recirculation.

The ventilation and recirculation program controls the operation of the outside air dampers when the introduction of outside air would impose an additional thermal load during warm-up or cool-down cycles prior to occupancy of the building. This program can also be used in those facilities which maintain environmental conditions for electronic equipment or other humidity sensitive devices during building unoccupied periods. During unoccupied periods, the outside air dampers remain closed. During building occupied cycles, the outside air, return and relief dampers are under local loop control.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Day of week.
- (b) Time of day.
- (c) Equipment schedules.
- (d) Equipment status.
- (e) Occupancy schedules.
- (f) Outside air dry bulb temperature.
- (g) Equipment constraints.

(2) Program output. Automatic/close damper control signal.

Application notes. This program operates in conjunction with scheduled start/stop and optimum start/stop programs prior to building occupancy.

Hot deck/cold deck temperature reset.

The hot deck/cold deck temperature reset program can be applied to dual duct systems and multizone HVAC systems. These systems utilize a parallel arrangement of heating and cooling surfaces, commonly referred to as hot and cold decks, for providing heating and cooling capabilities simultaneously. The hot and cold air streams are combined in mixing boxes or plenums to satisfy the individual space temperature requirements. In the absence of optimization controls, these systems mix the two air streams to produce the desired temperature. While the space temperature may be acceptable, a greater difference between the temperature of the hot and cold decks results in inefficient system operation. This program selects the areas with the greater heating and cooling requirements, and establishes the minimum hot and cold deck temperature differentials which will meet the requirements, thus maximizing system efficiency. Space temperature sensors and mixing box or plenum damper positions are used to determine the minimum and maximum deck temperatures necessary to satsify the space temperature requirements during the building occupied period. Where humidity control is required, the program will prevent the cooling coil from further upward cooling coil control.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Space temperature set point.
(b) Space humidity set point (where required).
(c) Mixing box damper position or proportional signal from primary element.
(d) Hot deck temperature.
(e) Cold deck temperature.

(f) Space temperature.
(g) Space relative humidity.
(h) Equipment constraints.

(2) Program outputs.

(a) Hot deck temperature.
(b) Cold deck temperature.

Application notes. This program operates in conjunction with the chilled water reset program.

Reheat coil reset.

Terminal reheat systems operate with a constant cold deck discharge temperature. Air supplied at temperatures below the individual space temperature requirements is elevated in temperature by reheat coils in response to signals from an individual space thermostat. The reheat coil reset program selects the reheat coil with the lowest discharge temperature or the reheat coil valve nearest closed (the zone with the least amount of reheat required) and resets the cold deck discharge temperature upward until it equals the discharge temperature of the reheat coil with the lowest demand. Where humidity control is required, the program will prevent the cooling coil discharge temperature from being set upward. For air conditioning systems, where reheat coils are not used, the program will reset the cold deck discharge temperature upward until the space with the greatest cooling requirement is just satisfied.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Space temperature set point.
(b) Space relative humidity.
(c) Cold deck temperature.
(d) Reheat coil valve positions or proportional signals from primary elements.
(e) Equipment constraints.

(2) Program output. Cold deck temperature.

Application notes. This program operates in conjunction with the chilled water reset program.

Steam boiler optimization.

The steam boiler optimization program can be implemented in heating plants with multiple boilers. Optimization of boiler plants can be accomplished through the selection of the most efficient boiler to satisfy the heating load. Boiler operating data must be obtained from the manufacturer, or developed by monitoring fuel input as a function of the steam output. Determination of boiler efficiency also takes into account the heat content of the condensate return and make-up water. Based on the efficiency curves, fuel input vs. steam output, the boilers with the highest efficiency can be selected to satisfy the heating load. Boilers may be started manually by a boiler operator or automatically by EMCS depending on site requirements. Burner operating efficiency can be monitored by measuring the O_2 or CO_2 in each boiler flue.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Heating value of fuel.
- (b) Boiler steam supply pressures.
- (c) Boiler steam temperatures.
- (d) Boiler steam flows.
- (e) Boiler fuel flows.
- (f) Boiler temperatures.
- (g) Boiler feedwater flows.
- (h) Boiler feedwater temperatures.
- (i) Boiler water levels.
- (j) Oil temperatures (if heated).
- (k) Flame status.
- (l) Flue gas analysers.
- (m) Common steam supply pressure.
- (n) Common steam supply temperature.
- (o) OA temperature.
- (p) Common condensate return total flow.
- (q) Common condensate return temperature.

(r) Equipment constraints.

(2) Program outputs.

(a) Start signals.
(b) Stop signals.
(c) Boiler efficiency data.

Application notes. The hardware and software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of boiler in lieu of operator supervised startups.

Hot water boiler optimization.

Hot water boiler optimization can be implemented in heating plants with multiple boilers. The techniques and considerations are the same as discussed in the previous section on steam boiler optimization.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Heating value of fuel.
(b) Boiler hot water supply temperatures.
(c) Boiler hot water return temperatures.

- (d) Boiler hot water flows.
- (e) Boiler fuel flows.
- (f) Boiler pressures.
- (g) Boiler water levels.
- (h) Boiler oil temperatures (if heated).
- (i) Flame status.
- (j) Flue gas analysis.
- (k) Equipment constraints.

(2) Program outputs.

- (a) Start signals.
- (b) Stop signals.
- (c) Boiler efficiency data.

Application notes. The hardware and software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of boiler in lieu of operator supervised startups.

Hot water OA reset.

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are generally designed to supply hot water at a fixed temperature. Depending on the system design, the hot water supply temperature can be reduced, as the heating requirements for the facility decrease. A reduction in hot water supply temperature results in reduction of heat loss from equipment and piping. To implement this program, the temperature controller for the hot water supply is reset as a function of outside air temperature.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Reset schedule.
- (b) Outside air dry bulb temperature.
- (c) Hot Water supply temperature.
- (d) Equipment constraints.

(2) Program outputs. Hot water temperature.

Application notes. A dedicated local loop controller may be implemented.

Chiller optimization.

The chiller optimization program can be implemented in chilled water plants with multiple chillers. Based on chiller operating data and the energy input requirements obtained from the manufacturer for each chiller, the program will select the chiller or chillers required to meet the load with the minimum energy consumption. The program must follow the manufacturer's startup and shutdown sequence requirements. Interlocks between chilled water pumps, condenser water pumps, and chiller must be in accordance with the chiller manufacturer requirements.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) Efficiency curves.
(b) Chiller water supply temperatures.
(c) Chiller water return temperatures.
(d) Chiller water flows (for variable flow systems only).
(e) Entering condenser water temperatures.
(f) Leaving condenser water temperatures.
(g) Condenser water flows (for variable flow system only).
(h) Instantaneous kW to chillers.
(i) Instantaneous kW to chilled water pumps (if variable).
(j) Instantaneous kW to condenser water pumps (if variable).
(k) Instantaneous kW to cooling tower fans (if variable).
(l) Common chilled water supply temperatures.
(m) Common chilled water return temperatures.
(n) Total chilled water flow.
(o) Chilled water pumps status.
(p) Equipment constraints.

(2) Program outputs.

(a) Start/stop signals for chillers.
(b) Start/stop signals for chilled water pumps.
(c) Start/stop signals for condenser water pumps.
(d) Start/stop signals for cooling tower fans.
(e) Chiller efficiency data.

Application notes. The hardware and software inputs described may not be required in every case. The designer must study the existing or new system to determine which of the parameters are necessary. Care must be observed when providing automatic start/stop of boiler in lieu of operator supervised startups.

Chiller water temperature reset.

The energy required to produce chilled water in a reciprocating or centrifugal refrigeration machine is a function of the chilled water leaving temperature. The refrigerant suction temperature is also a direct function of the leaving water temperature; the higher the suction temperature, the lower the energy input per ton of refrigeration. Chiller discharge water temperatures (leaving chiller) can be reset upward during non-peak design operating hours to the maximum which will still satisfy space cooling and dehumidification requirements. The program resets chilled water temperature upward until the required space temperature or humidity setpoints can no longer be maintained. This determination is made by monitoring positions of the chilled water values on various cooling systems or by monitoring space temperatures.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Chilled water valve position.
- (b) High limit for space dry bulb temperature.
- (c) Chiller supply water temperature.
- (d) Chilled water temperature limits.
- (e) High limit for space relative humidity.
- (f) Equipment constraints.

(2) Program outputs. Chilled water supply temperature.

Application notes. The chilled water temperature reset program will affect any system requiring chilled water.

Condenser water temperature reset.

The energy required to operate systems is directly related to the temperature of the condenser water temperature entering the machine. Conventionally, heat rejection systems are designed to produce a specified condenser water temperature such as 85 F at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain a specified temperature at conditions other than peak wet bulb temperatures. In order to optimize the performance of refrigeration systems, condenser water temperature can be reset downward when OA wet bulb temperature will produce lower condenser water temperature. The program must incorporate manufacturer requirements governing acceptable condenser water temperature range.

Software I/O requirements. The software requirements are:

(1) Program inputs.

- (a) Condenser water temperature limits.
- (b) Condenser water supply temperature.
- (c) Outside air dry bulb temperature.
- (d) Outside air relative humidity.
- (e) Equipment constraints.

(2) Program output. Condenser water supply temperature.

Application notes. A dedicated local loop controller may be implemented.

Chiller demand limit.

Centrifugal water chillers are normally factory equipped with an adjustable control system which limits the maximum available cooling capacity; thus, the power the machine can use. An interface between the EMCS and the chiller controls allows the EMCS to reduce the maximum available cooling capacity in several fixed steps in a demand limiting situation, thereby reducing the electric demand without completely shutting down the chiller. The method of accomplishing this function varies with the manufacturer of the chiller. The chiller percent capacity can be obtained by monitoring the chiller current input. When a chiller is selected for demand limiting, a single step signal is transmitted, reducing the chiller limit adjustment by a fixed amount. The chiller demand limit adjustment can be performed by shutting out taps of transformers in the control circuit or by resetting the control air pressure to the chiller compressor vane operator. As further need arises, additional stop signals can be transmitted until the demand limiting situation is corrected. Extreme caution must be exercised when applying this program, since incorrect control can cause the refrigeration machine to operate in a surge condition, potentially causing it considerable damage. The chiller manufacturer's recommended minimum cooling capacity limit must be incorporated into the program logic. In general, surges occur in chillers at loads less than 20% of the rated capacity.

Software I/O requirements. The software requirements consist of the following:

(1) Program input.

(a) Chiller percent capacity.
(b) Minimum cooling capacity.
(c) Equipment priority schedules.
(d) Equipment constraints.

(2) Program output. Calculated percent load point.

Application notes. This program is used in conjunction with the demand limiting program and each chiller demand control step must be assigned an equipment priority level.

Lighting control.

Time scheduled operation of lighting consists of turning on and off lights, based on the time of day and the day of the week. Additional off commands may be generated at regular intervals to assure that lights are off (relay operated zoned lighting only). An alternative to this program is to initiate only the off function and require that the lights be turned on manually. Emergency lighting is not to be controlled by this program.

Software I/O requirements. The software requirements are:

(1) Program inputs.

(a) On signal.
(b) Off signal.

Application notes. The lighting control program is used in conjunction with the scheduled start/stop program.

To summarize, the basic application programs for energy management are:

A. Scheduled Start/Stop
B. Optimum Start/Stop
C. Duty Cycling
D. Demand Limiting
E. Day/Night Setback
F. Economizer
G. Enthalpy
H. Ventilation and Recirculation
I. Hot Deck/Cold Deck Temperature Reset
J. Reheat Coil Reset
K. Steam Boiler Optimization
L. Hot Water Boiler Optimization
M. Hot Water Outside Air Reset
N. Chiller Optimization
O. Chilled Water Temperature Reset
P. Condenser Water Reset
Q. Chiller Demand Limit
R. Lighting Control

Each of these applications will be considered for the six categories of controllers. The capacity of the controller type to perform these strategies will be presented. Where the controller cannot perform the function, alternatives will be presented.

Time Clocks and Microprocessor Based Thermostats

Time clocks and microprocessor based thermostats are either mechanical/electrical or electronic devices which provide opening or closing of electric contacts. Mechanical/electrical clocks are typically available in seven day or 24 hour models. Spring carryover and battery backup features are available to continue time clock functioning on power failure. Time clocks are typically available with either a single pole double throw switch or four snap acting single pole single throw switches, with two of these normally open, and two normally closed. The contacts are rated for pilot duty only, and must be interfaced to relays for switching of high amperage loads (typically over 1 horsepower).

Scheduled Start/Stop: Time clocks are designed specifically for this function. Switching times are manually set through the placement of pins on a timing wheel. On 24 hour time clocks, the normal minimum on and off times are 1 hour, the maximum 23 hours, with a maximum of 12 on-off operations per day. Seven day time clocks have a 2 hour minimum on and off time, and a 22 hour maximum with a maximum of 6 on-off operations per day and 42 per week for single pole double throw models. Seven day time clocks have a 3.5 hour minimum on and off time, and a 166 hour maximum with a maximum of 3 on and off operations per day and 21 per week on single pole single throw models. A typical interface to a connected load is shown in Figure 18, Chapter 4.

Optimum Start/Stop: Time clocks have a disadvantage in that start/stop times are normally set to meet the worst possible condition, i.e. the earliest necessary start up time. Digital time clocks such as the Johnson Controls C-7505 are available which optimize start-up time during heating based on indoor and outside temperature, and optimize start-up of cooling based on indoor temperature only. These devices do not meet all the requirements described in the Optimum Start/Stop narrative, but offer substantial improvements over standard time clock control.

Duty Cycling: Time clocks do not provide for duty cycling due to the long minimum off-on times.

Demand Limiting: Time clocks can limit demand on only a very simple basis. If a building routinely experiences an electric demand peak at a given time each day, the clock function could be used to turn off a completely non-essential load, with control of space temperature over a wider range using the techniques outlined in "Day/Night Setback" which follows. See Figure 19, Chapter 14 for details. The time clock is not normally used as a demand limiting device.

Day/Night Setback: A time clock used in conjunction with a two position electric room thermostat can provide effective night setback control. Either a two position thermostat with a heating (setback) setpoint can be used, or a dual setpoint two position thermostat which can be wired to close when a high setpoint (setup) or low setpoint (setback) value is reached during system shutdown. Pneumatic or electric/electronic temperature controls are normally sequenced so that all heating and cooling devices and controls are disabled when the supply fan of a system is stopped. When the timeclock shuts down a fan as shown in Figure 18, the total heating, ventilating and air conditioning system becomes inactive. When a single setpoint night thermostat or a dual setpoint thermostat is included in the controls, the entire system is reactivated until night setback/setup points are achieved (see Chapter 4, Figures 19 and 20 for installation details). Night setback control is thus a feasible option with time clock control. Outside air dampers are normally closed during night setback through a second time clock.

Economizer: Standard dry bulb economizer control is independent of the time clock function. Economizer control can be accomplished with an EMCS. Economizer control is also a continue control strategy normally included in pnuematic or electric/electronic control sequences.

Enthalpy: Enthalpy control is a refinement of economizer control. The changeover temperature is replaced with either a changeover enthalpy value or by comparing the enthalpy of the return air to the enthalpy of the outside air. This is a viable EMCS function, which can also be accomplished with standard controls. For changeover at a fixed enthalpy setpoint, the Barber Colman THC-2, Honeywell H205A, or similar devices can be used for electric switching without EMCS. Enthalpy control systems are only justified in special applications dependant on loads and weather parameters, and an optimized dry bulb changeover can often yield similar results.

Ventilation and Recirculation: This function controls the opening and closing of outside air dampers during unoccupied periods. This open-closed action is similar to a start-stop with a electric pneumatic switch in the pneumatic output line to exhaust, return, and outside air dampers. This is shown in detail in Chapter 4 discussions of the Mixed Air Section. The outside air dampers are normally controlled on a different schedule from the air handling unit. For example, if the time clock or optimum start timer brings on the unit at 6:30 A.M. and occupancy does not occur until 8:00 A.M., the outside air dampers can remain closed. Figure 9 indicated that start times for ventilation can normally be delayed beyond occupancy times. When the condition exists where cooling is required for cooldown prior to occupancy, and the outside air temperature is lower than the space temperature, outside air can be introduced with an override to the damper time clock lock-out through the use of a normally open pneumatic-electric switch and two position outside thermostat wired in series with the time clock signal. Ventilation and recirculation can thus be accomplished with a time clock input.

Hot Deck/Cold Deck Temperature Reset: This option is not a time clock function, but can easily be accomplished through standard pneumatic or electric/electronic controls.

Reheat Coil Reset: This option is not a time clock function, but can also be accomplished with standard pneumatic or electric/electronic controls. Both Hot Deck/Cold Deck temperature reset and reheat coil reset are typical EMCS functions.

Steam Boiler Optimization: This is not a time clock function.

Hot Water Boiler Optimization: This is not a time clock function.

Hot Water Outside Air Reset: This function is normally performed with either EMCS or local pneumatic or electric/electronic controls. Situations arise where constant hot water temperatures are required during certain hours due to process or other loads, and during unoccupied periods, the water temperature can be reset. In this case a time clock can be used in lieu of EMCS to switch from constant hot water temperature to reset control.

AD-A134 006 SELECTION AND IMPLEMENTATION OF SINGLE BUILDING EMCS (ENERGY MONITORING AND CONTROL SYSTEMS)(U) STAN AND ASSOCIATES INC DAYTON OH R STAN AUG 83 NCEL-CR-83.037 2/3

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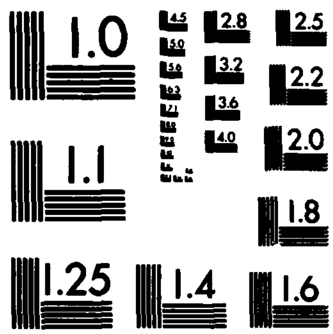


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Chiller Optimization: This is not a time clock function.

Chilled Water Temperature Reset: This function, like hot water outside air reset, is either performed with EMCS or standard pneumatic or electric/electronic controls. EMCS strategies normally reset based on space temperatures and relative humidities. Reset from outside air temperature, outside air solar, return air, and/or key zones can be equally effective if properly engineered. Situations again arise where constant chilled water temperatures are required for process cooling. Where the hours of this requirement vary, a time clock can be used to switch the standard reset controls into and out of the chilled water control system.

Condenser Water Temperature reset: This is not normally a time clock function. Condenser water loops to chillers are often controlled at fixed temperatures, such as 85 degrees to the chiller condenser from the cooling towers. This temperature can normally be reduced to 55 to 60 degrees (consult manufacturer for equipment constraints) in two ways. The EMCS can reset the set point of the controller as cooler tower water becomes available, or the controller setpoint can be manually changed to a lower setting. Start-up problems may be encountered which require raising the condenser loop temperature on start-up of chillers.

Chiller Demand Limit: This is not a time clock function.

position outside thermostat wired in series with the time clock signal. Ventilation and recirculation can thus be accomplished with a time clock input.

Hot Deck/Cold Deck Temperature Reset: This option is not a time clock function, but can easily be accomplished through standard pneumatic or electric/electronic controls.

Reheat Coil Reset: This option is not a time clock function, but can also be accomplished with standard pneumatic or electric/electronic controls. Both Hot Deck/Cold Deck temperature reset and reheat coil reset are typical EMCS functions.

Steam Boiler Optimization: This is not a time clock function.

Hot Water Boiler Optimization: This is not a time clock function.

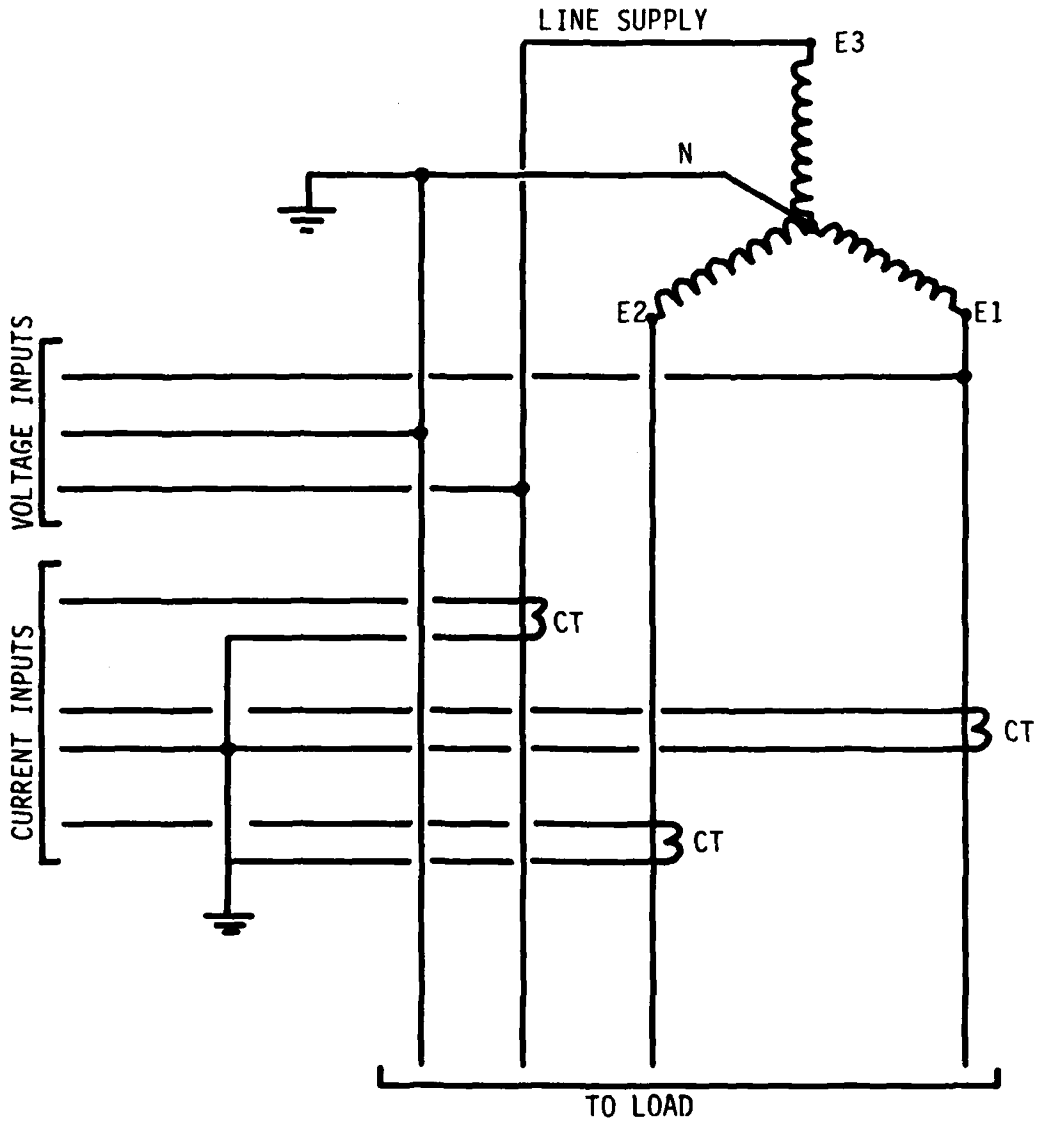
Hot Water Outside Air Reset: This function is normally performed with either EMCS or local pneumatic or electric/electronic controls. Situations arise where constant hot water temperatures are required during certain hours due to process or other loads, and during unoccupied periods, the water temperature can be reset. In this case a time clock can be used in lieu of EMCS to switch from constant hot water temperature to reset control.

Lighting Control: This is either a time clock control or EMCS option. Controlling at individual switches would require extensive wiring. Where determined to be a viable option, lighting and control should be executed at the power distribution panel for lighting (Caution! examine circuits to assure night lighting or emergency lighting circuits are not locked out).

Time clocks can thus directly control 5 of the 18 total EMCS application programs. Standard controls could also be used to implement an additional seven EMCS applications programs. It should be fully realized however that there are limitations involved. For example, to change start/stop times with time clocks will require manual setting at the device; with EMCS schedule changes are made from the master control room. There is no feedback that start or stop actually occurred when time clocks are used (until the complaints start to flow in from the occupants!) The optimum start/stop strategies available are greatly simplified functions. While a great improvement over fixed start/stop, there will not refine start/stop times as with EMCS application software. Day/Night setback can be accomplished, but again changes in settings require manual resetting or calibration of controllers. There is no feedback at a master control room to identify malfunctions such as temperatures out of limit or failure of the clock. Economizer and Enthalpy economizer controls are effective, but require field calibration at least twice each year. Minimum positioners on economizers are often out of calibration causing wasted energy. Hot deck/cold deck reset, reheat coil reset, chilled water reset, and condenser water reset are all common functions of standard controls, but calibration is very difficult. Should the changing of reset schedules be desired,the entire controller must be recalibrated. The EMCS offers significant advantages in the ability to control with feedback, and can be used effectively to revise reset schedules, set points, and general system operation at will without extensive field recalibration. Detailed information on costs and capabilities of commercially available equipment in this category can be found in CR 82.028 "Controlling Energy Consumption in Single Buildings".

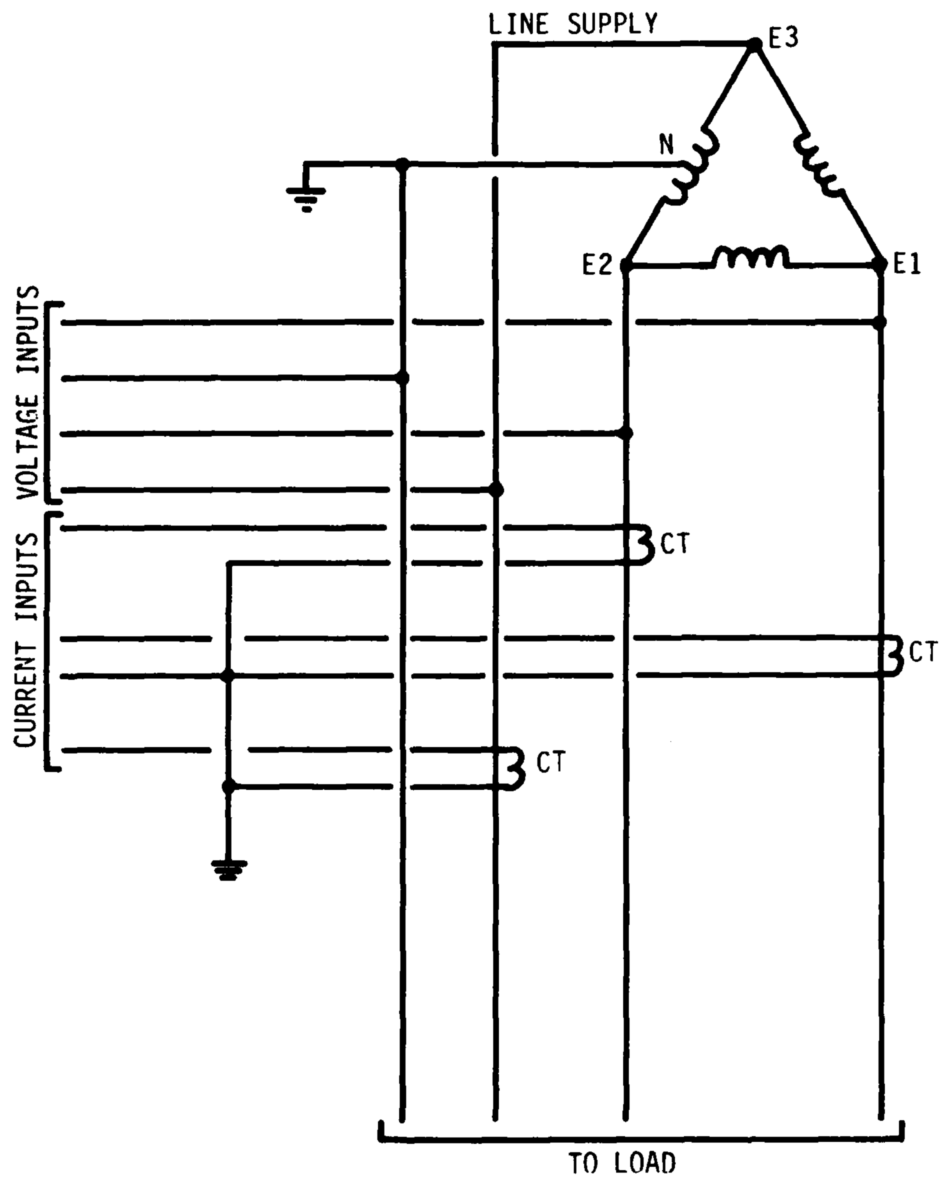
Demand Limiters and Duty Cyclers

The equipment in this category has the primary function of reducing peak electrical demand through duty cycling and/or demand limiting. Kilowatt hour consumption for a building is controlled by turning off loads on a rotating basis. While these controllers are intended to reduce electric demand, a resulting reduction in kilowatt hours usually occurs. The controllers use an input signal from a watt transducer which measures true kilowatt power consumption by combining voltage input and current input signals. Monitoring is done in various configurations for wye or delta three phase power. An example of wye monitoring is shown in Figure 14, with delta monitoring shown in Figure 15. The outputs from the voltage and current transformer



TRANSFORMER WIRING, WYE CONFIGURATION

FIGURE 14



TRANSFORMER WIRING, DELTA CONFIGURATION

FIGURE 15

taps either enter the demand limiter directly or through an intermediate transducer. One current transformer normally monitors each phase. The power measured is the instantaneous demand. Loads are shed when demand exceeds a setpoint. Loads are then recovered when the demand drops below a predetermined dead band.

There are two different sequences for load shedding. A fixed sequence numbers connected loads in sequence, for example one through four. Number one is always the first to be shed when demand exceeds setpoint, two second, three third, and four fourth. The recovery sequence is the reverse, with load number one being turned on last. This has certain disadvantages of course. Load one can be off for long periods during peak demand. If this load is totally non-essential, no problems are created.

The second strategy is to rotate loads where load one is the first to go off,and the first to recover, and loads are cycled off in sequence on a rotating basis. The deadband is used to prevent the rapid cycling of loads on and off. Many controllers allow multiple setpoints based on time of day. Temperature overrides may be wired into the circuits as done during night setback with timeclocks.

In single buildings there often arises the problems of finding loads which can be duty cycled. A building for example may have a single air handling unit and a single chiller. This offers no diversity of loads, and to duty cycle would either turn off the chiller or the air handler (obviously if the air handler is off, the chiller isn't needed, and if the chiller is off, the cooling coil loses performance and the air handler becomes ineffective.) Thus a qualification for using duty cycling or demand limiting is a number of loads which can be cycled on and off.

Air handling units are often duty cycled. Take an example of six identical units pulling 10 kilowatts each. A typical duty cycle schedule would cycle each unit off for ten minutes out of each hour. In this way, the peak demand of the six operating together is reduced from 60 kilowatts to 50 kilowatts (because one of the six units is off at all times). The usage for the hour is reduced from 60 kilowatt-hours to 50 kilowatt-hours. The premise of duty cycling equipment is that systems or units are oversized. In the case of these air handlers the oversizing assumed is one sixth, since they are being turned off 10 minutes out of 60.

The alternative in this case is to reduce the air flow rate of each unit to match the loads (as discussed in Chapter 2). If the air flow is decreased one sixth, the fan speed is reduced by one sixth also,and the motor electric draw is reduced to approximately 5.8 kilowatts. The air handlers can no longer be duty cycled since they operate at full capacity. The new peak demand is 6 times 5.8, or 34.8 kilowatts, and the new hourly consumption 34.8 kilowatt-hours. This result is an electric demand and consumption 30 percent below the duty cycling value. (This displays the importance of matching system capacity to loads as discussed in Chapter 2). The advantage of duty cycling is that the interval of on-off can be varied with EMCS based on temperatures in the space. The obvious best situation is to first reduce system capacity to the absolute minimum capacity to meet peak loads. In this case duty cycling will not be possible at full load, but electric demand and usage in this situation will already be reduced to a minimum. During off peak periods, the properly sized systems can then be duty cycled, to further increase electric usage savings.

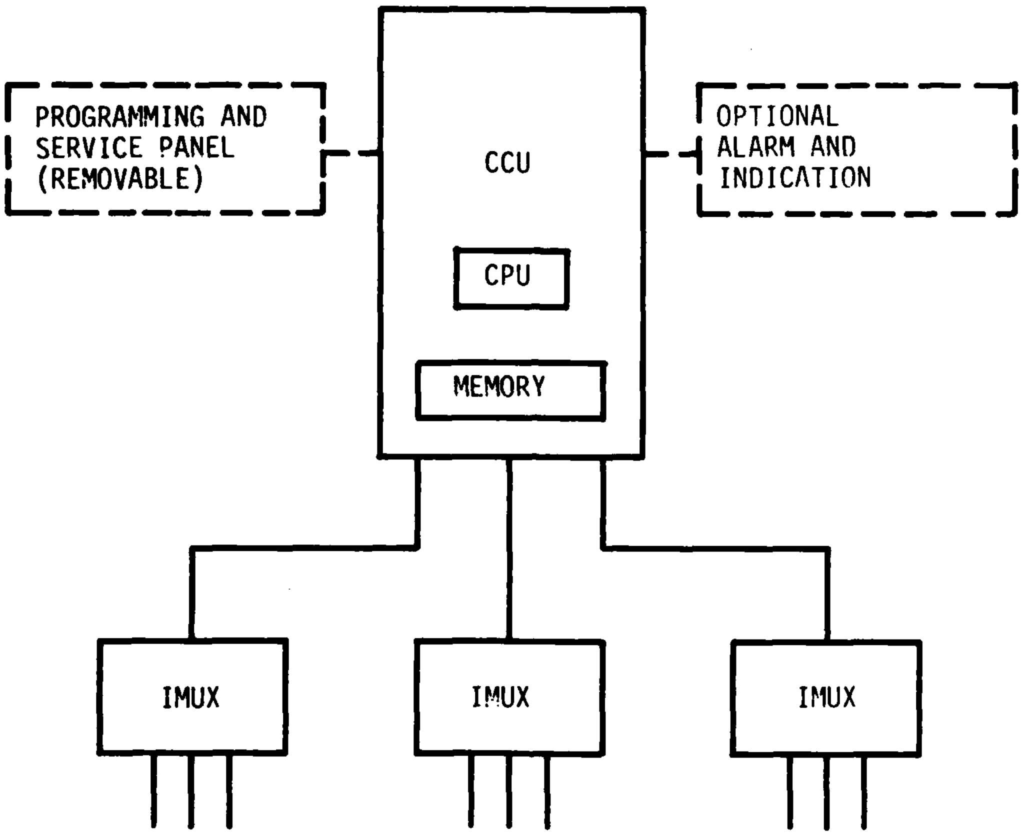
Where an EMCS can be justified based on the total economics of a project, the capability to install temperature compensated duty cycling is preferable to duty cycle/demand limiting controllers. These devices are most applicable where equipment is oversized. When equipment, in particular air handling units, is properly sized, loads on heating and cooling primary equipment are reduced accordingly offering good net results. The proper sizing gives minimum electric usage and demand with or without further energy management.

Programmable Controllers

Programmable controllers are microprocessor based devices that were originally used in the manufacturing industry for process control. These devices have analog inputs and outputs, and digital inputs and outputs. They are normally programmed in "ladder-logic" which is easily learned, and quite common in the controls industry. These controllers are powerful devices, capable of standard EMCS functions (which normally override existing control systems) and of complete system control, often termed "direct digital control". When used for direct digital control,the EMCS functions are on integral part of the control of each system, not an override or supervisory function. These units normally contain a microprocessor, power supply, a power bus, and analog input, analog output, digital input, and digital output devices. The programmable controllers can be coordinated into a system of several controllers, and tied to accessory devices such as CRT's and printers. Several companies have developed standard application software for these systems. The controllers are useful for single building applications. See CR82.028 "Controlling Energy Consumption in Single Buildings" for price and performance data on these devices.

Micro EMCS

A micro EMCS which normally consists of 125 points or less is depicted in Figure 16. These systems contain a microprocessor based central control unit, a system real time clock, and optional alarm and indication devices. These systems support one or more intelligent multiplexer panels. They offer no distributed processing. These systems typically overlap the classification of programmable controllers (where programmable controllers are used for



TO LOCAL SYSTEMS AND CONTROLS (DATA ENVIRONMENT)

MICRO EMCS BLOCK DIAGRAM

FIGURE 16

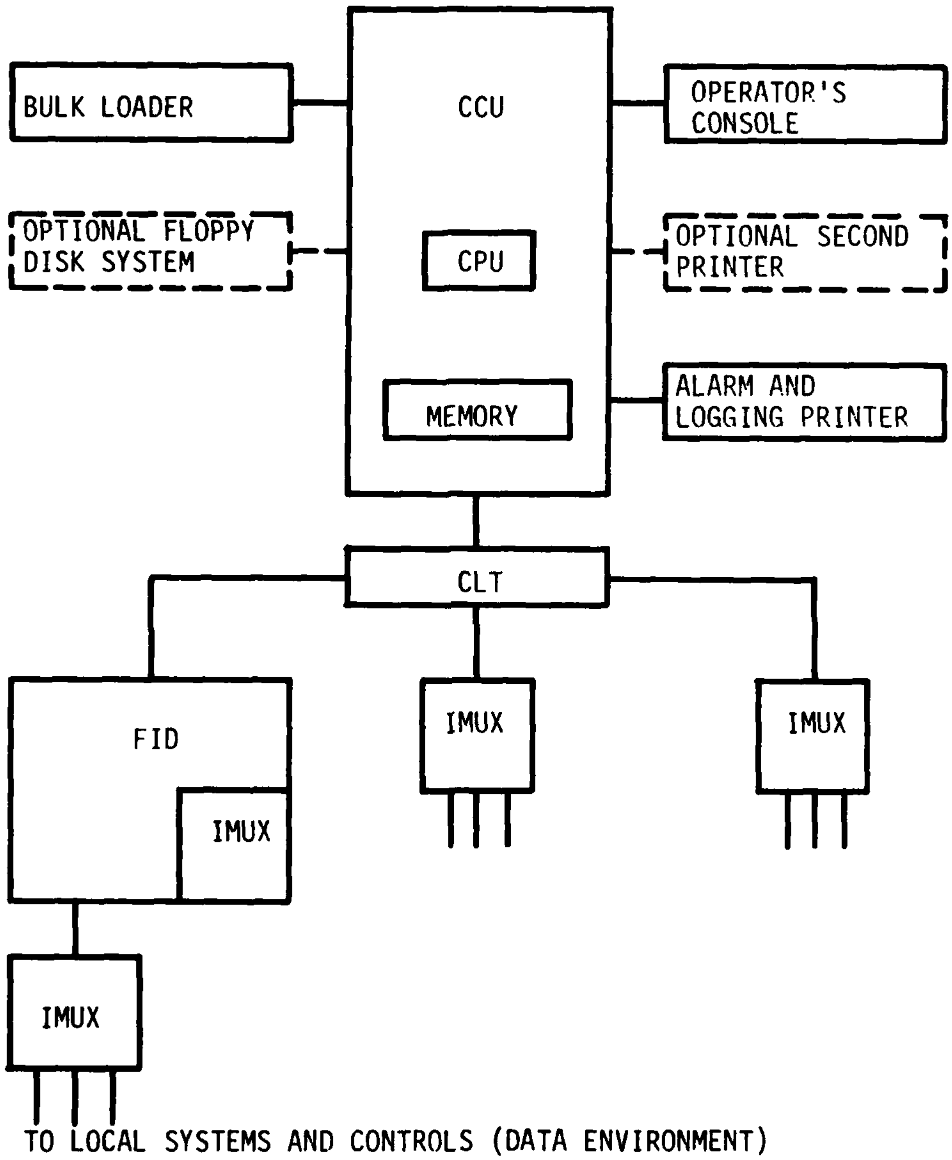
EMCS functions only). Typically, direct digital control is not available with these systems.

Small EMCS

Small EMCS normally consist of 50 to 600 points. This system is depicted in Figure 17. The central control unit is a microcomputer. The operators console contains an alphanumeric CRT, alarm and logging printer, and a real time clock. Mass storage systems may be added for historical data collection. These systems typically support intelligent multiplexer panels, but may also support distributed processing.

Cost estimating data for these systems is available in CR82.028 "Controlling Energy Consumption in Single Buildings" and in CR83.008 "EMCS Cost Estimating Data". Details on systems design and configuration and a complete description of components is available in "Energy Monitoring and Control Systems", NAVFAC DM-4.9.

Both EMCS systems support all or some of the application programs listed earlier. In currently available systems, there is a great deal of overlap in capabilities between programmable controllers, micro, and small EMCS. Oftentimes a manufacturers system can fall into either category depending on the selection of standard components and optional equipment.



SMALL EMCS BLOCK DIAGRAM

FIGURE 17

The following tables present data on the capabilities of equipment currently available. Each section addresses micro and small EMCS individually. Most manufacturers classify a micro EMCS as having from 4 to 60 points, with expansion to the 125 point range defined earlier. The small EMCS normally include 25 to 250 points, expandable in certain cases to 600 points. The lists which follow are of necessity partial lists only, and are intended to show the capabilities of typical manufacturers.

APPLICATION BY BUILDING TYPE

Manufacturers often recommend systems based on the type of building. Table 5 lists micro EMCS manufacturers products as they apply to building types. Table 6 lists small EMCS manufacturers products as they apply to building types. The column headings are self explanatory.

TABLE 5 Micro EMCS
Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Aegis Energy Systems, Inc.		Y	Y	Y	Y		Y	Y	Y	Y	Y
AMF/Paragon Electric Co.		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
AMF Texas Controls, Inc.	Y	Y					Y	Y		Y	
Anderson Cornelius Co.	Y	Y									
Andover Controls	Y	Y					Y	Y	Y		Y
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Automated Intelligence Corp.	Y	Y					Y	Y			
Barber-Colman Co., Environmental Products Div.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Broadmoor Electric Co.		Y			Y				Y		Y
Conlog, Inc.		Y	Y		Y	Y	Y	Y	Y	Y	Y
Control Pak Corp.	Y	Y	Y		Y	Y	Y	Y	Y	Y	
CSL Industries, Inc.	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y
Distributed Control Systems, Inc.	Y	Y					Y			Y	
Dynelco Div. of El Fuego Corp.	Y	Y	Y				Y	Y		Y	Y
Eagle Signal EMS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eaton Corp., Cuttler-Hammer Products	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electronic Systems International	Y	Y						Y			
Encon Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y
Enercon Data Corp.	Y	Y	Y				Y	Y	Y		
Energy Conservice, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

TABLE 5 (continued) Micro EMCS
Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Energy Management & Control Systems, Inc.									Y		
Energy Sentinel Co.	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Fuel Computer Corp. of America	Y	Y					Y	Y	Y		Y
Johnson Controls, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Leland Energy Corp.	Y	Y						Y	Y		
Leviton Manufacturing	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mac Victor Manufacturing, a Wiremold Company	Y	Y	Y	Y	Y		Y	Y	Y	Y	
Margaux Controls	Y	Y						Y			
Microcontrol Systems Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
National Enco Mfg. Co.	Y	Y	Y	Y		Y	Y	Y	Y	Y	
National Energy Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pacific Technology Div.,Butler Mfg. Co.	Y	Y	Y				Y	Y	Y	Y	
Power Controls Products, Inc.							Y	Y	Y	Y	Y
Radix II Inc.		Y	Y	Y	Y	Y	Y			Y	Y
Robertshaw Controls Co., Control Systems Div.	Y	Y			Y	Y	Y	Y	Y	Y	Y
Robertshaw Controls Co., Integrated Systems Div.		Y	Y	Y	Y	Y	Y			Y	Y
Robertshaw Controls Co., Uni-Line Div.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solid State Systems	Y	Y				Y	Y	Y	Y	Y	
Solidyne Corp.	Y	Y						Y			Y
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

TABLE 5 (continued) Micro EMCS Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Square D Co.	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Surgeonics Limited	Y	Y					Y	Y			
Teletrol, Inc.			Y	Y	Y	Y	Y	Y	Y		Y
Tempmaster Corp.		Y	Y				Y		Y		Y
Tork	Y	Y	Y					Y	Y		Y
Tour & Anderson Inc.		Y	Y	Y	Y	Y	Y			Y	Y
The Trane Company	Y	Y					Y	Y	Y	Y	Y
Trimax Controls Inc.	Y	Y	Y				Y	Y	Y		Y
United Technologies, Building Systems Co.		Y					Y				Y
Vertex Corp.		Y	Y	Y			Y				Y
Vigilance Systems Corp.	Y	Y					Y	Y	Y		Y
The Wiremold Company	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y
Xencon	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Honeywell	Y	Y	Y				Y	Y	Y	Y	

TABLE 6 Small EMCS Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Advanced Electrical Applications, Inc.			Y		Y	Y	Y			Y	Y
Aegis Energy Systems, Inc.			Y	Y	Y	Y	Y			Y	Y
American Multiplex Systems, Inc.		Y	Y	Y	Y	Y	Y			Y	Y
AMF Texas Controls, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Anderson Cornelius Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Andover Controls Corp.		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Atlantic Energy Technologies, Inc.			Y	Y	Y	Y	Y			Y	Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Beckman Instruments Inc.		Y		Y	Y	Y					Y
Broadmoor Electric Co.		Y	Y		Y				Y		Y
CESCO			Y	Y	Y	Y	Y			Y	Y
Climatron, Inc.			Y	Y	Y	Y	Y	Y	Y		Y
Conlog, Inc.		Y	Y		Y	Y	Y	Y	Y	Y	Y
Control Devices-Div. AEL Microtel Ltd.		Y	Y	Y		Y				Y	Y
Control Pak Corp.	Y	Y	Y		Y	Y	Y	Y	Y	Y	
CSL Industries, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distributed Control Systems, Inc.		Y	Y		Y						Y
Dynapar Corp.											Y
Eaton Corp., Cuttler-Hammer Products			Y	Y	Y	Y	Y	Y	Y	Y	Y

TABLE 6 (continued) Small EMCS Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Elan Energy Systems			Y	Y	Y	Y	Y			Y	Y
Emsco Systems Corp.										Y	
Enercon Data Corp.			Y	Y	Y	Y	Y			Y	Y
Energy Management Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Energy Micro-Systems			Y				Y		Y		Y
Functional Devices, Inc.										Y	
General Electric, Energy Management Systems			Y	Y	Y	Y	Y			Y	Y
IBM Corp.	Y	Y	Y		Y		Y		Y	Y	Y
Intelligent Terminals, Ltd.		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Johnson Controls, Inc.		Y	Y	Y	Y	Y	Y				Y
Leland Energy Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Leviton Manufacturing		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Margaux Controls			Y	Y	Y	Y	Y	Y	Y	Y	Y
Margaux Systems, Inc.				Y	Y	Y	Y			Y	Y
MCC Powers				Y	Y	Y	Y				Y
McQuay-POerfex, Inc.			Y	Y	Y	Y	Y			Y	Y
National Energy Corp.			Y	Y	Y	Y	Y	Y	Y	Y	Y
National Semiconductor, Systems Division									Y		
Pacific Technology Div., Butler Mfg. Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Power Management Systems, Inc.			Y	Y	Y		Y		Y	Y	Y

TABLE 6 (continued) Small EMCS Application by Building Type

	Small Retail Stores	Small Office Buildings	Large Retail Stores	Large Office Buildings	Hospitals	Campuses	Schools	Restaurants	Supermarkets	Hotel/Motel	Industrial Plants
Radix II, Inc.		Y	Y	Y	Y	Y	Y			Y	Y
Raytheon Service Co.			Y	Y	Y	Y	Y		Y	Y	Y
Robertshaw Controls Co., Integrated Systems Div.		Y	Y	Y	Y	Y	Y			Y	Y
Scientific-Atlanta, Inc.		Y	Y	Y	Y	Y	Y			Y	
Solid State Systems, Inc.			Y	Y	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Staefa Control Systems, Inc.			Y	Y	Y	Y	Y			Y	Y
TANO Corp.		Y	Y	Y	Y	Y	Y				Y
Teletrol, Inc.			Y	Y	Y	Y	Y	Y	Y		Y
Temperature Systems Inc.			Y	Y	Y	Y	Y				Y
Tempmaster Corp.			Y	Y	Y		Y			Y	
Tour & Anderson Inc.			Y	Y	Y	Y	Y			Y	Y
The Trane Company	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Trane Sentinel, Inc.		Y	Y	Y	Y	Y	Y		Y		Y
United Technologies, Building Systems Co.		Y	Y	Y	Y	Y	Y				Y
Vigilance Systems Corp.			Y	Y	Y	Y	Y		Y	Y	Y
Voltage Control Corp.		Y	Y	Y			Y		Y		Y
Honeywell			Y	Y	Y	Y	Y			Y	Y

APPLICATION BY BUILDING SIZE AND ANNUAL UTILITY BILLINGS

EMCS systems are often designed with a particular size of building in mind. For example, a manufacturer with a four point controller hardly expects to control a 200,000 square foot building; the controller could not handle the requirements, nor was it intended to be used in this application. Similarly, manufacturers often select a range of utility billings that are most appropriate when considering their product. Table 7 lists these quantities for micro EMCS, and Table 8 lists the quantities for small EMCS.

TABLE 7 Micro EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Aegis Energy Systems, Inc.		Y	Y	Y	Y			Y	
AMF/Paragon Electric Co.			Y	Y	Y		Y		
AMF Texas Controls, Inc.	Y	Y	Y	Y	Y		Y		
Anderson Cornelius Co.		Y	Y	Y	Y		Y		
Andover Controls	Y	Y	Y				Y		
Atlantic Energy Technologies, Inc.	Y						Y		
Automated Intelligence Corp.		Y	Y	Y	Y			Y	
Barber-Colman Co., Environmental Products Div.		Y	Y	Y				Y	
Broadmoor Electric Co.			Y	Y	Y			Y	
Conlog, Inc.	-	-	-	-	-		Y		
Control Pak Corp.	-	-	-	-	-	-	-	-	-
CSL Industries, Inc.		Y	Y	Y	Y		Y		
Distributed Control Systems, Inc.		Y	Y	Y	Y			Y	
Dynelco Div. of El Fuego Corp.	Y	Y	Y	Y	Y	-	-	-	-
Eagle Signal EMS			Y	Y	Y			Y	
Eaton Corp., Cuttler-Hammer Products	-	-	-	-	-	-	-	-	-
Electronic Systems International		Y							Y
Encon Systems, Inc.	-	-	-	-	-		Y		
Enercon Data Corp.	Y	Y	Y				Y		
Energy Conservice, Inc.	-	-	-	-	-			Y	

TABLE 7 (continued) Micro EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Energy Management & Control Systems, Inc.		Y	Y	Y	Y				Y
Energy Sentinel Co.	Y	Y	Y	Y		-	-	-	-
Fuel Computer Corp. of America	Y	Y	Y	Y	Y		Y		
Johnson Controls, Inc.	Y	Y	Y	Y	Y	-	-	-	-
Leland Energy Corp.	-	-	-	-	-	Y			
Leviton Manufacturing	Y	Y	Y	Y	Y		Y		
Mac Victor Manufacturing, a Wiremold Company	Y	Y	Y			-	-	-	-
Margaux Controls			Y	Y		-	-	-	-
Microcontrol Systems Inc.	Y	Y	Y	Y	Y			Y	
National Enco Mfg. Co.	Y	Y	Y	Y	Y		Y		
National Energy Corp.	Y	Y	Y	Y	Y		Y		
Pacific Technology Div.,Butler Mfg. Co.	-	-	-	-	-	-	-	-	-
Power Controls Products, Inc.	-	-	-	-	-	Y	Y		
Radix II Inc.	-	-	-	-	-	-	-	-	-
Robertshaw Controls Co., Control Systems Div.		Y	Y	Y	Y		Y		
Robertshaw Controls Co., Integrated Systems Div.					Y				Y
Robertshaw Controls Co., Uni-Line Div.		Y	Y	Y			Y		
Solid State Systems	Y	Y	Y						Y
Solidyne Corp.	Y	Y				Y			
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y			

TABLE 7 (continued) Micro EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Square D Co.	-	-	-	-	-		Y		
Surgeonics Limited	Y	Y				Y			
Teletrol, Inc.		Y	Y	Y	Y	-	-	-	-
Tempmaster Corp.			Y	Y	Y	-	-	-	-
Tork	-	-	-	-	-	-	-	-	-
Tour & Anderson Inc.	Y	Y				-	-	-	-
The Trane Company			Y	Y	Y	-	-	-	-
Trimax Controls Inc.	Y	Y	Y	Y	Y	Y			
United Technologies, Building Systems Co.	-	-	-	-	-				Y
Vertex Corp.	Y	Y	Y	Y	Y		Y		
Vigilance Systems Corp.	Y	Y	Y			-	-	-	-
The Wiremold Company	Y	Y	Y	Y	Y				Y
Xencon	Y	Y	Y	Y	Y	Y			
Honeywell	Y	Y	Y			Y	Y	Y	Y

TABLE 6 Small EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Advanced Electrical Applications, Inc.			Y	Y	Y		Y		
Aegis Energy Systems, Inc.		Y	Y	Y	Y		Y		
American Multiplex Systems, Inc.		Y	Y						
AMF Texas Controls, Inc.	Y						Y		
Anderson Cornelius Co.			Y			Y			
Andover Controls Corp.		Y	Y	Y	Y		Y		
Atlantic Energy Technologies, Inc.	Y	Y				Y			
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y			
Barber-Colman Co., Environmental Controls Div.			Y	Y	Y			Y	
Beckman Instruments Inc.			Y	Y	Y				Y
Broadmoor Electric Co.				Y	Y		Y		
CESCO		Y				Y			
Climatron, Inc.									
Conlog, Inc.						Y			
Control Devices-Div. AEL Microtel Ltd.									
Control Pak Corp.									
CSL Industries, Inc.			Y	Y	Y			Y	
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y	Y			
Dynapar Corp.									
Eaton Corp., Cuttler-Hammer Products									

TABLE 8 (continued) Small EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Elan Energy Systems							Y		
Emsco Systems Corp.									
Enercon Data Corp.		Y	Y	Y	Y				
Energy Management Corp.									
Energy Micro-Systems	Y	Y	Y	Y					
Functional Devices, Inc.									
General Electric, Energy Management Systems			Y	Y	Y	Y			
IBM Corp.				Y	Y		Y		
Intelligent Terminals, Ltd.	Y	Y	Y	Y	Y			Y	
Johnson Controls, Inc.			Y	Y	Y				
Leland Energy Corp.									
Leviton Manufacturing			Y	Y	Y	Y			
Margaux Controls			Y	Y	Y				
Margaux Systems, Inc.					Y				Y
MCC Powers			Y	Y	Y				
McQuay-POerfex, Inc.			Y	Y	Y				
National Energy Corp.			Y	Y	Y		Y		
National Semiconductor, Systems Division							Y		
Pacific Technology Div., Butler Mfg. Co.									
Power Management Systems, Inc.							Y		

TABLE 8 (continued) Small EMCS Application by Building Size/Billings

	0-10,000 square feet	10-25,000 square feet	25-50,000 square feet	50-100,000 square feet	100,000 square feet +	$5,000/yr. plus	$10,000/yr. plus	$25,000/yr. plus	$50,000/yr. plus
Radix II, Inc.									
Raytheon Service Co.			Y				Y		
Robertshaw Controls Co., Integrated Systems Div.				Y	Y				Y
Scientific-Atlanta, Inc.				Y	Y	Y			
Solid State Systems, Inc.			Y	Y	Y			Y	
Solidyne Corp.	Y	Y	Y	Y	Y	Y			
Sparton Southwest Inc.									
Staefa Control Systems, Inc.								Y	
TANO Corp.				Y	Y				
Teletrol, Inc.		Y	Y	Y					
Temperature Systems Inc.			Y				Y		
Tempmaster Corp.		Y	Y	Y	Y				
Tour & Anderson Inc.		Y	Y	Y	Y				
The Trane Company	Y	Y	Y	Y	Y				
Trane Sentinel, Inc.			Y	Y	Y				
United Technologies, Building Systems Co.									Y
Vigilance Systems Corp.			Y	Y	Y				
Voltage Control Corp.									
Honeywell				Y	Y			Y	Y

APPLICATION PROGRAMS

Of the manufacturers surveyed, most provided some but not all of the application programs defined earlier in this chapter. The following tables list several of the application programs discussed earlier. See this section of the report for definitions. "Load Management" is defined here as the ability to rotate equipment loads such as lead chillers or compressors. Temperature sensing options are listed by the ability of the manufacturer to sense outdoor air (OA) or room air (RA) conditions. The impact on this ability influences the type of standard application programs. For example, if a manufacturer cannot sense indoor temperature, temperature compensated duty cycling would not be possible, or, if outdoor air temperature cannot be sensed, then economizer control and optimum start/stop is not possible. Time of day scheduling is the ability to change control action with time of day and time of week. Multi building application refers to the ability to serve remote buildings. Fire safety and security programs are auxiliary programs offered by many manufacturers. The ability to schedule maintenance, and to monitor and alarm is also presented. Results for micro EMCS are listed in Table 9. Results for small systems are listed in Table 10.

TABLE 9 Micro EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Aegis Energy Systems, Inc.	Y	Y		Y	Y	Y			
AMF/Paragon Electric Co.	Y	Y		Y	Y	Y			
AMF Texas Controls, Inc.	Y			Y					
Anderson Cornelius Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Andover Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Products Div.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Broadmoor Electric Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Conlog, Inc.	Y	Y		Y	Y	Y		Y	Y
Control Pak Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
CSL Industries, Inc.	Y	Y		Y	Y	Y		Y	Y
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dynelco Div. of El Fuego Corp.						Y			
Eagle Signal EMS	Y	Y		Y					
Eaton Corp., Cuttler-Hammer Products	Y	Y		Y	Y	Y	Y	Y	Y
Electronic Systems International	Y	Y							
Encon Systems, Inc.	Y			Y	Y	Y			
Enercon Data Corp.	Y	Y		Y	Y	Y			
Energy Conservice, Inc.	Y	Y		Y	Y	Y			

TABLE 9 (continued) Micro EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Aegis Energy Systems, Inc.	Y	Y	Y	Y	Y	Y	Y		Y
AMF/Paragon Electric Co.	Y	Y	Y	Y	Y				
AMF Texas Controls, Inc.			Y	Y					
Anderson Cornelius Co.	Y	Y	Y	Y	Y	Y	Y		Y
Andover Controls	Y	Y	Y	Y				Y	Y
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y				Y
Automated Intelligence Corp.	Y	Y	Y	Y			Y	Y	Y
Barber-Colman Co., Environmental Products Div.	Y	Y	Y	Y	Y				Y
Broadmoor Electric Co.	Y	Y	Y	Y	Y				Y
Conlog, Inc.	Y	Y	Y	Y		Y	Y		Y
Control Pak Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
CSL Industries, Inc.	Y	Y	Y	Y	Y				
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dynelco Div. of El Fuego Corp.		Y							
Eagle Signal EMS		Y	Y	Y	Y				
Eaton Corp., Cuttler-Hammer Products		Y		Y				Y	Y
Electronic Systems International									
Encon Systems, Inc.		Y	Y	Y	Y				Y
Enercon Data Corp.	Y		Y		Y				Y
Energy Conservice, Inc.	Y	Y	Y	Y	Y				Y

TABLE 9 (continued) Micro EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Energy Management & Control Systems, Inc.									
Energy Sentinel Co.					Y	Y			
Fuel Computer Corp. of America	Y				Y	Y			
Johnson Controls, Inc.	Y		Y	Y	Y	Y	Y	Y	Y
Leland Energy Corp.	Y	Y		Y				Y	Y
Leviton Manufacturing	Y	Y		Y					
Mac Victor Manufacturing, a Wiremold Company	Y				Y	Y			
Margaux Controls	Y	Y		Y					
Microcontrol Systems Inc.	Y	Y	Y	Y	Y	Y			Y
National Enco Mfg. Co.	Y	Y		Y		Y			
National Energy Corp.	Y	Y		Y					
Pacific Technology Div.,Butler Mfg. Co.	Y	Y		Y	Y	Y			
Power Controls Products, Inc.	Y	Y		Y					
Radix II Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Robertshaw Controls Co., Control Systems Div.	Y	Y		Y	Y	Y			
Robertshaw Controls Co., Integrated Systems Div.	Y	Y		Y	Y	Y			
Robertshaw Controls Co., Uni-Line Div.	Y	Y		Y	Y	Y			
Solid State Systems	Y	Y		Y	Y	Y			
Solidyne Corp.	Y	Y		Y	Y				
Sparton Southwest Inc.	Y	Y		Y	Y	Y			

TABLE 9 (continued) Micro EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Energy Management & Control Systems, Inc.		Y							Y
Energy Sentinel Co.		Y		Y					
Fuel Computer Corp. of America	Y	Y	Y	Y	Y				
Johnson Controls, Inc.	Y	Y		Y					Y
Leland Energy Corp.		Y	Y	Y	Y			Y	
Leviton Manufacturing		Y	Y	Y	Y	Y	Y		Y
Mac Victor Manufacturing, a Wiremold Company		Y	Y	Y					
Margaux Controls			Y	Y					
Microcontrol Systems Inc.	Y	Y	Y	Y	Y	Y	Y		
National Enco Mfg. Co.		Y	Y	Y					
National Energy Corp.		Y	Y	Y	Y				
Pacific Technology Div.,Butler Mfg. Co.	Y	Y	Y	Y					
Power Controls Products, Inc.	Y	Y	Y	Y	Y				
Radix II Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Robertshaw Controls Co., Control Systems Div.	Y	Y	Y	Y	Y				
Robertshaw Controls Co., Integrated Systems Div.	Y	Y	Y	Y	Y	Y	Y		Y
Robertshaw Controls Co., Uni-Line Div.	Y	Y	Y	Y	Y				
Solid State Systems	Y	Y	Y	Y		Y	Y		
Solidyne Corp.	Y	Y	Y	Y	Y				
Sparton Southwest Inc.	Y	Y	Y	Y	Y		Y	Y	Y

TABLE 9 (continued) Micro EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Square D Co.	Y	Y		Y					
Surgeonics Limited					Y	Y			Y
Teletrol, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tempmaster Corp.	Y	Y			Y	Y			
Tork	Y			Y	Y				
Tour & Anderson Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
The Trane Company	Y	Y		Y	Y	Y			
Trimax Controls Inc.	Y	Y		Y	Y	Y			
United Technologies, Building Systems Co.	Y				Y	Y	Y	Y	Y
Vertex Corp.					Y				
Vigilance Systems Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
The Wiremold Company	Y	Y		Y					
Xencon	Y	Y		Y					
Honeywell	Y	Y		Y					

TABLE 9 (continued) Micro EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Square D Co.				Y					
Surgeonics Limited									
Teletrol, Inc.	Y	Y	Y	Y	Y			Y	Y
Tempmaster Corp.	Y	Y	Y	Y					Y
Tork	Y	Y	Y	Y					
Tour & Anderson Inc.	Y	Y	Y	Y	Y			Y	Y
The Trane Company	Y	Y	Y	Y					Y
Trimax Controls Inc.	Y	Y		Y	Y				
United Technologies, Building Systems Co.	Y	Y	Y	Y					
Vertex Corp.	Y	Y	Y						
Vigilance Systems Corp.	Y	Y	Y	Y			Y	Y	Y
The Wiremold Company		Y	Y	Y	Y				
Xencon		Y	Y	Y					
Honeywell		Y	Y	Y					

TABLE 10 Small EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Advanced Electrical Applications, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Aegis Energy Systems, Inc.	Y	Y		Y	Y	Y			
American Multiplex Systems, Inc.	Y	Y		Y	Y	Y		Y	Y
AMF Texas Controls, Inc.	Y	Y	Y	Y	Y	Y			
Anderson Cornelius Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Andover Controls Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Beckman Instruments Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Broadmoor Electric Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
CESCO	Y	Y	Y	Y	Y	Y	Y		
Climatron, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Conlog, Inc.	Y	Y	Y	Y	Y	Y		Y	Y
Control Devices-Div. AEL Microtel Ltd.				Y					
Control Pak Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
CSL Industries, Inc.	Y	Y		Y	Y	Y	Y	Y	Y
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dynapar Corp.	Y	Y		Y					
Eaton Corp., Cuttler-Hammer Products	Y	Y		Y	Y	Y	Y	Y	Y

TABLE 10 (continued) Small EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Advanced Electrical Applications, Inc.	Y	Y	Y	Y	Y				Y
Aegis Energy Systems, Inc.	Y	Y	Y	Y	Y	Y	Y		Y
American Multiplex Systems, Inc.	Y	Y	Y	Y	Y	Y	Y		Y
AMF Texas Controls, Inc.	Y	Y	Y	Y	Y				
Anderson Cornelius Co.	Y	Y	Y	Y	Y	Y	Y		Y
Andover Controls Corp.	Y	Y	Y	Y	Y			Y	Y
Atlantic Energy Technologies, Inc.	Y	Y			Y				Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y		Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y	Y			Y	Y
Beckman Instruments Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Broadmoor Electric Co.	Y	Y	Y	Y	Y				Y
CESCO	Y	Y	Y	Y	Y				
Climatron, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Conlog, Inc.	Y	Y	Y	Y		Y	Y		Y
Control Devices-Div. AEL Microtel Ltd.			Y	Y	Y		Y		Y
Control Pak Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
CSL Industries, Inc.	Y	Y	Y	Y	Y				
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dynapar Corp.				Y					
Eaton Corp., Cuttler-Hammer Products	Y	Y	Y	Y	Y			Y	Y

TABLE 10 (continued) Small EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Elan Energy Systems	Y	Y			Y	Y	Y		
Emsco Systems Corp.						Y			
Enercon Data Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Energy Management Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Energy Micro-Systems	Y	Y	Y	Y	Y	Y		Y	Y
Functional Devices, Inc.	Y	Y		Y	Y				
General Electric, Energy Management Systems	Y	Y		Y	Y	Y			
IBM Corp.	Y	Y			Y	Y			
Intelligent Terminals, Ltd.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Johnson Controls, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Leland Energy Corp.	Y	Y		Y	Y	Y	Y	Y	Y
Leviton Manufacturing	Y	Y		Y	Y	Y			
Margaux Controls	Y	Y		Y	Y	Y	Y	Y	Y
Margaux Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
MCC Powers	Y	Y	Y	Y	Y	Y	Y	Y	Y
McQuay-POerfex, Inc.	Y	Y		Y	Y	Y		Y	Y
National Energy Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
National Semiconductor, Systems Division	Y	Y		Y	Y	Y		Y	
Pacific Technology Div., Butler Mfg. Co.	Y	Y		Y	Y	Y			
Power Management Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y

TABLE 10 (continued) Small EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Elan Energy Systems	Y		Y	Y	Y		Y		
Emsco Systems Corp.									
Enercon Data Corp.	Y	Y	Y	Y				Y	Y
Energy Management Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Energy Micro-Systems	Y	Y	Y	Y	Y				Y
Functional Devices, Inc.		Y	Y	Y					
General Electric, Energy Management Systems	Y	Y	Y	Y	Y				Y
IBM Corp.	Y	Y	Y	Y					
Intelligent Terminals, Ltd.	Y	Y	Y	Y	Y		Y	Y	Y
Johnson Controls, Inc.	Y	Y	Y	Y	Y	Y	Y		Y
Leland Energy Corp.	Y	Y	Y	Y	Y			Y	Y
Leviton Manufacturing		Y	Y	Y	Y	Y	Y		Y
Margaux Controls	Y	Y	Y	Y	Y			Y	Y
Margaux Systems, Inc.	Y	Y	Y	Y	Y			Y	Y
MCC Powers	Y	Y	Y	Y	Y	Y	Y	Y	Y
McQuay-POerfex, Inc.	Y	Y	Y	Y	Y	Y	Y		Y
National Energy Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
National Semiconductor, Systems Division	Y	Y	Y	Y		Y	Y		
Pacific Technology Div., Butler Mfg. Co.	Y	Y	Y	Y	Y				
Power Management Systems, Inc.	Y	Y	Y	Y					

TABLE 10 (continued) Small EMCS Application Programs

	Duty Cycling	Demand Control	Chiller Optimization	Load Management	OA Temperature Sensing	RA Temperature Sensing	Enthalpy Control	Supply Air Reset	Hot Water Reset
Radix II, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Raytheon Service Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Robertshaw Controls Co., Integrated Systems Div.	Y	Y		Y	Y	Y			
Scientific-Atlanta, Inc.	Y	Y		Y	Y				
Solid State Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.	Y	Y		Y	Y				
Sparton Southwest Inc.	Y	Y		Y	Y	Y			
Staefa Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
TANO Corp.	Y	Y	Y	Y	Y	Y			
Teletrol, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Temperature Systems Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tempmaster Corp.	Y	Y		Y	Y	Y		Y	Y
Tour & Anderson Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
The Trane Company	Y	Y		Y	Y	Y	Y		
Trane Sentinel, Inc.	Y	Y		Y	Y	Y	Y	Y	Y
United Technologies, Building Systems Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vigilance Systems Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Voltage Control Corp.	Y	Y		Y	Y	Y			
Honeywell	Y	Y	Y	Y	Y	Y	Y	Y	Y

TABLE 10 (continued) Small EMCS Application Programs

	Optimum Start/Stop	Night Setback	Lighting Control	Time-of-day Scheduling	Multi-Building Applic.	Fire Safety	Security	Preventive Maint. Sch.	Monitoring & Alarm
Radix II, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Raytheon Service Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Robertshaw Controls Co., Integrated Systems Div.	Y	Y	Y	Y	Y	Y	Y		Y
Scientific-Atlanta, Inc.	Y	Y	Y	Y	Y				
Solid State Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.	Y	Y	Y	Y	Y				
Sparton Southwest Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Staefa Control Systems, Inc.	Y	Y	Y	Y	Y		Y		Y
TANO Corp.			Y	Y	Y				
Teletrol, Inc.	Y	Y	Y	Y	Y			Y	Y
Temperature Systems Inc.	Y	Y	Y	Y		Y			
Tempmaster Corp.	Y	Y	Y	Y					Y
Tour & Anderson Inc.	Y	Y	Y	Y	Y			Y	Y
The Trane Company	Y	Y	Y	Y					Y
Trane Sentinel, Inc.	Y	Y	Y	Y	Y		Y		Y
United Technologies, Building Systems Co.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vigilance Systems Corp.	Y	Y	Y	Y	Y		Y	Y	Y
Voltage Control Corp.	Y	Y	Y	Y	Y			Y	Y
Honeywell	Y	Y	Y	Y	Y	Y	Y	Y	Y

HARDWARE FEATURES

The hardware available with each manufacturers products is listed. Automatic alarms refers to the capability to initiate alarm action, such as sound an alarm or autodial a phone. Analog temperatures refers to the ability to accept analog inputs. Uses personal computers is the ability for panels to be addressed from small microcomputers, often referred to as personal computers. Trend logging is the ability to monitor inputs and log outputs, either on printout or tape, or in a software routine to watch items such as utility usage. This feature is required to monitor EMCS performance by analyzing utility data, or to monitor utility consumption prior to EMCS implementation. Interface to lighting is the ability to interface to common lighting controllers. Other column headings are self explanatory. Table 11 list results for micro EMCS systems. Table 12 lists results for small EMCS systems.

TABLE 11 Micro EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Aegis Energy Systems, Inc.	Y	Y	Y	Y				Y	Y
AMF/Paragon Electric Co.	Y	Y	Y			Y	Y	Y	Y
AMF Texas Controls, Inc.						Y		Y	
Anderson Cornelius Co.	Y	Y	Y	Y			Y	Y	Y
Andover Controls	Y	Y	Y	Y		Y	Y	Y	Y
Atlantic Energy Technologies, Inc.	Y	Y		Y		Y	Y	Y	Y
Automated Intelligence Corp.	Y	Y					Y	Y	Y
Barber-Colman Co., Environmental Products Div.	Y	Y	Y	Y		Y		Y	Y
Broadmoor Electric Co.	Y	Y	Y	Y		Y		Y	Y
Conlog, Inc.	Y	Y	Y	Y		Y	Y	Y	Y
Control Pak Corp.	Y	Y	Y	Y		Y	Y	Y	Y
CSL Industries, Inc.	Y		Y	Y		Y	Y	Y	Y
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Dynelco Div. of El Fuego Corp.		Y							
Eagle Signal EMS	Y					Y		Y	Y
Eaton Corp., Cuttler-Hammer Products	Y	Y	Y			Y	Y	Y	Y
Electronic Systems International									
Encon Systems, Inc.		Y	Y	Y		Y		Y	Y
Enercon Data Corp.		Y				Y		Y	
Energy Conservice, Inc.		Y	Y			Y	Y	Y	Y

TABLE 11 (continued) Micro EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Energy Management & Control Systems, Inc.	Y	Y				Y		Y	
Energy Sentinel Co.									
Fuel Computer Corp. of America	Y	Y	Y	Y		Y		Y	
Johnson Controls, Inc.		Y					Y		
Leland Energy Corp.			Y	Y		Y	Y		Y
Leviton Manufacturing	Y		Y	Y		Y		Y	Y
Mac Victor Manufacturing, a Wiremold Company									
Margaux Controls									
Microcontrol Systems Inc.	Y	Y	Y	Y				Y	
National Enco Mfg. Co.		Y							
National Energy Corp.									Y
Pacific Technology Div.,Butler Mfg. Co.		Y				Y			
Power Controls Products, Inc.									
Radix II Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Robertshaw Controls Co., Control Systems Div.	Y	Y	Y	Y		Y	Y	Y	
Robertshaw Controls Co., Integrated Systems Div.	Y		Y			Y		Y	Y
Robertshaw Controls Co., Uni-Line Div.		Y	Y	Y		Y	Y	Y	Y
Solid State Systems	Y	Y	Y					Y	Y
Solidyne Corp.	Y	Y	Y			Y		Y	Y
Sparton Southwest Inc.	Y	Y	Y	Y		Y		Y	

TABLE 11 (continued) Micro EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Square D Co.	Y		Y		Y	Y		Y	
Surgeonics Limited									
Teletrol, Inc.	Y	Y				Y	Y	Y	Y
Tempmaster Corp.	Y	Y	Y	Y		Y		Y	Y
Tork									
Tour & Anderson Inc.	Y	Y	Y	Y		Y	Y	Y	Y
The Trane Company	Y	Y	Y					Y	
Trimax Controls Inc.	Y	Y	Y			Y	Y	Y	Y
United Technologies, Building Systems Co.		Y							Y
Vertex Corp.		Y							
Vigilance Systems Corp.	Y	Y						Y	Y
The Wiremold Company									Y
Xencon									
Honeywell								Y	

TABLE 12 Small EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Advanced Electrical Applications, Inc.	Y	Y	Y	Y	Y			Y	Y
Aegis Energy Systems, Inc.	Y	Y	Y	Y		Y	Y	Y	Y
American Multiplex Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
AMF Texas Controls, Inc.		Y	Y	Y		Y	Y	Y	
Anderson Cornelius Co.	Y	Y	Y	Y			Y	Y	Y
Andover Controls Corp.	Y	Y	Y	Y			Y	Y	Y
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	
Automated Intelligence Corp.	Y	Y	Y	Y			Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y		Y	Y	Y	Y
Beckman Instruments Inc.	Y	Y	Y	Y	Y		Y	Y	
Broadmoor Electric Co.	Y	Y	Y	Y		Y		Y	Y
CESCO		Y				Y	Y	Y	Y
Climatron, Inc.	Y	Y	Y	Y			Y	Y	Y
Conlog, Inc.	Y	Y	Y	Y		Y	Y	Y	Y
Control Devices-Div. AEL Microtel Ltd.		Y	Y	Y		Y		Y	
Control Pak Corp.	Y	Y	Y	Y		Y	Y	Y	Y
CSL Industries, Inc.	Y		Y	Y		Y	Y	Y	Y
Distributed Control Systems, Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Dynapar Corp.	Y		Y	Y					
Eaton Corp., Cuttler-Hammer Products	Y	Y	Y	Y		Y	Y	Y	Y

TABLE 12 (continued) Small EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Elan Energy Systems	Y	Y				Y		Y	Y
Emsco Systems Corp.						Y			
Enercon Data Corp.	Y	Y	Y	Y				Y	
Energy Management Corp.	Y	Y	Y	Y		Y	Y	Y	Y
Energy Micro-Systems	Y	Y	Y	Y				Y	Y
Functional Devices, Inc.			Y	Y					
General Electric, Energy Management Systems	Y	Y	Y	Y		Y	Y	Y	Y
IBM Corp.	Y	Y	Y	Y		Y	Y	Y	Y
Intelligent Terminals, Ltd.	Y	Y	Y	Y		Y	Y	Y	Y
Johnson Controls, Inc.	Y	Y	Y	Y			Y	Y	
Leland Energy Corp.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Leviton Manufacturing	Y		Y	Y		Y		Y	Y
Margaux Controls	Y	Y	Y	Y		Y	Y	Y	Y
Margaux Systems, Inc.	Y	Y	Y	Y			Y	Y	Y
MCC Powers	Y	Y	Y	Y	Y		Y		Y
McQuay-POerfex, Inc.	Y		Y	Y				Y	Y
National Energy Corp.	Y	Y	Y	Y		Y		Y	Y
National Semiconductor, Systems Division	Y	Y	Y	Y		Y		Y	Y
Pacific Technology Div., Butler Mfg. Co.		Y	Y	Y		Y	Y	Y	
Power Management Systems, Inc.	Y	Y	Y	Y				Y	

TABLE 12 (continued) Small EMCS Hardware Features

	Automatic Alarms	Analog Temperatures	Hard-copy Printout	CRT Display	Colorgraphics	Uses Pers. Computers	Trend Logging	Remote Communications	Interface to Lighting
Radix II, Inc.	Y	Y	Y	Y	Y		Y	Y	Y
Raytheon Service Co.	Y	Y	Y	Y	Y		Y	Y	Y
Robertshaw Controls Co., Integrated Systems Div.	Y		Y			Y		Y	Y
Scientific-Atlanta, Inc.	Y			Y				Y	
Solid State Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.	Y	Y	Y			Y		Y	Y
Sparton Southwest Inc.	Y	Y	Y	Y		Y		Y	
Staefa Control Systems, Inc.	Y	Y	Y	Y	Y		Y	Y	Y
TANO Corp.	Y	Y	Y	Y			Y	Y	Y
Teletrol, Inc.	Y	Y				Y	Y	Y	Y
Temperature Systems Inc.	Y	Y	Y	Y		Y		Y	
Tempmaster Corp.	Y	Y	Y	Y		Y		Y	Y
Tour & Anderson Inc.	Y	Y	Y	Y		Y	Y	Y	Y
The Trane Company	Y	Y	Y	Y		Y	Y	Y	Y
Trane Sentinel, Inc.	Y	Y	Y	Y			Y	Y	Y
United Technologies, Building Systems Co.	Y	Y	Y	Y	Y		Y	Y	Y
Vigilance Systems Corp.	Y		Y					Y	Y
Voltage Control Corp.	Y	Y	Y	Y		Y		Y	Y
Honeywell	Y	Y	Y	Y		Y	Y	Y	Y

DATA TRANSMISSION AND HVAC CONTROL TECHNIQUES

The available methods for data transmission are presented. "Analog" refers to the ability to receive and transmit analog signals; i.e. if the manufacturer can only transmit on-off signals, this column would not be checked. Control point adjustment is another indication of the ability to deliver analog signals for reset and other functions. Other headings are self explanatory. The results for micro EMCS are listed in Table 13. The results for small EMCS are listed in Table 14.

TABLE 13 Micro EMCS Data Trans. and HVAC Control

	Data Transmission:	Digital	Analog	Power Line Carrier	Telephone Lines	HVAC Control Technique:	Direct Digital Control	Control Point Adjustment	Closed loop control
Aegis Energy Systems, Inc.		Y		Y	Y				
AMF/Paragon Electric Co.		Y	Y		Y		Y		
AMF Texas Controls, Inc.		Y		Y	Y			Y	
Anderson Cornelius Co.		Y	Y		Y		Y	Y	Y
Andover Controls		Y	Y		Y		Y	Y	Y
Atlantic Energy Technologies, Inc.		Y	Y		Y		Y	Y	Y
Automated Intelligence Corp.		Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Products Div.		Y	Y	Y	Y	Y	Y	Y	Y
Broadmoor Electric Co.		Y			Y		Y		
Conlog, Inc.					Y		Y		Y
Control Pak Corp.		Y	Y		Y		Y	Y	Y
CSL Industries, Inc.		Y		Y	Y		Y		
Distributed Control Systems, Inc.		Y			Y		Y	Y	Y
Dynelco Div. of El Fuego Corp.									Y
Eagle Signal EMS		Y	Y	Y	Y				Y
Eaton Corp., Cuttler-Hammer Products		Y		Y	Y		Y		
Electronic Systems International			Y				Y		
Encon Systems, Inc.					Y				
Enercon Data Corp.		Y					Y		
Energy Conservice, Inc.		Y	Y	Y	Y		Y		

TABLE 13 (continued) Micro EMCS Data Trans. and HVAC Control

	Data Transmission:	Digital	Analog	Power Line Carrier	Telephone Lines	HVAC Control Technique:	Direct Digital Control	Control Point Adjustment	Closed loop control
Energy Management & Control Systems, Inc.		Y	Y		Y		Y		
Energy Sentinel Co.									Y
Fuel Computer Corp. of America		Y			Y			Y	
Johnson Controls, Inc.		Y					Y		Y
Leland Energy Corp.					Y				Y
Leviton Manufacturing		Y		Y	Y		Y		
Mac Victor Manufacturing, a Wiremold Company		Y							
Margaux Controls		Y						Y	
Microcontrol Systems Inc.		Y	Y	Y			Y		Y
National Enco Mfg. Co.		Y		Y			Y		
National Energy Corp.		Y		Y			Y		
Pacific Technology Div.,Butler Mfg. Co.		Y	Y	Y	Y			Y	
Power Controls Products, Inc.			Y				Y		
Radix II Inc.		Y	Y		Y		Y	Y	Y
Robertshaw Controls Co., Control Systems Div.				Y	Y				
Robertshaw Controls Co., Integrated Systems Div.				Y	Y		Y		
Robertshaw Controls Co., Uni-Line Div.		Y		Y	Y				
Solid State Systems		Y	Y	Y	Y				Y
Solidyne Corp.				Y			Y		
Sparton Southwest Inc.		Y	Y	Y	Y		Y	Y	Y

TABLE 13 (continued) Micro EMCS Data Trans. and HVAC Control

	Data Transmission: Digital	Analog	Power Line Carrier	Telephone Lines	HVAC Control Technique: Direct Digital Control	Control Point Adjustment	Closed loop control
Square D Co.	Y		Y				
Surgeonics Limited							
Teletrol, Inc.	Y	Y	Y	Y	Y	Y	Y
Tempmaster Corp.	Y	Y					Y
Tork							Y
Tour & Anderson Inc.	Y			Y	Y	Y	Y
The Trane Company	Y	Y	Y	Y			Y
Trimax Controls Inc.	Y		Y	Y			
United Technologies, Building Systems Co.	Y				Y	Y	Y
Vertex Corp.		Y	Y	Y			Y
Vigilance Systems Corp.	Y				Y		Y
The Wiremold Company	Y				Y		
Xencon	Y				Y		
Honeywell	Y			Y			

TABLE 14 Small EMCS Data Trans. and HVAC Control

	Data Transmission:				HVAC Control Technique:		
	Digital	Analog	Power Line Carrier	Telephone Lines	Direct Digital Control	Control Point Adjustment	Closed loop control
Advanced Electrical Applications, Inc.	Y			Y	Y		Y
Aegis Energy Systems, Inc.	Y		Y	Y			
American Multiplex Systems, Inc.	Y			Y		Y	Y
AMF Texas Controls, Inc.	Y	Y	Y	Y			Y
Anderson Cornelius Co.	Y	Y		Y	Y	Y	Y
Andover Controls Corp.	Y	Y		Y	Y	Y	Y
Atlantic Energy Technologies, Inc.	Y	Y		Y	Y	Y	Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y	Y	Y	Y
Beckman Instruments Inc.	Y			Y	Y		
Broadmoor Electric Co.	Y			Y	Y		
CESCO	Y			Y	Y	Y	
Climatron, Inc.	Y				Y		
Conlog, Inc.				Y	Y		Y
Control Devices-Div. AEL Microtel Ltd.	Y			Y	Y		
Control Pak Corp.	Y	Y		Y	Y	Y	Y
CSL Industries, Inc.	Y			Y	Y		Y
Distributed Control Systems, Inc.	Y			Y	Y	Y	Y
Dynapar Corp.							
Eaton Corp., Cuttler-Hammer Products	Y		Y	Y	Y		

TABLE 14 (continued) Small EMCS Data Trans. and HVAC Control

	Data Transmission: Digital	Analog	Power Line Carrier	Telephone Lines	HVAC Control Technique: Direct Digital Control	Control Point Adjustment	Closed loop control
Elan Energy Systems	Y		Y	Y	Y		Y
Emsco Systems Corp.					Y		
Enercon Data Corp.	Y				Y	Y	Y
Energy Management Corp.	Y	Y	Y	Y	Y	Y	Y
Energy Micro-Systems	Y	Y		Y	Y		
Functional Devices, Inc.			Y				
General Electric, Energy Management Systems	Y			Y			
IBM Corp.	Y	Y		Y	Y	Y	Y
Intelligent Terminals, Ltd.	Y			Y	Y	Y	
Johnson Controls, Inc.	Y			Y		Y	
Leland Energy Corp.			Y	Y			Y
Leviton Manufacturing	Y		Y	Y	Y		
Margaux Controls	Y			Y		Y	Y
Margaux Systems, Inc.	Y	Y	Y	Y	Y	Y	Y
MCC Powers	Y	Y	Y	Y	Y	Y	Y
McQuay-POerfex, Inc.	Y		Y	Y	Y	Y	Y
National Energy Corp.	Y		Y		Y		
National Semiconductor, Systems Division	Y			Y			Y
Pacific Technology Div., Butler Mfg. Co.	Y	Y	Y	Y		Y	
Power Management Systems, Inc.	Y	Y		Y	Y	Y	Y

TABLE 14 (continued) Small EMCS Data Trans. and HVAC Control

	Data Transmission: Digital	Analog	Power Line Carrier	Telephone Lines	HVAC Control Technique: Direct Digital Control	Control Point Adjustment	Closed loop control
Radix II, Inc.	Y	Y		Y	Y	Y	Y
Raytheon Service Co.	Y			Y		Y	Y
Robertshaw Controls Co., Integrated Systems Div.			Y	Y	Y		
Scientific-Atlanta, Inc.	Y		Y	Y			Y
Solid State Systems, Inc.	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.			Y		Y		
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y	Y
Staefa Control Systems, Inc.	Y			Y	Y	Y	Y
TANO Corp.	Y			Y			Y
Teletrol, Inc.	Y	Y	Y	Y	Y	Y	Y
Temperature Systems Inc.	Y	Y		Y	Y		
Tempmaster Corp.	Y	Y					Y
Tour & Anderson Inc.	Y			Y	Y	Y	Y
The Trane Company	Y	Y	Y	Y			Y
Trane Sentinel, Inc.	Y	Y		Y		Y	
United Technologies, Building Systems Co.	Y		Y	Y	Y	Y	Y
Vigilance Systems Corp.	Y			Y	Y		Y
Voltage Control Corp.	Y	Y		Y			
Honeywell	Y	Y	Y	Y		Y	Y

AUXILIARY FUNCTIONS

Three general categories are presented in this series of tables. The first three columns list the capability of the manufacturers system to be a stand alone system, distributed processing, or both (combined). The second three columns lists the ability to survive power problems. Power interrupt protected indicates the ability to recover from power failure. Surge protection indicates built in components exist to accept spikes in the power supply and other power irregularities. Auxiliary memory refers to an auxiliary memory used to reload software after power failure, such that complete manual loading is not required. Software input is most important. System prompted indicates that the EMCS will prompt all questions in a defined format to load pertinent data. Manual guided indicates that a standard routine is used to input data, in lieu of prompting from the system. Table 15 lists results for the micro EMCS. Table 16 lists results for the small EMCS.

TABLE 15 Micro EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input: System Prompted	Software Input: Manual Guided
Aegis Energy Systems, Inc.		Y		Y	Y			Y
AMF/Paragon Electric Co.		Y		Y	Y		Y	Y
AMF Texas Controls, Inc.		Y		Y			Y	Y
Anderson Cornelius Co.	Y	Y	Y	Y	Y		Y	
Andover Controls		Y		Y	Y		Y	
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y			Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Products Div.	Y	Y	Y	Y	Y	Y	Y	
Broadmoor Electric Co.	Y	Y	Y	Y	Y		Y	
Conlog, Inc.	Y	Y	Y	Y	Y	Y	Y	
Control Pak Corp.		Y		Y	Y	Y	Y	Y
CSL Industries, Inc.		Y		Y	Y		Y	
Distributed Control Systems, Inc.	Y			Y	Y		Y	
Dynelco Div. of El Fuego Corp.	Y			Y	Y			Y
Eagle Signal EMS		Y		Y			Y	
Eaton Corp., Cuttler-Hammer Products		Y		Y	Y		Y	
Electronic Systems International		Y		Y	Y			Y
Encon Systems, Inc.			Y	Y	Y	Y	Y	
Enercon Data Corp.		Y		Y				Y
Energy Conservice, Inc.		Y		Y	Y			Y

TABLE 15 (continued) Micro EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input: System Prompted	Manual Guided
Energy Management & Control Systems, Inc.		Y		Y	Y	Y	Y	
Energy Sentinel Co.				Y				Y
Fuel Computer Corp. of America	Y	Y	Y	Y	Y			Y
Johnson Controls, Inc.		Y		Y	Y	Y		Y
Leland Energy Corp.		Y		Y	Y			Y
Leviton Manufacturing		Y		Y	Y			Y
Mac Victor Manufacturing, a Wiremold Company		Y		Y	Y		Y	
Margaux Controls		Y		Y			Y	
Microcontrol Systems Inc.	Y	Y	Y	Y	Y		Y	Y
National Enco Mfg. Co.		Y		Y	Y		Y	
National Energy Corp.		Y		Y	Y		Y	
Pacific Technology Div.,Butler Mfg. Co.		Y		Y	Y			Y
Power Controls Products, Inc.		Y		Y	Y		Y	Y
Radix II Inc.	Y	Y	Y	Y	Y	Y	Y	
Robertshaw Controls Co., Control Systems Div.		Y		Y	Y	Y	Y	
Robertshaw Controls Co., Integrated Systems Div.	Y			Y	Y		Y	
Robertshaw Controls Co., Uni-Line Div.				Y			Y	Y
Solid State Systems	Y	Y	Y	Y			Y	Y
Solidyne Corp.			Y	Y	Y		Y	
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y	Y	

TABLE 15 (continued) Micro EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input:	System Prompted	Manual Guided
Square D Co.		Y		Y	Y			Y	Y
Surgeonics Limited									
Teletrol, Inc.	Y	Y	Y	Y	Y				
Tempmaster Corp.			Y	Y	Y	Y		Y	Y
Tork									
Tour & Anderson Inc.	Y	Y	Y	Y	Y	Y		Y	
The Trane Company				Y	Y	Y		Y	
Trimax Controls Inc.		Y		Y	Y			Y	
United Technologies, Building Systems Co.	Y	Y	Y	Y	Y				Y
Vertex Corp.		Y		Y	Y				Y
Vigilance Systems Corp.	Y	Y	Y	Y	Y	Y		Y	
The Wiremold Company				Y	Y			Y	
Xencon		Y		Y	Y				Y
Honeywell		Y		Y	Y			Y	

TABLE 16 Small EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input: System Prompted	Software Input: Manual Guided
Advanced Electrical Applications, Inc.	Y	Y	Y	Y	Y		Y	
Aegis Energy Systems, Inc.		Y		Y	Y	Y		Y
American Multiplex Systems, Inc.		Y		Y	Y	Y	Y	Y
AMF Texas Controls, Inc.	Y	Y	Y	Y	Y	Y	Y	Y
Anderson Cornelius Co.	Y	Y	Y	Y	Y		Y	
Andover Controls Corp.	Y	[illegible]	Y	Y	Y		Y	
Atlantic Energy Technologies, Inc.	Y	Y	Y	Y	Y			Y
Automated Intelligence Corp.	Y	Y	Y	Y	Y	Y	Y	Y
Barber-Colman Co., Environmental Controls Div.	Y	Y	Y	Y	Y	Y	Y	
Beckman Instruments Inc.	Y			Y	Y		Y	
Broadmoor Electric Co.	Y	Y	Y	Y	Y		Y	
CESCO	Y	Y	Y	Y	Y		Y	
Climatron, Inc.	Y	Y	Y	Y			Y	
Conlog, Inc.	Y	Y	Y	Y	Y	Y	Y	
Control Devices-Div. AEL Microtel Ltd.			Y	Y	Y		Y	
Control Pak Corp.		Y		Y	Y	Y	Y	Y
CSL Industries, Inc.			Y	Y	Y	Y	Y	
Distributed Control Systems, Inc.	Y			Y	Y		Y	
Dynapar Corp.		Y						Y
Eaton Corp., Cuttler-Hammer Products			Y	Y	Y		Y	

TABLE 16 (continued) Small EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input:	System Prompted	Manual Guided
Elan Energy Systems	Y							Y	
Emsco Systems Corp.		Y							Y
Enercon Data Corp.			Y	Y	Y	Y		Y	
Energy Management Corp.	Y	Y	Y	Y	Y			Y	
Energy Micro-Systems			Y	Y	Y	Y		Y	
Functional Devices, Inc.		Y		Y	Y			Y	Y
General Electric, Energy Management Systems		Y		Y	Y	Y		Y	
IBM Corp.		Y		Y	Y			Y	
Intelligent Terminals, Ltd.	Y	Y	Y	Y				Y	
Johnson Controls, Inc.		Y		Y	Y	Y		Y	
Leland Energy Corp.	Y	Y	Y	Y	Y			Y	
Leviton Manufacturing		Y		Y	Y	Y		Y	
Margaux Controls	Y		Y	Y	Y	Y		Y	
Margaux Systems, Inc.	Y	Y	Y	Y	Y	Y		Y	
MCC Powers			Y	Y				Y	
McQuay-POerfex, Inc.				Y	Y	Y		Y	Y
National Energy Corp.		Y		Y	Y	Y		Y	
National Semiconductor, Systems Division		Y		Y	Y				Y
Pacific Technology Div., Butler Mfg. Co.	Y	Y	Y	Y	Y	Y		Y	
Power Management Systems, Inc.		Y		Y	Y			Y	

TABLE 16 (continued) Small EMCS Auxiliary Functions

	Distributed Processing	Stand-alone Processing	Combination	Power Interrupt Protected	Surge Protection	Auxilary Memory	Software Input: System Prompted	Manual Guided
Radix II, Inc.	Y	Y	Y	Y	Y	Y	Y	
Raytheon Service Co.	Y	Y	Y	Y	Y	Y	Y	
Robertshaw Controls Co., Integrated Systems Div.	Y			Y	Y		Y	
Scientific-Atlanta, Inc.		Y		Y	Y	Y	Y	
Solid State Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	Y
Solidyne Corp.			Y	Y	Y	Y	Y	
Sparton Southwest Inc.	Y	Y	Y	Y	Y	Y	Y	
Staefa Control Systems, Inc.	Y	Y	Y	Y	Y	Y	Y	
TANO Corp.	Y	Y	Y	Y	Y	Y	Y	
Teletrol, Inc.	Y	Y	Y	Y	Y			
Temperature Systems Inc.	Y	Y	Y	Y	Y		Y	
Tempmaster Corp.			Y	Y	Y	Y	Y	Y
Tour & Anderson Inc.	Y	Y	Y	Y	Y	Y	Y	
The Trane Company		Y		Y	Y	Y	Y	
Trane Sentinel, Inc.				Y	Y		Y	
United Technologies, Building Systems Co.	Y	Y	Y	Y	Y	Y	Y	
Vigilance Systems Corp.	Y	Y	Y	Y	Y	Y	Y	
Voltage Control Corp.				Y			Y	Y
Honeywell		Y		Y	Y	Y	Y	Y

Chapter 3: Selecting Single Building Energy Controllers

SUMMARY

The capabilities of commercially available products varies widely as shown in the brief tables. This reinforces the need for good plans and specifications to outline what is expected of the manufacturer. The manufacturers definition of an application program may not match what is specified, so due caution is necessary in review of seemingly qualified proposals.

A sample calculation of savings potential follows for two extremes of the presented systems; time clock control versus small EMCS control of an air handling unit.

Sample Savings Analysis

A manual technique for calculating savings is outlined in "Standard EMCS Energy Savings Calculations". This technique will be used to compare three options as an example:

1) Time clock control only.
2) Time clock control and pneumatic control retrofit.
3) Small EMCS control.

The example is for a hypothetical six zone multizone unit located in a building in Springfield Missouri. Pertinent information follows:

Area Square Footage	= 20,000 SF
System Total Air Volume	= 15,000 cfm
Outside Air Requirement	= 3,000 cfm
System Fan Total Static Pressure	= 3.0" wg
Fan Brake Horsepower	= 13
Fan Motor Horsepower	= 15
Constant Cold Deck	= 55 degrees
Constant Hot Deck	= 100 degrees
Dry Bulb Economizer	
No Night Setback or Optimum Start/Stop	
24 Hour Operation	
5 Day Use, 0800 through 1700	

Building Thermal Transmission = 0.81 Btu/hr ft^2degree F

0.8 KW per ton Centrifugal Chiller

0.70 Boiler Seasonal Efficiency

Natural Gas Fuel = 1,031,000 Btu per MCF

The calculation procedure follows the guide referenced above. Table 17 is the summary table of calculations based on two time clocks. At $0.05 per kilowatt-hour and $5.00 per MCF of natural gas, the savings potential of this system is $8,523 for a $400 investment in time clocks.

Table 18 is the summary table for time clocks and control retrofit for hot deck/cold deck reset. The savings becomes $11,716 for a $1,100 investment in retrofit components.

Table 19 is the summary table for EMCS control. Cost estimates are from "EMCS Cost Estimating Data". Projected savings is $19,375 (based on $20.00 per hour for labor) for $4,856 investment in interface equipment. This cost does not include the cost of the small EMCS system, only the interface hardware. Payback will be substantially longer if these costs are included.

SECONDARY SYSTEM
SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ **SYSTEM NO.** _____ **SYSTEM TYPE** Time Clock only

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	SAVINGS KWH	SAVINGS MCF	SAVINGS MH	COST
Scheduled Start/Stop	Clg: .00507 x .81 Btu/ft² hr°F x 20000 ft² x (168 - 55) x 1 x 0.8/ton Htg: 286 x .81 Btu/ft² hr°F x 20000 ft² x (168 - 55) x 1 /(0.7 x 1031000) V-Clg: .0301 x 15000 cfm x .20 x (168 - 55) x 1 x 0.8 /ton V-Htg: .679 x 15000 cfm x .20 x (168 - 55) x 1 /(0.7 x 103) Aux: 28.5 x 13 hp x (168 - 55) x 1		7425 8163 41866	 725 319		BASIC FUNCTIONS 200
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					
Ventilation/ Recirculation	WU V-htg: 5512 x 15000 cfm x .20 x (4 -.25)/(0.7 x 1031000) V-clg: .0301 x ___ cfm x ___ x((___ -(.25x ___ dy/wk)) x ___ /ton V-htg: .679 x ___ cfm x ___ x((___ -(.25x ___ dy/wk))/(___ x ___)			86		200
Economizer	(Computer simulation required.)					
Day/Night Setback	Clg: .00195 x ___ Btu/ft²hr°F x ___ ft² x ___ °F x (168 - ___) x ___ /ton Htg: 28.6 x ___ Btu/ft²hr°F x ___ ft² x ___ °F x (168 - ___)/(___ x ___)					
Reheat Coil Reset	Clg: .00526 x ___ hr/wk x ___ cfm x ___ °F x ___ /ton Htg: 56.16 x ___ hr/wk x ___ cfm x ___ °F/(___ x ___)					
Hot/Cold Deck Reset	Clg: .00526 x ___ hr/wk x ___ cfm x ___ x ___ °F x ___ /ton Htg: 1.08 x ___ hr/wk x ___ cfm x ___ x(23.4 x ___ + 28.6 x ___)/(___ x ___)					
Safety Alarms	Labor: 2 Manhours					
	TOTALS FOR SYSTEM		57454	1130		$400

Table 17

SECONDARY SYSTEM
SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ **SYSTEM NO.** _____ **SYSTEM TYPE** Time Clock with Minor Control Retrofit

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	SAVINGS KWH	SAVINGS MCF	SAVINGS MH	COST
Scheduled Start/Stop	Clg: .00507 x .81 Btu/ft² hr°F x 20000 ft² x (168 − 55) x 1 x 0.8 /ton Htg: 286 x .81 Btu/ft² hr°F x 20000 ft² x (168 − 55) x 1 /(0.7 x 1031000) V-Clg: .0301 x 15000 cfm x .20 x (168 − 55) x 1 x 0.8 /ton V-Htg: .679 x 15000 cfm x .20 x (168 − 55) x 1 /(0.7 x 1031000) Aux: 28.5 x 13 hp x (168 − 55) x 1		7425 8163 41866	 725 319		BASIC FUNCTIONS 200
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					
Ventilation/ Recirculation	WU V-htg: 5512 x 15000 cfm x .20 x (4 −.25)/(0.7 x 1031000) V-clg: .0301 x _____ cfm x ____ x((____ −(.25x ___ dy/wk)) x ______ /ton V-htg: .679 x _____ cfm x ____ x((____ −(.25x ___ dy/wk))/(____ x _____)			86		200
Economizer	(Computer simulation required.)					
Day/Night Setback	Clg: .00195 x ___ Btu/ft² hr°F x ___ ft² x __ °F x (168 − ___) x ______ /ton Htg: 28.6 x ___ Btu/ft² hr°F x ___ ft² x __ °F x (168 − ___)/(____ x _____)					
Reheat Coil Reset	Clg: .00526 x ____ hr/wk x ____ cfm x ____ °F x ______ /ton Htg: 56.16 x ____ hr/wk x _____ cfm x ____ °F/(_____ x ________)					
Hot/Cold Deck Reset	Clg: .00526 x 55 hr/wk x 15000 cfm x 0.50 x 10 °F x 0.8 /ton Htg: 1.08 x 55 hr/wk x 15000 cfm x 0.5 x (23.4 x 20 + 28.6 x 10)/(0.7 x 1031000)		17358	 465		700
Safety Alarms	Labor: 2 Manhours					
	TOTALS FOR SYSTEM		74812	1595		$1100

Table 18

SECONDARY SYSTEM
SAVINGS CALCULATIONS AND COSTS

BUILDING NO. ______ **SYSTEM NO.** _____ **SYSTEM TYPE** Small EMCS

FUNCTION	SAVINGS CALCULATIONS	SAVINGS KW	SAVINGS KWH	SAVINGS MCF	SAVINGS MH	COST
Scheduled Start/Stop	Clg: .00507 x .81 Btu/ft² hr°F x 20000 ft² x (168 - 55) x 1 x 0.8 /ton Htg: 286 x .81 Btu/ft²hr°F x 20000 ft² x (168 - 55) x 1 /(6.7 x 1031000) V-Clg: .0301 x 15000 cfm x .20 x (168 - 55) x 1 x 0.8 /ton V-Htg: .679 x 15000 cfm x .20 x (168 - 55) x 1 /(0.7 x 1031000) Aux: 28.5 x 13 hp x (168 - 55) x 1		7425 8163 41866	 725 319		BASIC FUNCTIONS 290
Duty Cycling	Aux: 5.17 x ______ hp x ______ hr					
Demand Limit	KW: 0.149 x ________ hp					
Optimum Start/Stop	WU Aux: .0852 x 15 hp x ((2 hr x 232) - 300 hr) x 5 days/wk CD Aux: 11.3 x 15 hp x (2 hr - .75) x 5 days/wk		1048 1059			
OA Limit	Aux: 0.597 x _______ hp x (273 + 204)					
Run Time	Labor: 2 Manhours				2	
Ventilation/ Recirculation	WU V-htg: .5512 x 15000 cfm x .20 x (4 -.25)/(0.7 x 1031000) V-clg: .0301 x _____ cfm x ____ x((____-(.25x___dy/wk)) x ______/ton V-htg: .679 x _____ cfm x ____ x((____-(.25x___dy/wk))/(____x_____)			86		459
Economizer	(Computer simulation required.)					
Day/Night Setback	Clg: .00195 x .81 Btu/ft²hr°F x 20000 ft² x 10 °F x (168 - 45) x 0.8 /ton Htg: 28.6 x .81 Btu/ft²hr°F x 20000 ft² x 15 °F x (168 - 45)/(0.7 x 1031000)		31085	1184		549
Reheat Coil Reset	Clg: .00526 x ____ hr/wk x _____ cfm x _____ °F x _______/ton Htg: 56.16 x ____ hr/wk x _____ cfm x _____ °F/(______ x ________)					
Hot/Cold Deck Reset	Clg: .00526 x 45 hr/wk x 15000 cfm x 0.5 x 10 °F x 0.8 /ton Htg: 1.08 x 45 hr/wk x 15000 cfm x 0.5 x (23.4 x 20 + 28.6 x 10)/(0.7 x 1031000)		17358	233		3758
Safety Alarms	Labor: 2 Manhours				2	300
	TOTALS FOR SYSTEM		108004	2547	4	4856

Table 19

The results are summarized below:

	Cost	Savings	Simple Payback
Time Clock	$400	$8523	1 Month
Time Clock & Controls	$1100	$11716	1.1 Months
EMCS	$4856	$18215	3.2 Months

Obviously, with the poor original system and high building loads, the payback looks very good. Comparative studies such as this are used to compare various levels of control. For systems operating continuously, time clocks will be a substantial improvement if operation over 24 hours is not required. Control retrofits, as discussed under time clocks, are also possible, however, routine maintenance is required to achieve projected savings through semiannual calibration. EMCS systems offer the greatest potential for total building management.

Conclusions

The proper selection of an energy management device for single buildings requires a comprehensive evaluation of savings potential for each alternative. The results are quantitative only, however, and the qualitative considerations of maintenance, expandability, and flexibility must also be considered. A time clock, at the low end of the range, is a high maintenance item with very limited flexibility. If building schedules are very routine and predictable, using clocks for shut-down may be acceptable. If schedules vary, either clocks will be rescheduled, or override switches must be incorporated into the circuits. Experience has shown that time clocks are prone to mechanical failure, and frequent abuse. When properly applied and maintained, time clocks are a practical alternative.

Duty cycling devices and demand limiters serve the sole purpose of monitoring and controlling electric demand to reduce utility billings. Application requires a diversity of loads, which may not be present in smaller single buildings. When these devices are used, proper override controls must be incorporated to prevent high or low temperature extremes.

Programmable controllers require a special knowledge of ladder logic programming techniques. These devices are applicable where a micro EMCS has excess capability for the given application, and where reporting, monitoring, print-outs and other feedback items are not required. These controllers do offer direct digital control, which can override or replace existing controls to create versatile and very powerful system control sequences.

Micro and small EMCS have the greatest capability and applicability for single buildings. These devices offer the ability to maintain building control from a single location, and monitor equipment status, temperatures, power consumption and more.

The proper selection must be made based on desired control, savings potential, estimated costs, economic payback, and budget constraints.

CHAPTER 4

GUIDES TO EFFICIENT INSTALLATION

This chapter is devoted to examining the actual hookup of EMCS controls to air handling unit fans, chillers, reciprocating compressors, boilers, and components of air handling units.

The tie of time clocks into fan starter circuits is necessary for effective control. The implementation is presented along with integration of single and dual setpoint night setback thermostats.

The supervisory control of chillers and reciprocating compressors is presented. Boiler control interface is discussed with reset concepts. Typical air handling units are presented, with details on control of the individual sections.

Only control interface details applicable to time clocks, processors, micro and small EMCS are presented. The capability to monitor also exists. The details of monitoring are presented in Figures 4-1 through 4-29 of NAVFAC DM-4.9 "Energy Monitoring and Control Systems". Symbols used are either standard industry symbols, or special symbols presented in Figure 1-30 of this reference. A list of standard symbols is included in Appendix D.

Time Clock Interface

The general interface technique of on-off or open-closed relays is presented here. These apply to time clocks, duty cyclers, demand limiters, and digital outputs from programmable controllers, micro EMCS, and small EMCS.

The digital interface is normally tied into the fan starter circuit. The exception to this is when fans are of fractional horsepower and the control relay is interfaced directly into the line voltage power feed to the motor. Typically in a magnetic starter circuit, the high temperature cut-out, low temperature cut-out (fire and freeze stats, respectively), and/or the smoke detector, are wired in series such that a break in any one of these normally closed devices deactivates the starter. When the contact closes the motor is reactivated. Controls are sequenced to close outside air, return air, and exhaust air dampers when the fan is deactivated, and send other devices to fail safe conditions.

Figure 18 details normal control relay interface into the holding coil circuit of the starter. Note that wiring must be in series such that other safety devices and overloads are never removed from the circuit. When night setback is required, for low temperature only, a two position thermostat is wired in parallel with the new control relay. This device is a normally open contact, which closes below the set point. The typical device is selected with a differential, which is the difference between make and break of the contacts, of 2 degrees. The wiring of the night setback thermostat is shown in Figure 19. Where both night setback and setup are desired, a second thermostat, or a dual setpoint thermostat is wired in parallel with the new control relay as shown in Figure 20. If the temperature falls below the low setpoint or above the high setpoint, this would cycle the controlled unit on until the temperature increases or decreases through the differential.

A wide variety of electric thermostats are available. Consult manufacturers catalogs for selection.

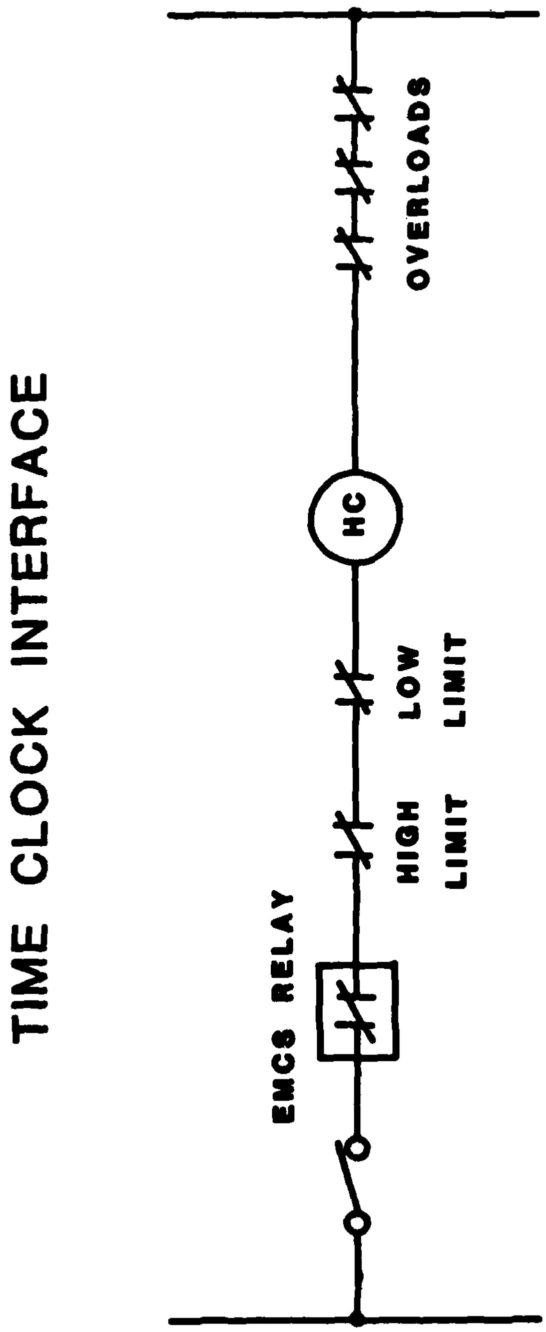

TIME CLOCK INTERFACE
OVERLOADS
HC
LOW LIMIT
HIGH LIMIT
EMCS RELAY

Figure 18

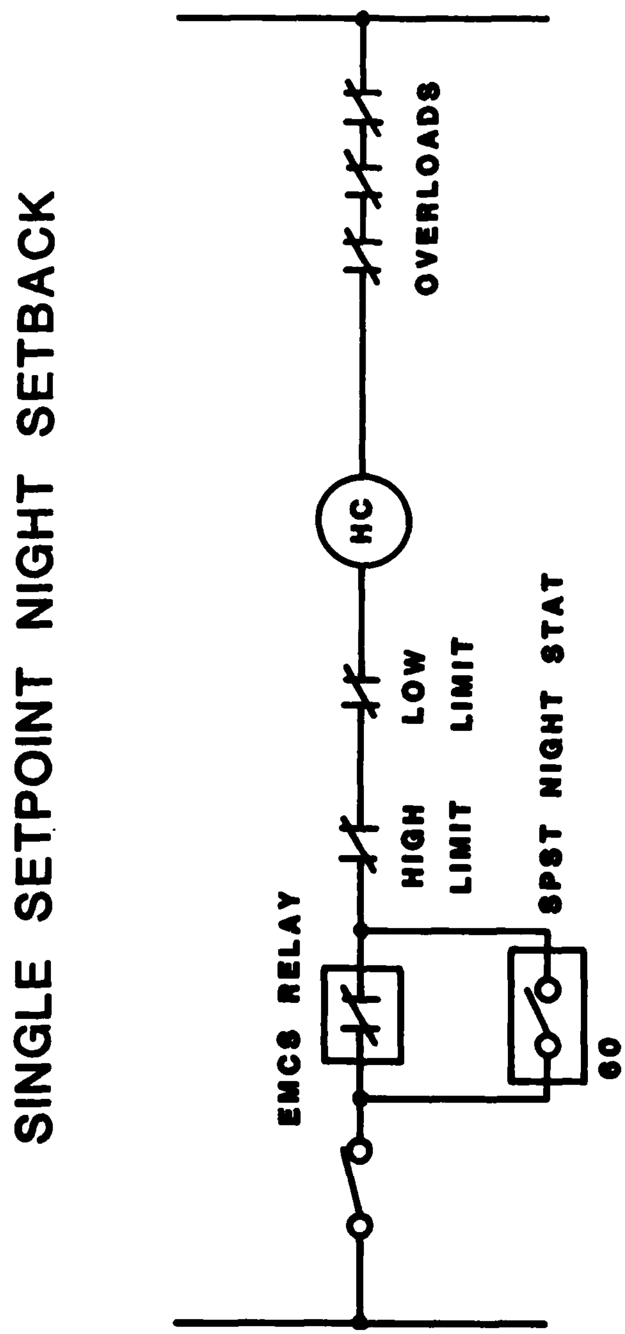

SINGLE SETPOINT NIGHT SETBACK
OVERLOADS
HC
LOW LIMIT
HIGH LIMIT
SPST NIGHT STAT
EMCS RELAY
60

Figure 19

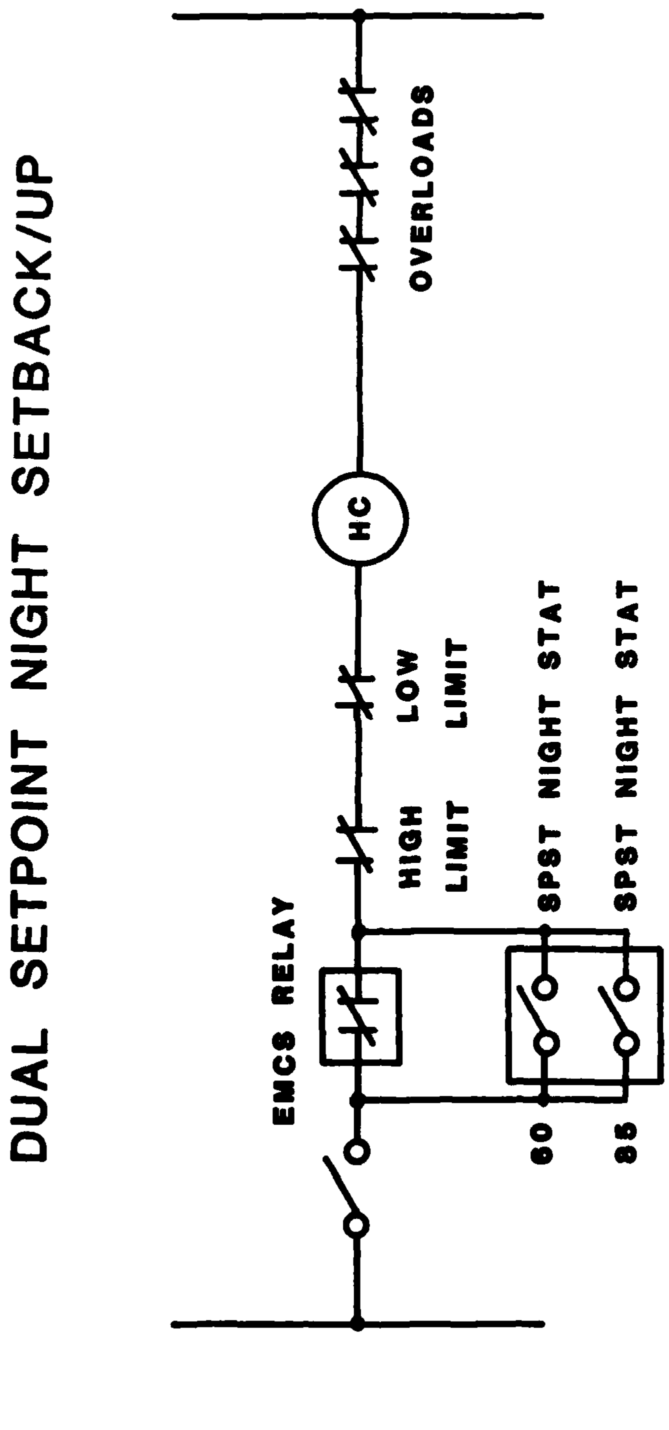

DUAL SETPOINT NIGHT SETBACK/UP
OVERLOADS
HC
LOW LIMIT
HIGH LIMIT
EMCS RELAY
SPST NIGHT STAT
SPST NIGHT STAT
60
85

Figure 20

Primary Cooling Equipment

The interface to chillers, condenser water controllers, and reciprocating compressors is presented in the five figures which follow.

The control of centrifugal chillers is normally done in three ways. The first option is to directly intercept the pneumatic control signal from the chiller controls to the inlet guide vanes. In this centrifugal device, the positioning of the inlet guide vanes controls capacity of the device. This option is not recommended, as all of the manufacturers safety controls to prevent surge are bypassed, and damage or destruction of the chiller could result on EMCS control failure.

There are two practical options. The first is feasible when analog output is available, which would be typical of a programmable controller, or micro or small EMCS. Figure 21 shows the control configuration to reset a two input pneumatic controller to limit demand, and reset chilled water temperature, thus this device serves dual purposes. If a standard controller has a set point of 44 degrees and a 4 degree throttling range, a 45 degree water temperature will adjust chiller capacity to 75 percent. If unloading of the chiller is desired, the set point could be reset to 45 degrees for example. The actual chilled water temperature of 45 degrees will, through the controller, reset chiller capacity to 50 percent. This reduces demand as desired.

The most important feature of this method is that no chiller controls are bypassed. This method is recommended where chillers are under warranty or extended service plans.

Where analog outputs are not available, as is the case of most duty cycling and demand limiting devices, the control circuit for chiller maximum capacity can be intercepted. This is detailed in Figure 22 for a standard capacity rotary switch of 40, 60, 80, and 100 percent. The normally open relays are positioned in each leg, and the duty cycle or demand program selects the capacity desired. If the chiller maximum capacity is set at 80 percent and demand reduction is required, switching to the 60 percent relay is executed, and so on, until demand is reduced. Note that if the chiller is only operating at 50 percent, the reduction of the maximum capacity switch from 80 to 60 percent will not reduce demand. For this reason, it is normally desirable to intercept the chilled water temperature controllers as outlined in Figure 21. On intercepting the capacity switching, one relay should be normally closed to continue chiller operation in a default maximum capacity condition on EMCS shutdown or failure.

Figure 23 details reset of a condenser water temperature controller. Lower condenser water temperatures are desirable to reduce chiller power consumption. Reset is best accomplished by replacing the existing single input controller with a dual input controller, providing the second input as the reset signal from an analog EMCS output.

Reciprocating chillers are normally controlled by pneumatic-electric switch (PE) activation, where the PE switch pneumatic input signal is from a standard controller. Two cases occur. The first is where either several compressors, or several stages of a single compressor, are activated by several PE switches. In this situation, lock out of these units is normally accomplished through a normally closed relay (if operation is desired on EMCS shutdown or failure) or a normally open relay (if operation is to stop on EMCS shutdown or failure) wired into each PE switch circuit. This is shown for a two stage control in Figure 24. Control of nominal horsepower hermetic compressors should be through a digital output relay in the electric thermostat control circuit, similar to Figure 22, where the control signal is the 100% circuit only.

The second case occurs where the coil is activated by a single PE switch, with internal controls providing unloading. Figure 25 details control of this option.

Control of these primary refrigeration machines should be done with due caution. When in doubt, always consult the manufacturer. Whenever chillers are controlled, emphasize design of the interface which does not circumvent any of the built in safety controls and devices.

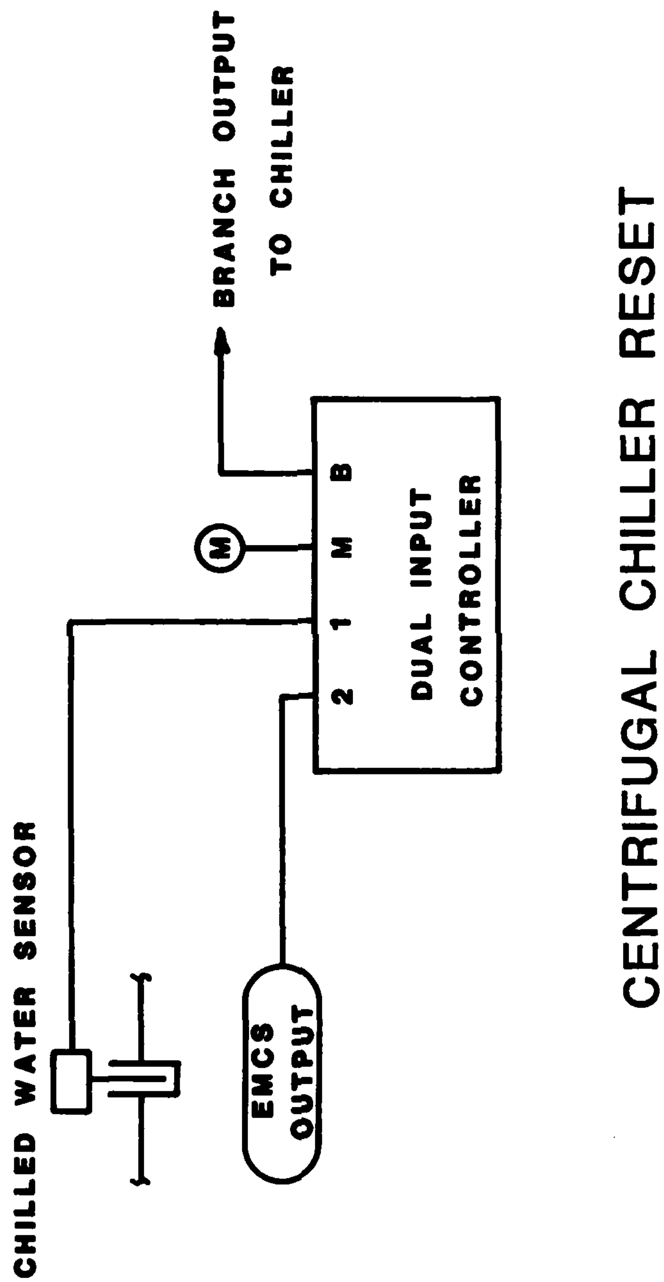

BRANCH OUTPUT
TO CHILLER
B
M
1
2
DUAL INPUT
CONTROLLER
CHILLED WATER SENSOR
EMCS
OUTPUT
CENTRIFUGAL CHILLER RESET

Figure 21

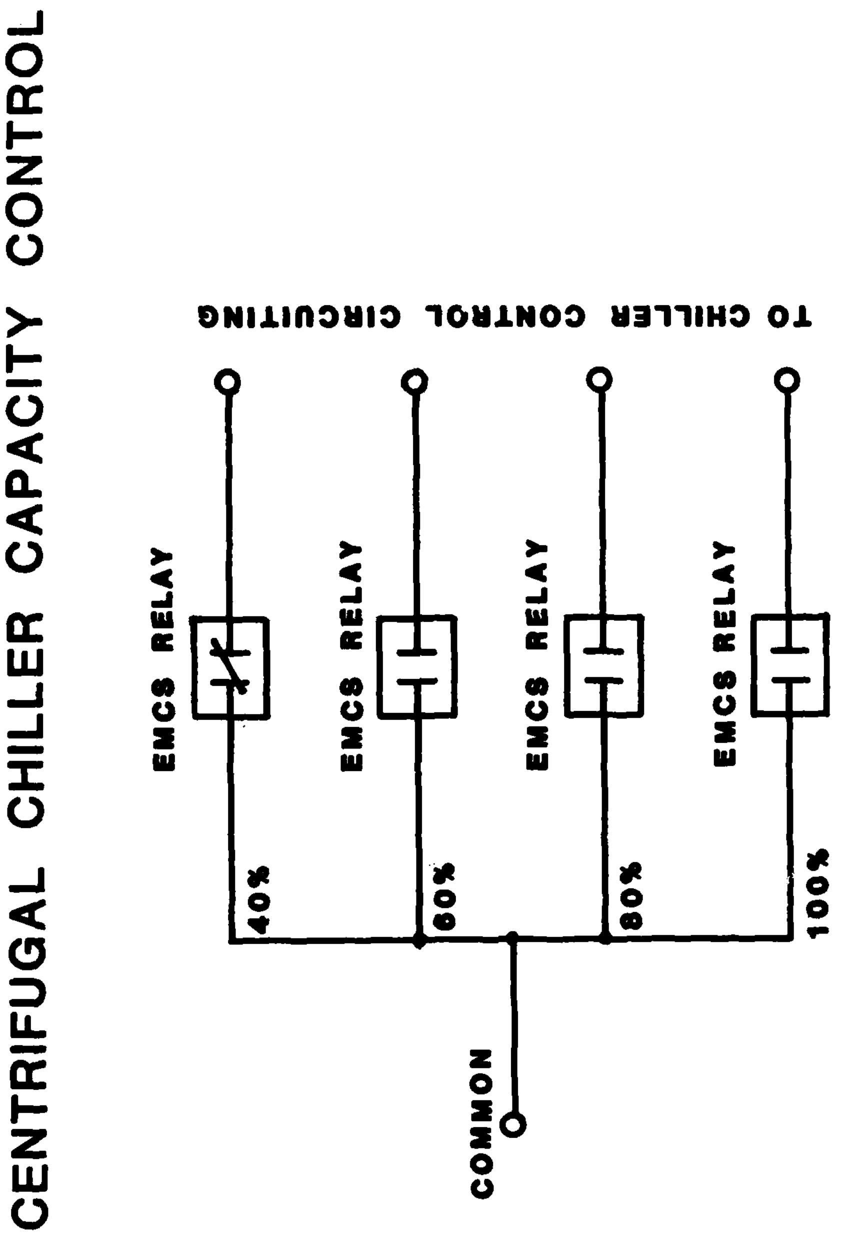

CENTRIFUGAL CHILLER CAPACITY CONTROL
TO CHILLER CONTROL CIRCUITING
EMCS RELAY
EMCS RELAY
EMCS RELAY
EMCS RELAY
40%
60%
80%
100%
COMMON

Figure 22

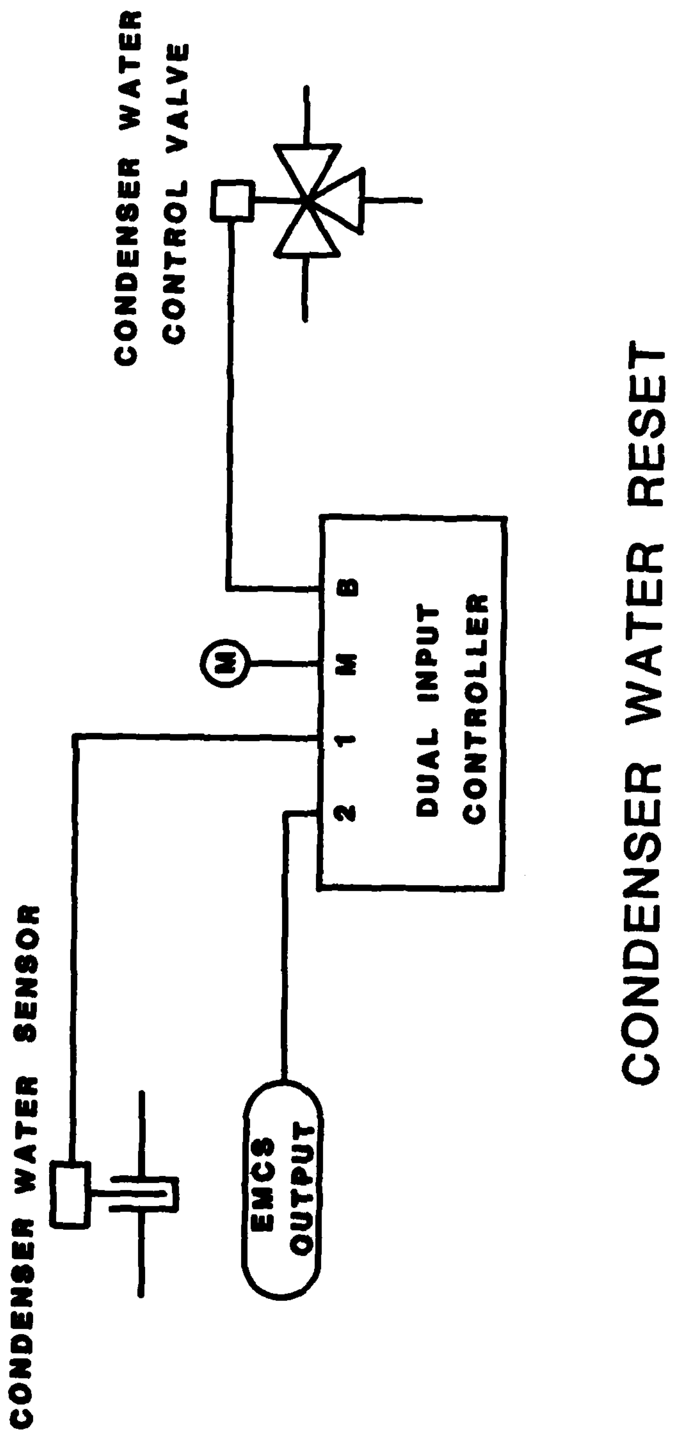

CONDENSER WATER
CONTROL VALVE
B
M
1
2
DUAL INPUT
CONTROLLER
CONDENSER WATER SENSOR
EMCS
OUTPUT
CONDENSER WATER RESET

Figure 23

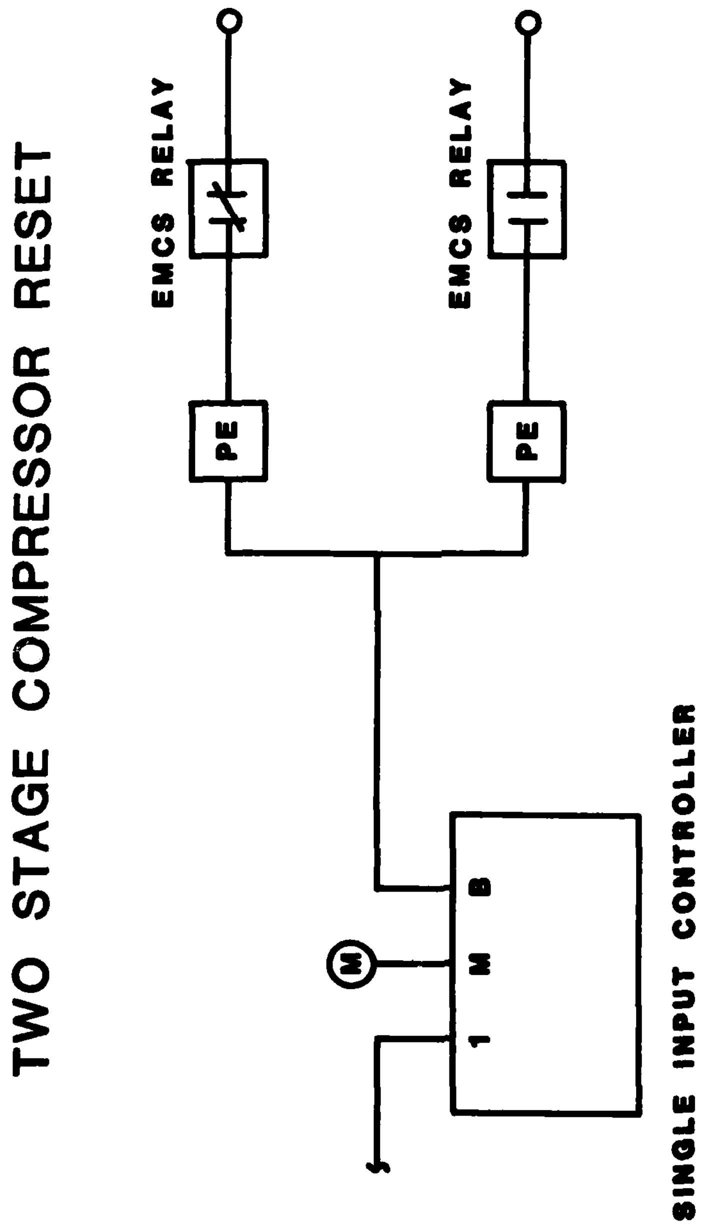

TWO STAGE COMPRESSOR RESET
EMCS RELAY
EMCS RELAY
PE
PE
M
1
M
B
SINGLE INPUT CONTROLLER

Figure 24

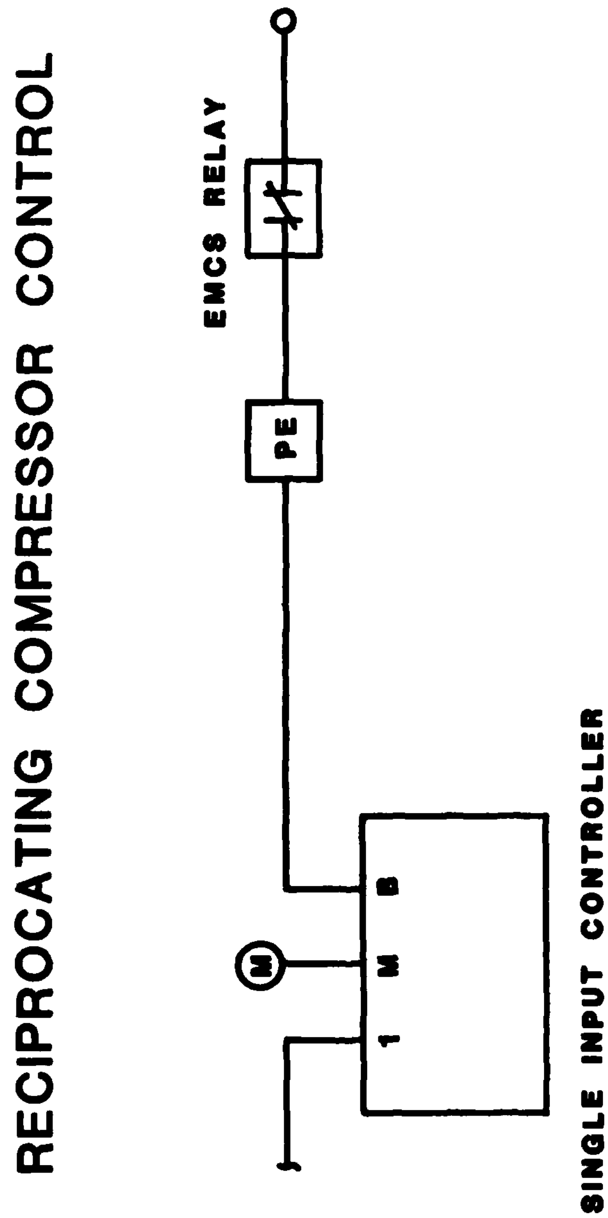

RECIPROCATING COMPRESSOR CONTROL
EMCS RELAY
PE
M
1
M
B
SINGLE INPUT CONTROLLER

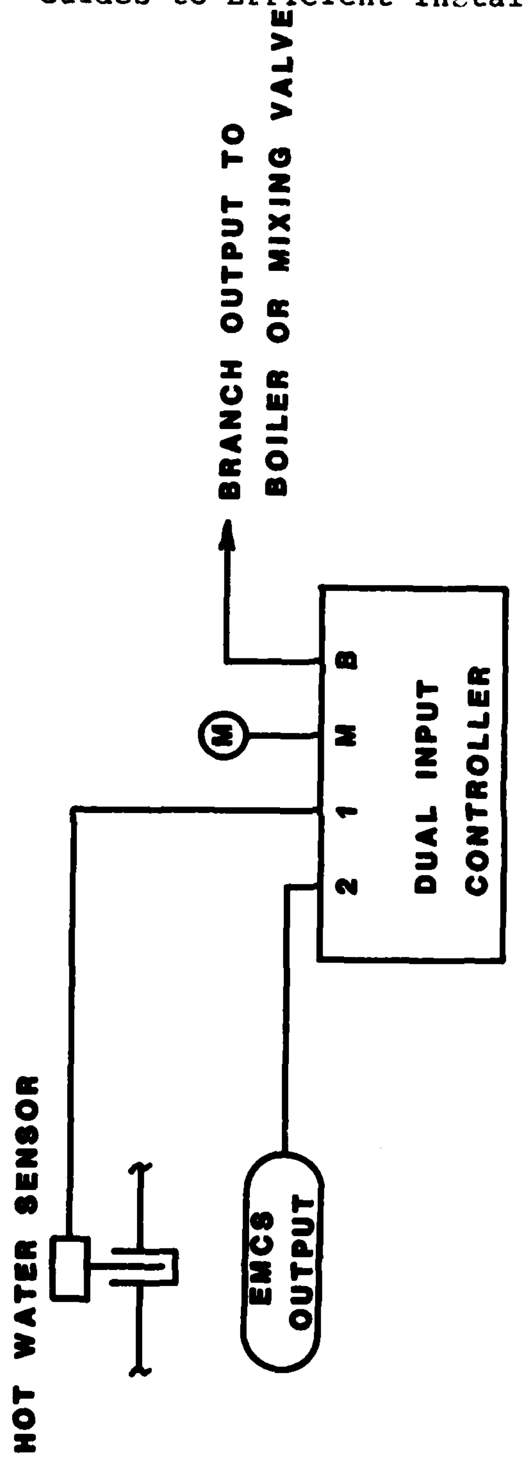
Figure 25

Boiler Control

Steam and hot water boilers require slightly different control techniques. Steam boilers are operated off of a pressure controller. Normally this pressure setting is determined based on the needs of the connected coils, heat exchangers, and other devices. EMCS control for single building applications is best accomplished in controlling the using devices to minimize use of steam, which will in turn reduce loads on the steam boiler.

Hot water boilers are controlled from temperature controllers. Where reset is not utilized,the controller is single input. This controller is replaced with a dual input device, with the second input from the EMCS to reset the controller setpoint. The setpoint reset can be based on outside air temperature, maximum zone load, return air temperature, and any other reset variable. A typical control scheme is shown in Figure 26.

Where boilers are controlled from two position electric controllers, reset does not apply. Control should be on/off similar to nominal horsepower hermetic compressors, as discussed for these devices.



HOT WATER BOILER RESET

Figure 26

Air Handling Unit Control

All air handling units are comprised of three main sections. These are the "mixing" section, the "air handling unit" section, and the "terminal devices" section. Almost any air handler in production today, or currently installed, can be modeled by selecting one schematic from each of these sections and combining. Each section has its own method of control. Control systems which are further refined interconnect some of the control between these sections to provide reset and optimization.

Four typical systems are shown. Figure 27 shows a single zone system which could be controlled as a reheat system, a standard heating/cooling system, or a variable air volume system. Figure 28 shows a terminal reheat system. Figure 29 shows a multizone system, and Figure 30 shows a dual duct system.

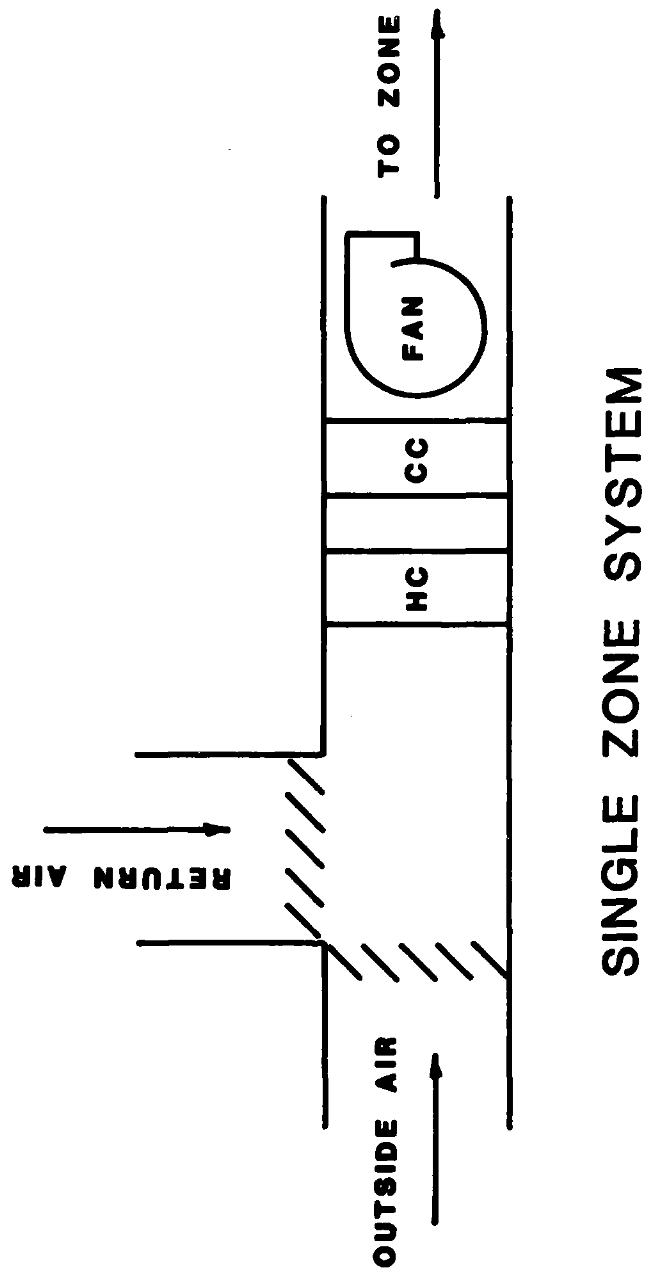
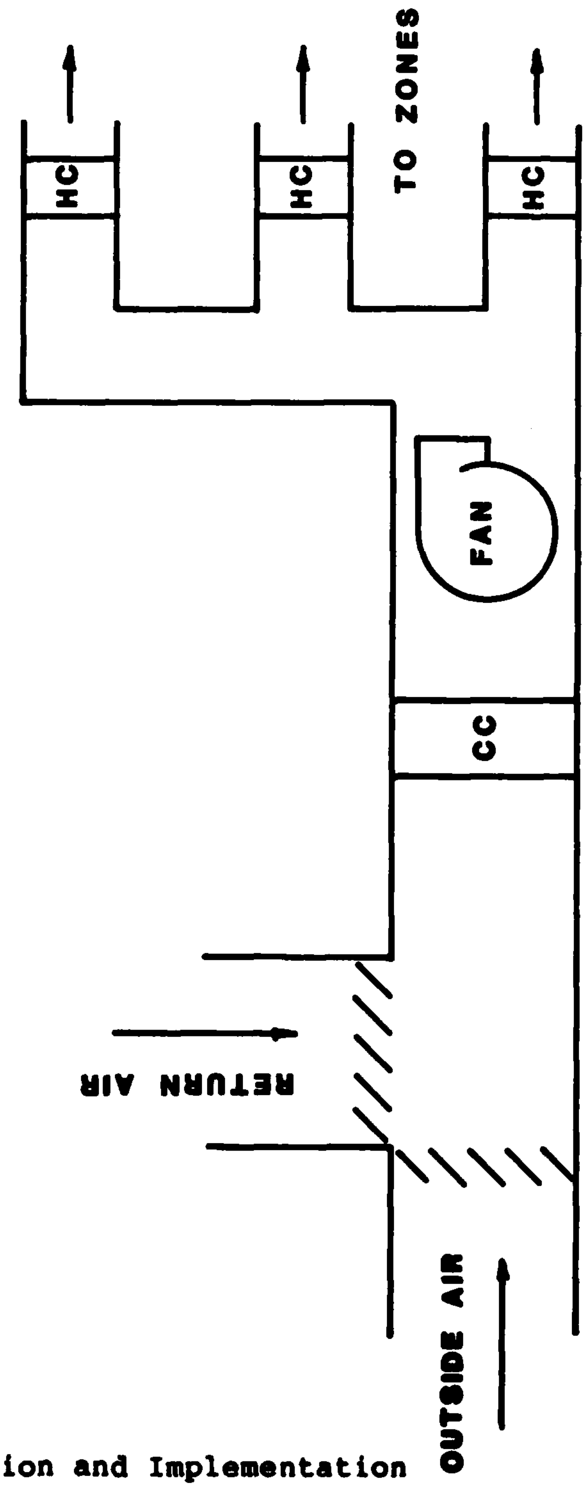


Figure 27



TERMINAL REHEAT SYSTEM

Figure 28

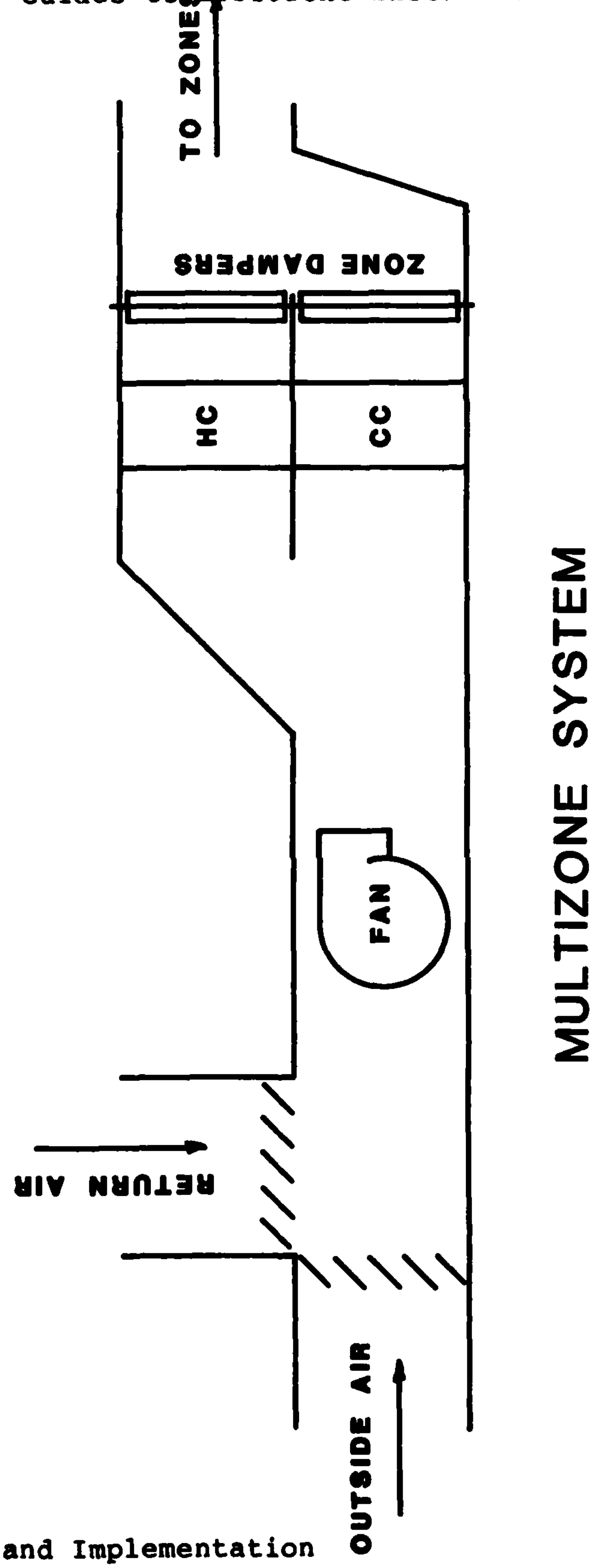
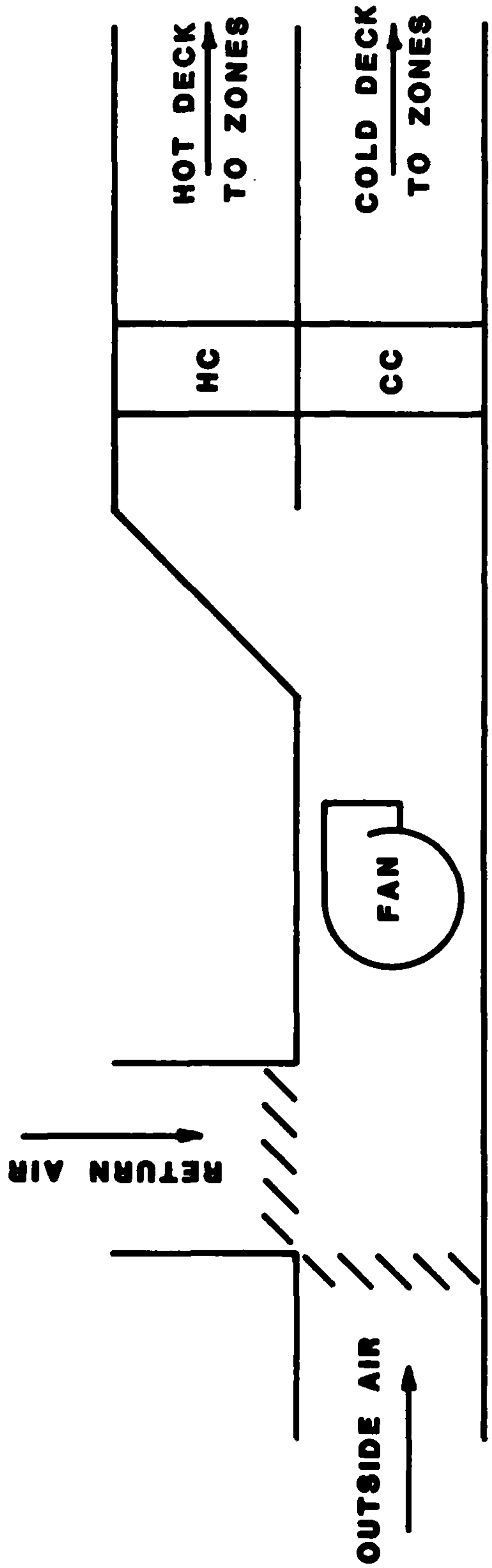

TO ZONES
ZONE DAMPERS
HC
CC
FAN
MULTIZONE SYSTEM
RETURN AIR
OUTSIDE AIR

Figure 29



DUAL DUCT SYSTEM

Figure 30

Mixed Air Section

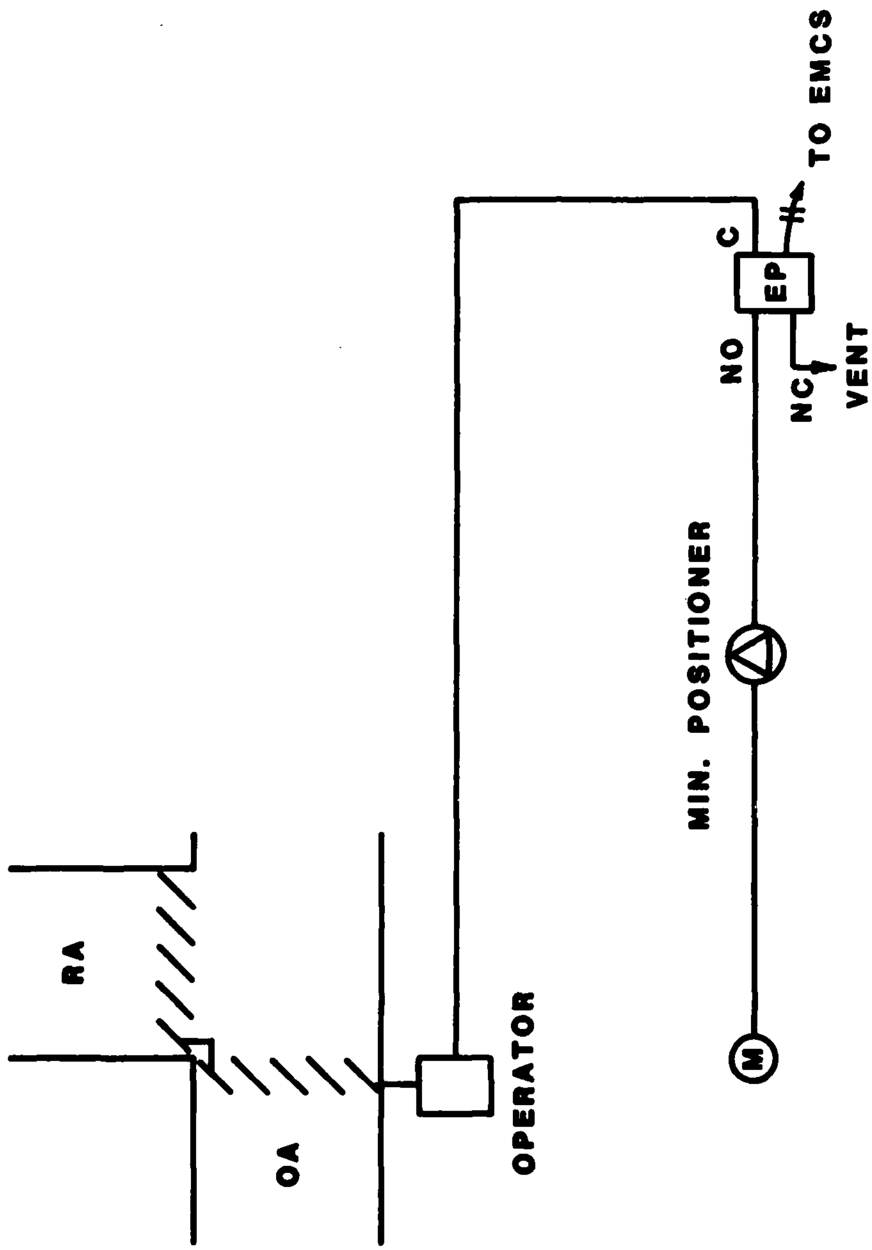
The mixed air section is the location where outside air is mixed with return air. The control of this section should be checked and calibrated at least semiannually to ensure maximum savings. Three typical mixed air sections are shown with EMCS control interface.

Figure 31 details a section with a fixed quantity of outside and return air. To control this system pneumatically, main air is sent to a minimum positioner where the output is adjusted to set damper position. To provide time clock (or any other digital control) of the outside air damper, the pneumatic branch line to the damper operators is intercepted with a solenoid air valve.

Where a dry bulb economizer exists, Figure 32 details interface requirements for closing of outside dampers. It is important that the final branch line to the actuator be intercepted. If the EMCS is used for economizer high limit changeover, the two position reverse acting controller C-1 is replaced with a solenoid air valve.

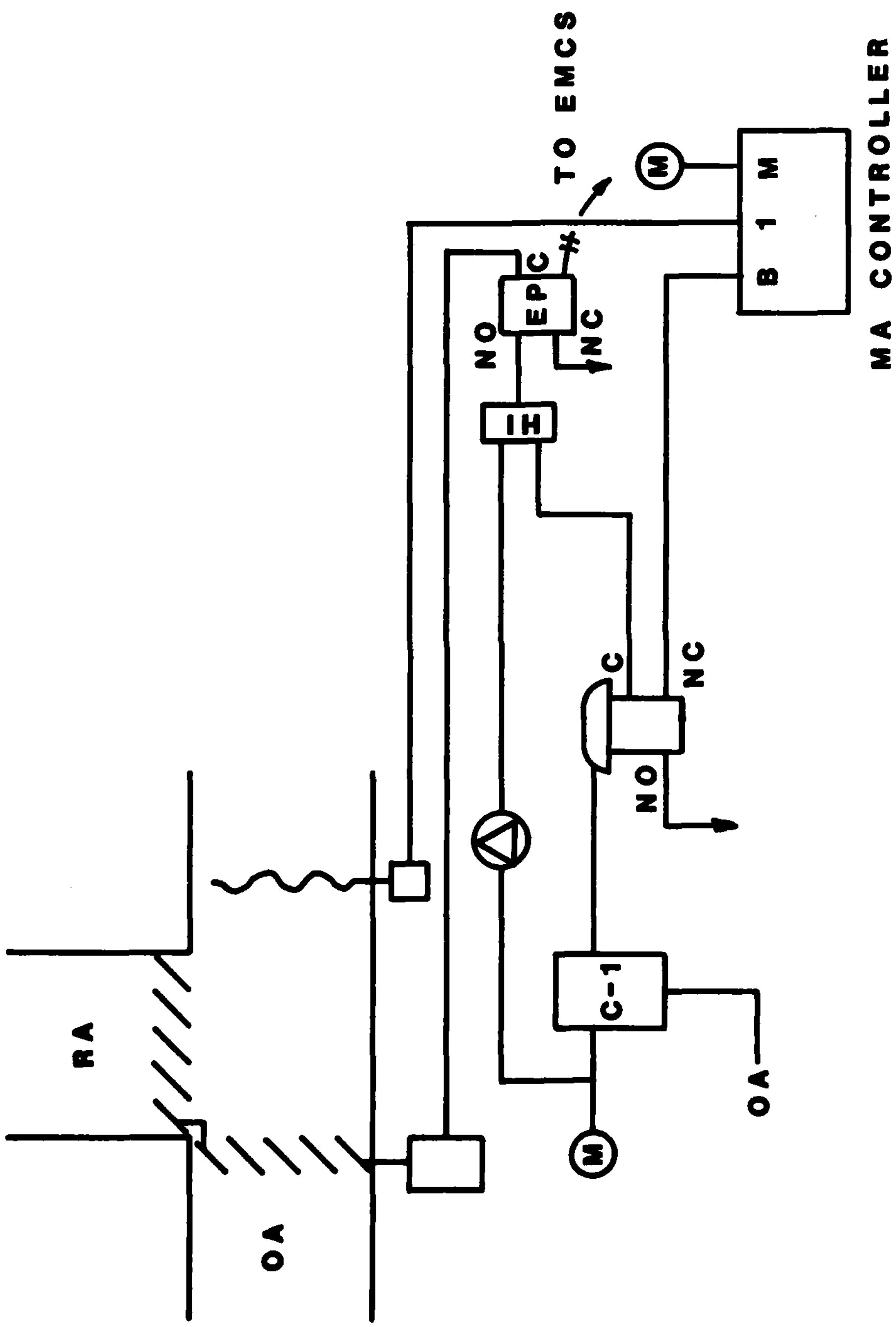
Where enthalpy changeover is desired, the EMCS commands the solenoid air valve V-2 to pass main air below the changeover valve, and vent to atmosphere (C to NO) above the changeover. Solenoid air valve V-1 is used for night shut down of outside air dampers to full closed when desired.

These mixed air sections can proceed any of the air handling unit sections described in the following section.



OPEN-CLOSE DAMPER CONTROL

Figure 31



ECONOMIZER DAMPER OVERRIDE

Figure 32

AD-A134 006 SELECTION AND IMPLEMENTATION OF SINGLE BUILDING EMCS (ENERGY MONITORING AND CONTROL SYSTEMS)(U) STAN AND ASSOCIATES INC DAYTON OH R STAN AUG 83 NCEL-CR-83.037 3/3

UNCLASSIFIED N68305-3018-7940 F/G 13/1 NL

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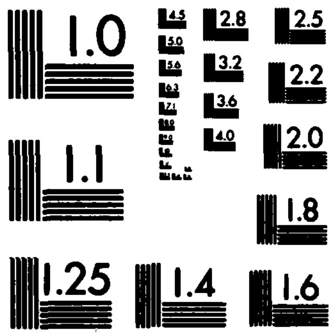
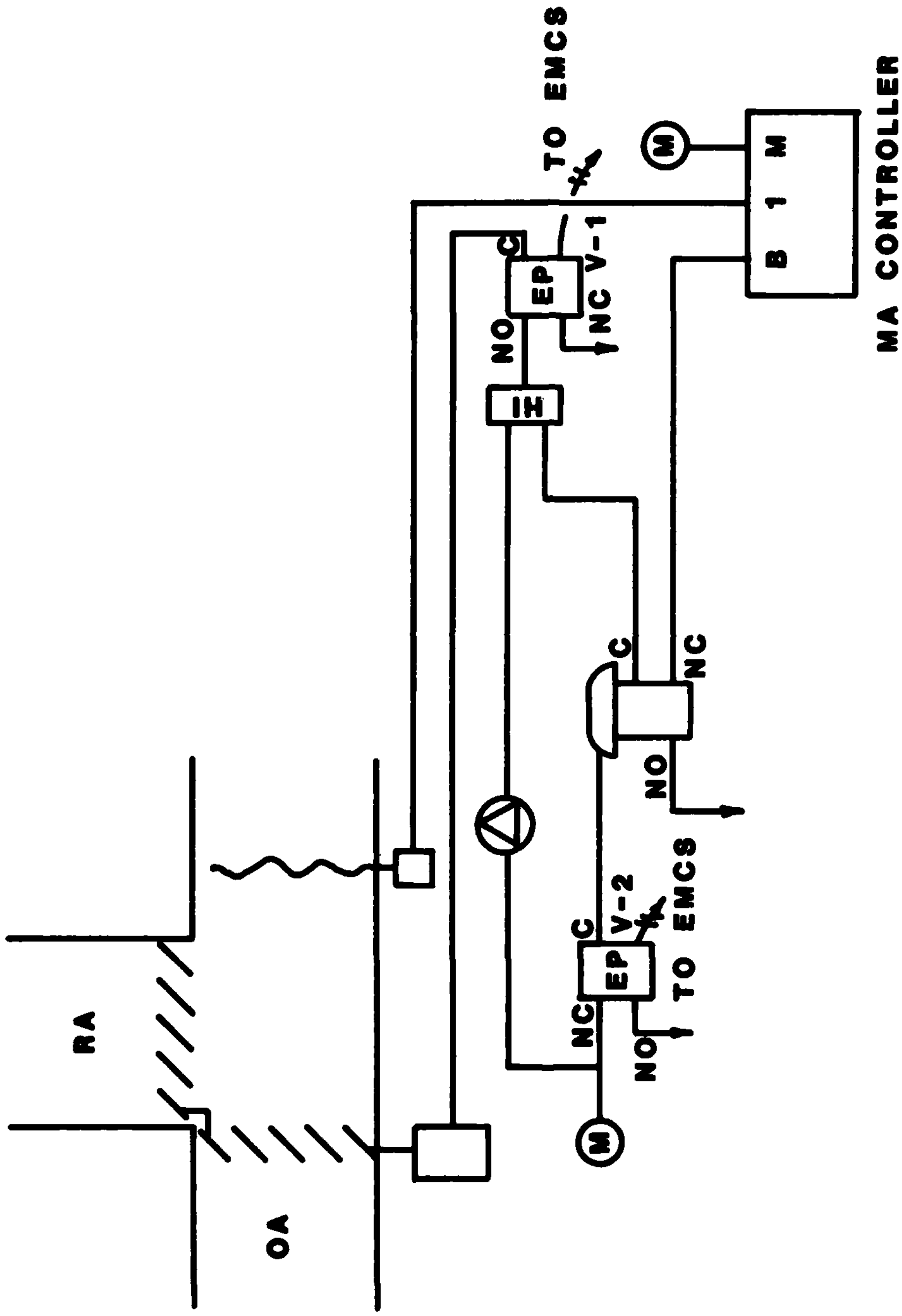


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



ENTHALPY CHANGEOVER

Figure 33

Air Handling Unit Section

The air handling unit section contains numerous devices; proportional chilled water coils, direct-expansion coils, bypass sections, steam coils, hot water coils, and electric resistance coils. There are other devices, but all are controlled in a similar fashion.

A chilled water coil is a typical proportionally controlled device. In single zone systems the coil is normally controlled directly from a room controller. In multizone or dual duct systems the control is normally from a discharge sensor. Figure 34 illustrates the typical EMCS tie to a new dual input controller for reset of cooling coil leaving conditions.

Direct expansion or "DX" coils are activated by liquid line solenoid valves, normally from a PE switch. To lock out mechanical cooling for duty cycling of the compressor, demand limiting, night shutdown, or reset, a normally closed EMCS relay is wired in series with the PE switch connection as shown in Figure 35.

Where a DX or chiller water coil runs wild and capacity is controlled by face and bypass, reset of the bypass section controller, and thus the leaving air temperature, is controlled as shown in Figure 36.

Two position coils such as steam are controlled by an on-off signal, again normally from a PE switch. Lockout of heating is performed with a normally closed relay as shown in Figure 37. (Caution! Watch out for freeze-up of coils.)

Hot water coils can be controlled in a two-position sequence, but are often controlled proportionally. Reset of heating coil discharge temperatures is shown in Figure 38.

Electric resistance devices are either controlled proportionally, or staged. Where proportional, reset the controller input as shown for the hot water coil of Figure 38. For staged coils, a control relay is normally placed in the control circuit of each stage of the heating to allow total or partial shutdown.

Each of these examples of the air handling unit section can be combined with any of the preceding mixing sections, or terminal devices sections to follow.

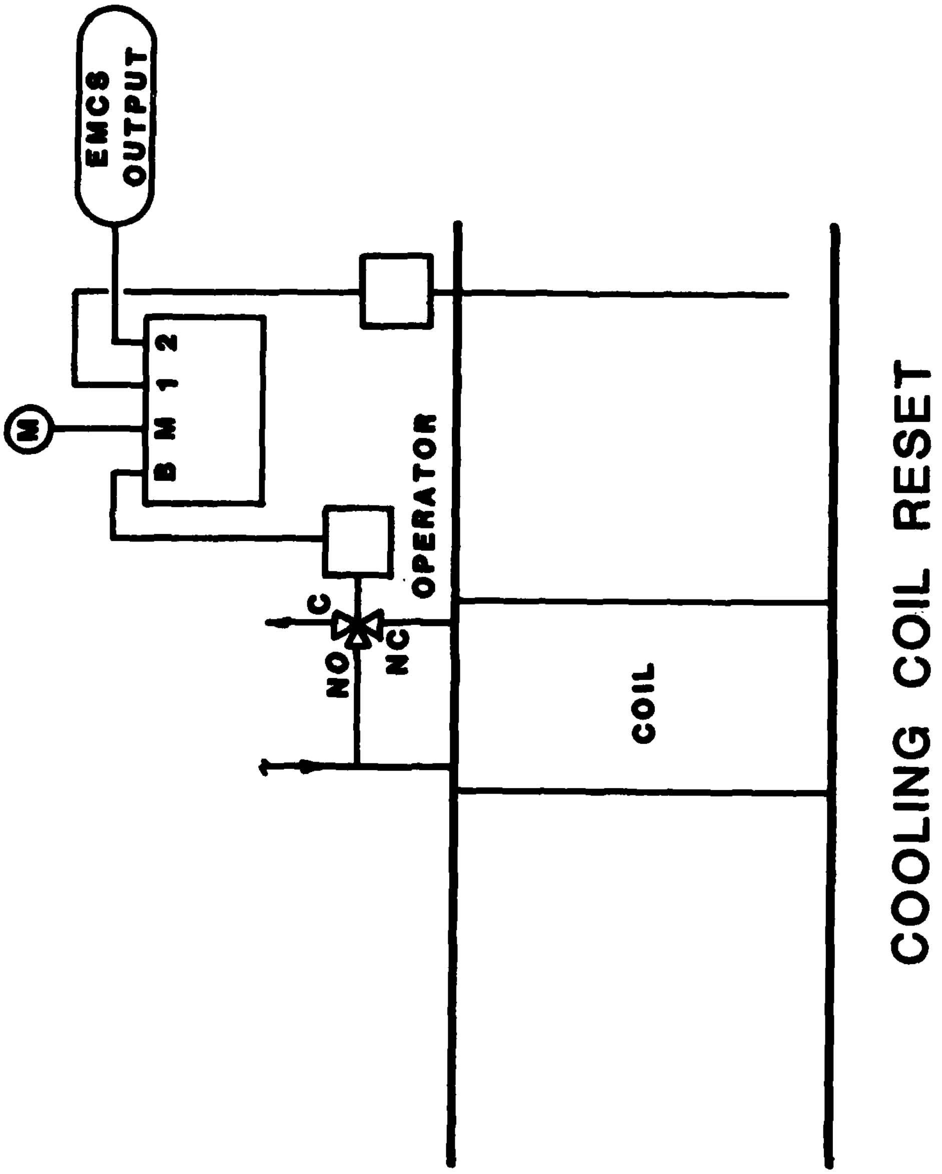


Figure 34

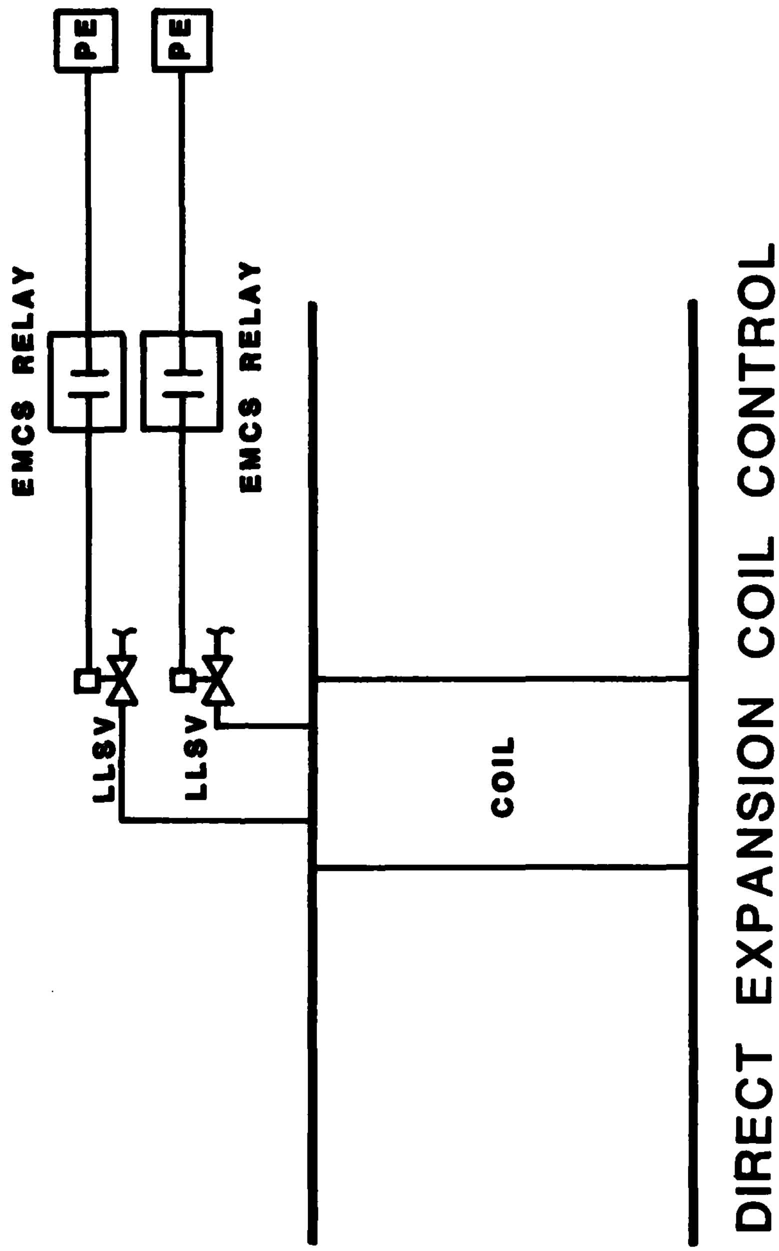
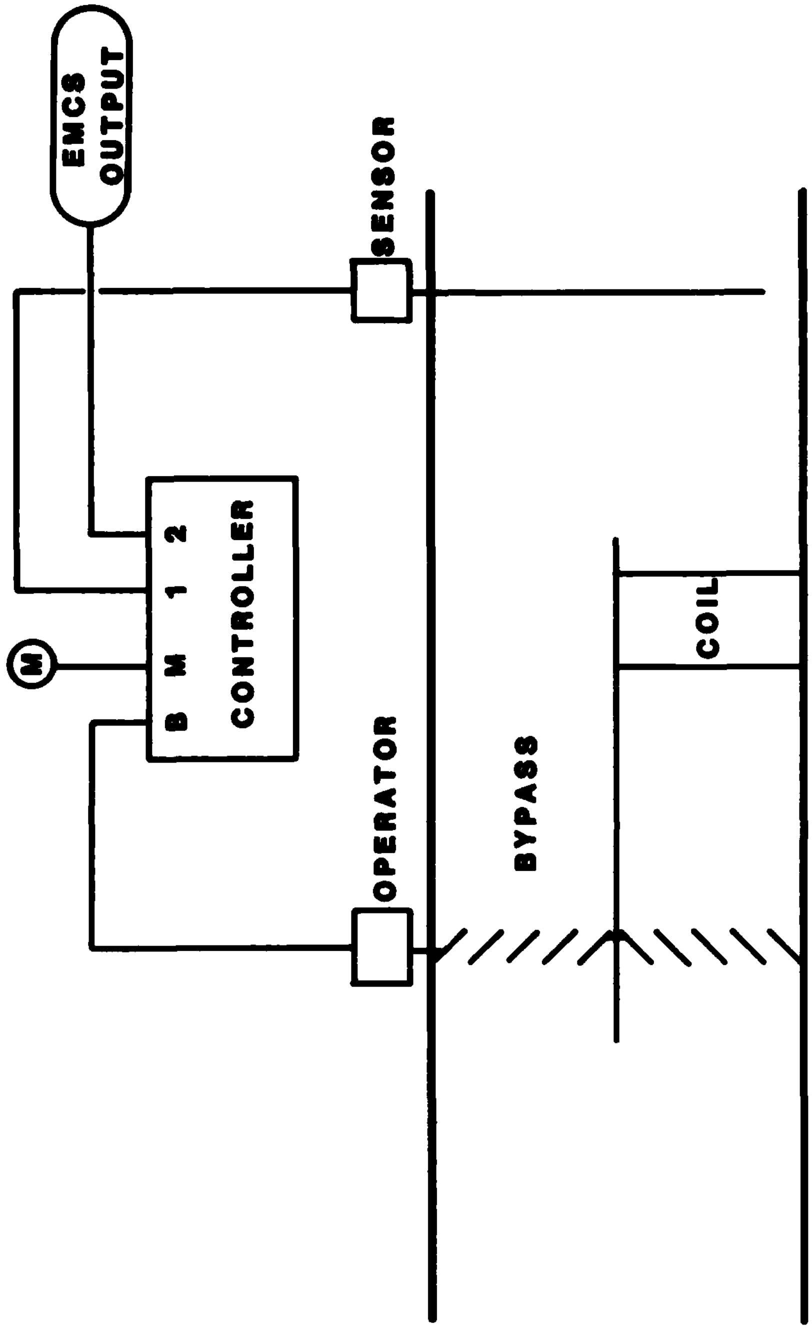

PE
PE
EMCS RELAY
EMCS RELAY
LLSV
LLSV
COIL
DIRECT EXPANSION COIL CONTROL

Figure 35



FACE AND BYPASS CONTROL

Figure 36

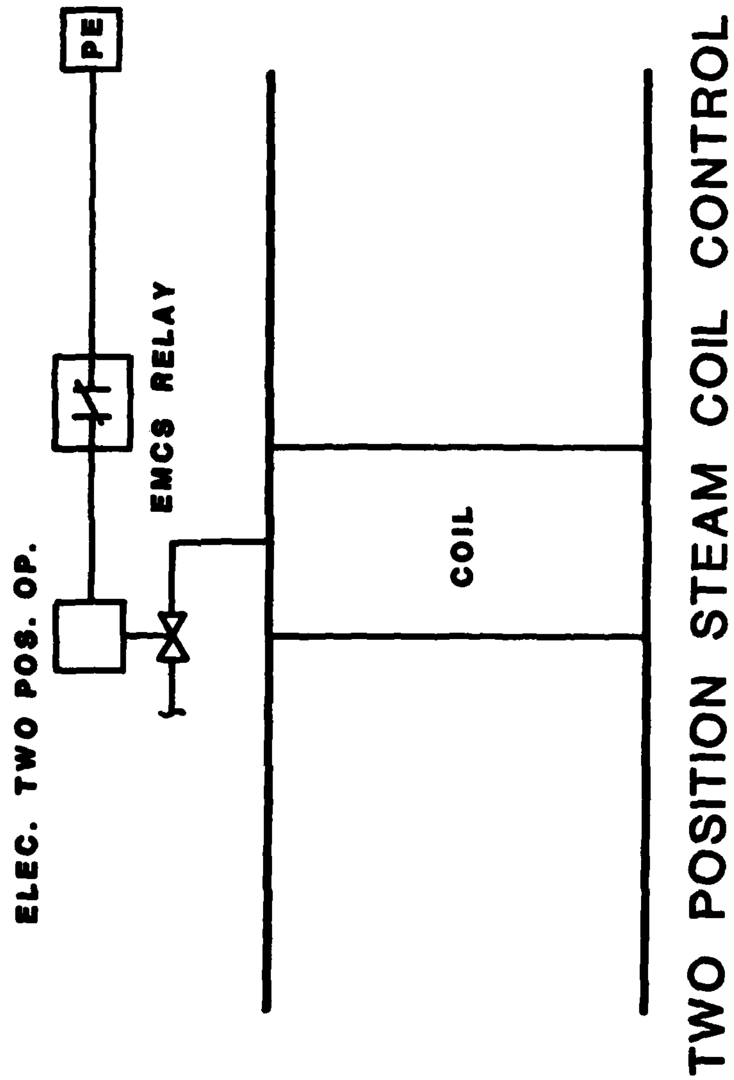
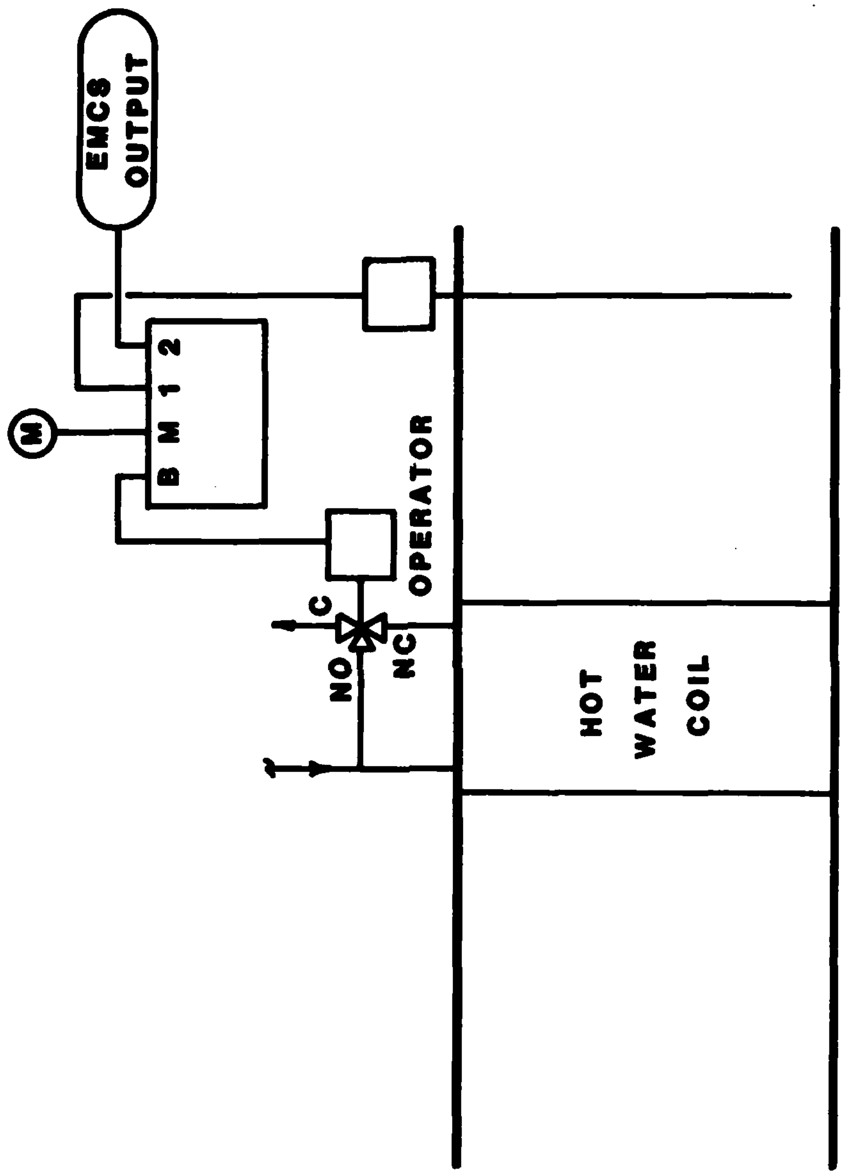
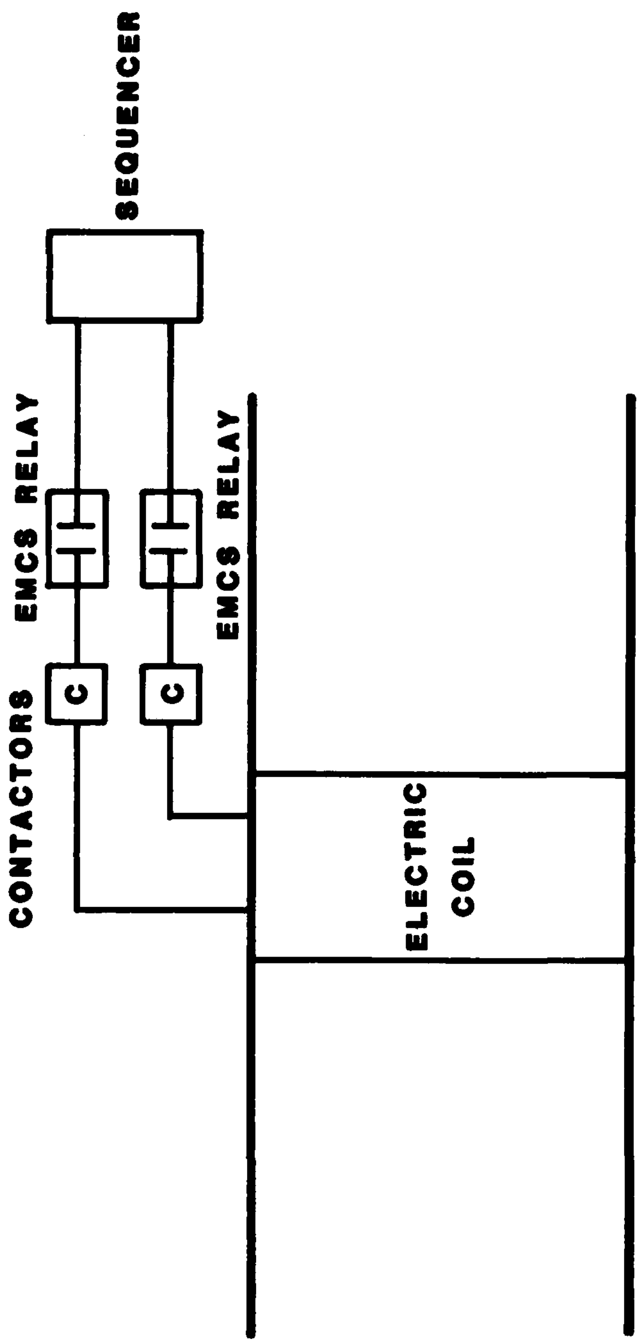

PE
EMCS RELAY
ELEC. TWO POS. OP.
COIL
TWO POSITION STEAM COIL CONTROL

Figure 37



HOT WATER COIL RESET

Figure 38



CONTROL OF TWO STAGE ELECTRIC HEAT

Figure 39

Terminal Devices Section

After heated and/or cooled air leaves the air handling unit section it is either delivered directly to the zone, tempered, or mixed.When delivered directly to the zone, no further control is required.

Tempering of the air is either done with reheat coils using hot water or steam, or staged electric reheat. Figure 40 illustrates hot water or steam coils,which are proportionally controlled as shown. While each coil could be reset, this is not practical due to the large number of devices. The normal control override is to either break the control signal to the coil if the valve is normally closed (this sends 0 psig to the valve, so it remains closed), or to switch the air pressure to the valve to main air if the valve is normally open. These options are shown in the figure.

Staged electric reheat is similar, with venting of the branch line or sending main air to the branch line entering the staging controller. A normally on example is illustrated in Figure 41.

Multizone and dual duct mixing boxes are examples of the mixing process for capacity control. The processes are the same except for location. In multizone systems, the mixing box hardware is attached directly to the air handling unit. In dual duct systems, the mixing boxes are connected to branch ducts throughout the building. Figure 42 illustrates the multizone terminal device section and Figure 43 illustrates the dual duct terminal device section. Control branch lines to either device could be intercepted if desired as previously illustrated.

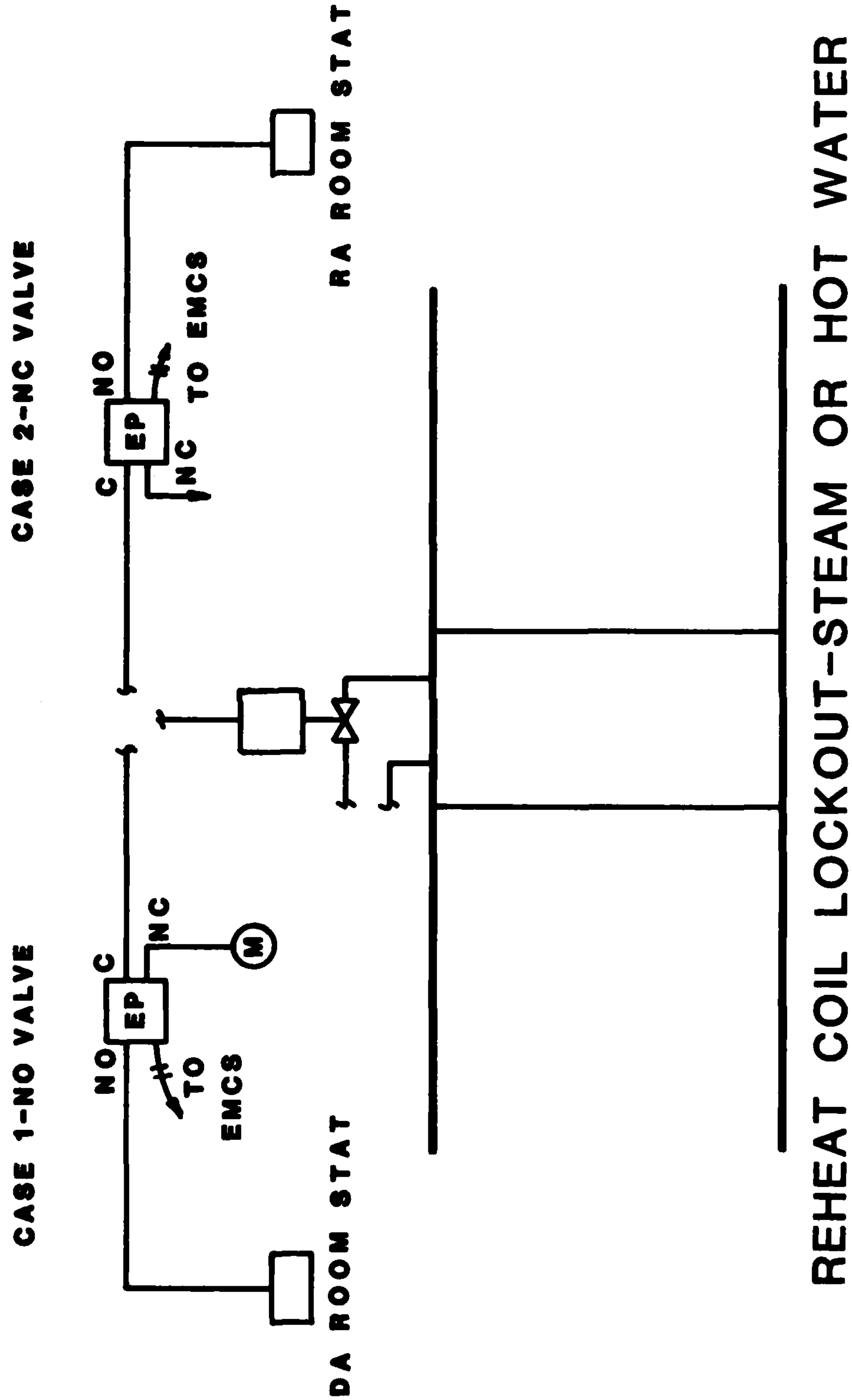

REHEAT COIL LOCKOUT-STEAM OR HOT WATER
CASE 1-NO VALVE
CASE 2-NC VALVE
EP
NO
C
NC
TO EMCS
M
DA ROOM STAT
RA ROOM STAT

Figure 40

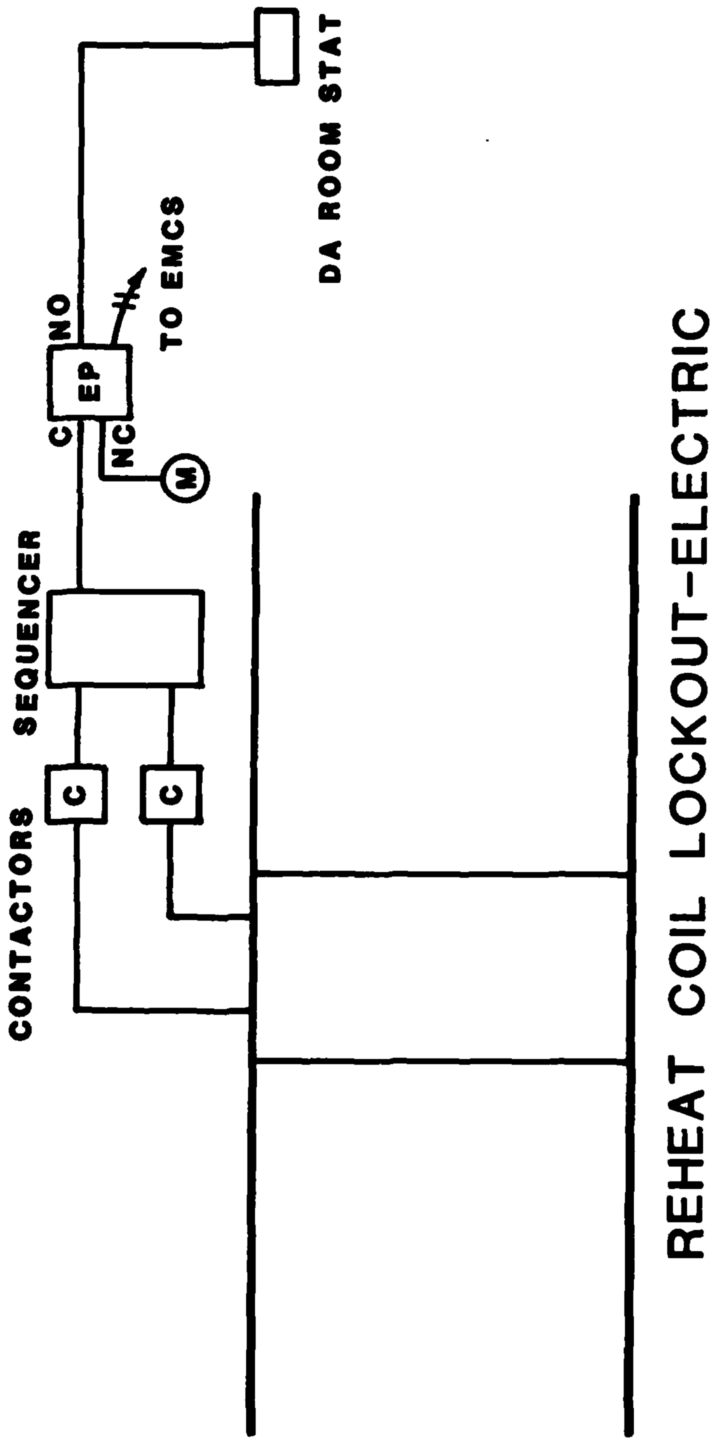

DA ROOM STAT
TO EMCS
NO
EP
C
NC
M
SEQUENCER
C
C
CONTACTORS
REHEAT COIL LOCKOUT-ELECTRIC

Figure 41

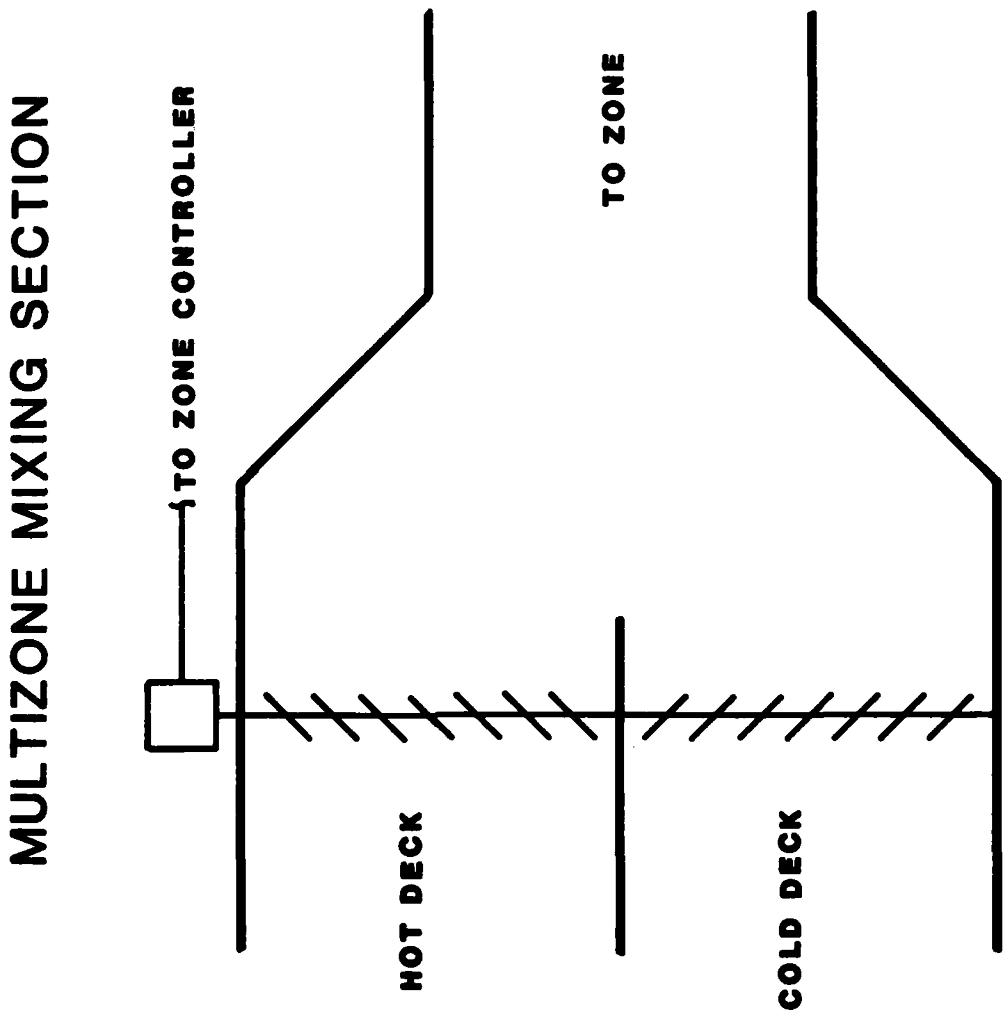

MULTIZONE MIXING SECTION
TO ZONE CONTROLLER
TO ZONE
HOT DECK
COLD DECK

Figure 42

DUAL DUCT MIXING BOX

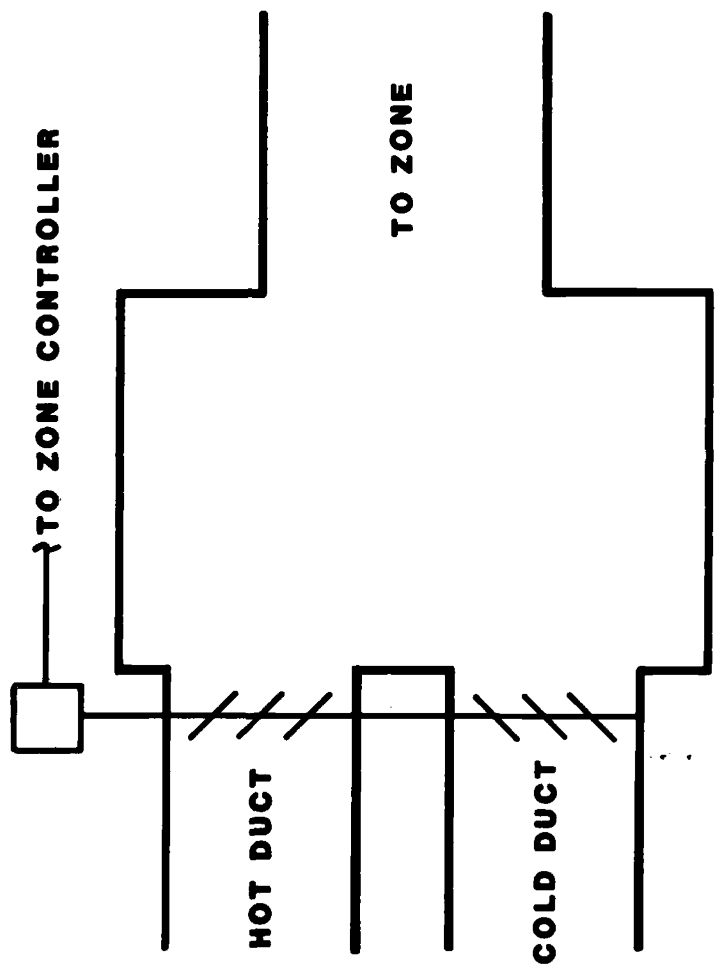


Figure 43

Conclusions

EMCS or time clock interface should be kept simple. The existing control sequences must be fully understood prior to interface. The controls should be tested after interface to assure that the sequence continues to operate as required. The three sections illustrated are combined as appropriate to give complete systems. Both the interaction between standard controls of each section and EMCS control of each section should be fully examined prior to implementation.

CHAPTER 5

SUMMARY

The study of selection and implementation of single building EMCS has proceeded in three main steps which parallel the actual design phase. To summarize, these steps where

1) Selecting Appropriate Buildings
2) Selecting Single Building Energy Controllers
3) Guides to Efficient Installation

The first step is the selection of appropriate buildings. Where available, utility billings should be examined to determine seasonal trends and equipment average and peak loading by month. This is useful in examining the ability to recover from peak demand load shedding and reset techniques. The operation of the building and the tuning of the heating, ventilating, and air conditioning system is an important phase of the building selection. Buildings where controls do not operate properly, or where systems are not adequate to meet loads, or where systems are oversized, should either not be selected, or they should be corrected prior to EMCS implementation. The controls which exist must be thoroughly examined. If the existing controls are not understood, there is no way to determine which EMCS strategies are applicable. It is of utmost importance to verify that the controls actually installed match the documentation used in the study. Where metered data is not available, measurements should be taken to verify actual power drawn of components. Long term metering is possible if desired. Standard techniques exist today for computer simulation to model base cases and alternate EMCS opportunities. The programs range from the very simple to the very complex. Select an appropriate model for the building being considered. All of these factors should be carefully weighed to identify initial candidates, followed by the detailed calculation of savings potential as shown in Chapter 3, and detailed in Appendix D.

The second step is the selection of the single building energy controller. The general procedure is to first review the available application programs, and compare these with building operating schedules and existing control sequences. Second, create a list of possible application programs to examine, and calculate the savings potential of each incrementally. Third, examine available equipment, and determine what level of control (i.e. time clock, programmable controller, duty cycler, demand limiter, micro EMCS, or small EMCS) is required to carry out each option. Compare the incremental savings with the cost of each option and evaluate economics. Select the system which meets current objectives for economic justification and other criteria.

After the system is selected, the installation must be coordinated. The interface to each system must be carefully examined. All EMCS controls must be installed to "fail safe" in appropriate equipment operating modes.

The selection and implementation of single building EMCS is a lengthy process which can be easily accomplished through a step-by-step approach as outlined in this report.

APPENDIX A

BOILER AND FUEL CONVERSION CONSTANTS

Equivalent Units for Defining Boiler Output

Item	Equivalent Units
1 Pound steam, from and at 212 degrees	970 Btu/lb
1 Square foot EDR steam	240 Btu/hr
1 Square foot EDR water	150 Btu/hr
1 Boiler horsepower, (Bhp)	34.5 Pounds of steam/hr from and at 212 degrees
	33,472 Btu/hr
	139.5 Square feet EDR steam
	223 Square feet EDR water

Item	Equivalent Units
No. 2 Oil	140,000 Btu/gal.
No. 5 Oil	148,000 Btu/gal.
No. 6 Oil	150,000 Btu/gal.
1 Therm	100,000 Btu
1 Kw	3,413 Btu

APPENDIX B

OUTDOOR AIR REQUIREMENTS FOR VENTILATION

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION
3.1 Commercial Facilities (Offices, stores, shops, hotels, sports facilities, etc.)

	Estimated Occupancy, persons per 1000 ft² or 100 m² floor area. Use only when design occupancy is not known	Outdoor Air Requirements				Comments
		Smoking	Non-smoking	Smoking	Non-smoking	
Dry Cleaners and Laundries		cfm/person		L/s · person		
Commercial	10	—	15	—	7.75	A blank (—) indicates that smoking (or non-smoking) in a space should not occur.
Storage/pick-up areas	30	35	10	17.5	5	
Coin-operated Laundries	20	35	15	17.5	7.5	Dry cleaning processes may require more air
Coin-operated dry cleaning	20	—	15	—	7.5	
Food & Beverage Services						
Dining rooms	70	35	7	17.5	3.5	
Kitchens	20	—	10	—	5	
Cafeterias, fast food facilities	100	35	7	17.5	3.5	
Bars and cocktail lounges	100	50	10	25	5	
Garages, auto repair shops, service stations		cfm/ft² floor		L/s · m² floor		
Parking garages (enclosed)	—	1.5	1.5	7.5	7.5	Distribution must consider worker location and concentration of running engines; stands where engines are run must incorporate systems for positive engine exhaust withdrawal.
Auto Repair workrooms (general)	—	1.5	1.5	7.5	7.5	
Hotels, Motels, Resorts, Dormitories, & Correctional Facilities		cfm/room		L/s · room		See also food & beverage services, merchandising, barber & beauty shops, garages
Bedrooms (single, double)	5	30	15	15	7.5	Independent of room size
Living rooms (suites)	20	50	25	25	12.5	
Baths, toilets (attached to bedrooms)		50	50	25	25	Independent of room size: installed capacity for intermittent use.
		cfm/person		L/s · person		
Lobbies	30	15	5	7.5	2.5	
Conference rooms (small)	50	35	7	17.5	3.5	
Assembly rooms (large)	120	35	7	17.5	3.5	
Gambling Casinos	120	35	7	17.5	3.5	
Offices						
Office Space	7	20	5	10	2.5	
Meeting & waiting spaces	60	35	7	17.5	3.5	

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION (cont.)
3.1 Commercial Facilities (cont.)

	Estimated occupancy, persons per 1000 ft² or 100 m² floor area. Use only when design occupancy is not known.	Outdoor Air Requirements				Comments
		Smoking	Non-smoking	Smoking	Non-smoking	
Public spaces		cfm/ft² floor		L/s · m² Floor		
Corridors & utility rooms		0.02	0.02	0.10	0.10	
		cfm/stall or urinal		L/s · stall or urinal		
Public restrooms	100	75	—	37.5	—	
		cfm/locker		L/s · locker		
Locker & dressing rooms	50	35	15	17.5	7.5	
Retail Stores		cfm/person		L/s · person		
Sales Floors & Showrooms						
Basement & Street floors	30	25	5	12.5	2.5	
Upper floors	20	25	5	12.5	2.5	
Storage Areas (serving sales & storerooms)	15	25	5	12.5	2.5	
Dressing rooms	—	25	5	12.5	3.5	
Malls & arcades	20	10	5	5	2.5	
Shipping & receiving areas	10	10	5	5	2.5	
Warehouses	5	10	5	5	2.5	
Elevators	—	—	15	—	7.5	
Smoking rooms	70	50	—	25	—	
Specialty Shops		cfm/person		L/s · person		
Barber & Beauty shops	25	35	20	17.5	10	
Reducing salons, health spas (exercise rooms)	20	—	15	—	7.5	
Florists	10	25	5	12.5	2.5	Ventilation to optimize plant growth may dictate requirements.
Greenhouses	1	—	5	—	2.5	
Shoe repair shops (combined workrooms/ trade areas)	10	15	10	7.5	5	
		cfm/ft² floor		L/s · m² floor		
Pet shops	—	1	1	5	5	
Sports & Amusement Facilities		cfm/person		L/s · person		
Ballrooms & Discos	100	35	7	17.5	3.5	
Bowling alleys (seating area)	70	35	7	17.5	3.5	When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates will be required.
Playing floors (e.g., gymnasiums, ice arenas)	30	—	20	—	10	
Spectator areas	150	35	7	17.5	3.5	
Game rooms (e.g., cards & billiards rooms)	70	35	7	17.5	3.5	
Swimming pools		cfm/ft² area		L/s · m² area		
Pool & deck areas	—	—	0.5	—	2.5	Higher values may be required for humidity control.
		cfm/person		L/s · person		
Spectators area	70	35	7	17.5	3.5	

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION (cont.)
3.1 Commercial Facilities (cont.)

	Estimated Occupancy, persons per 1000 ft² or 100 m² floor area. Use only when design occupancy is not known.	Outdoor Air Requirements				Comments
		Smoking	Non-smoking	Smoking	Non-smoking	
Theatres		cfm/person		L/s · person		
Ticket booths	—	20	5	10	2.5	
Lobbies, foyers, & lounges, & auditoriums in motion picture theatres, lecture, concert & opera halls	150	35	7	17.5	3.5	
Stages, TV & movie studios	70	—	10	—	5	Special ventilation will be needed to eliminate special stage effects (e.g. dry ice vapors, mists, etc.)
Transportation						
Waiting rooms, ticket & baggage areas, corridors & gate areas, platforms, concourses	150	35	7	17.5	3.5	Ventilation within vehicles will require special consideration.
Workrooms		Cfm/person		L/s · person		
Meat processing rooms	10	—	5	—	2.5	Spaces maintained at low temperatures (-10 F to +50 F, or -23°C to +10°C) are not covered by these requirements unless the occupancy is continuous. Ventilation from adjoining spaces is permissible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirement. (See Ref 21)
Pharmacists' workroom	20	—	7	—	3.5	
Bank vaults	10	—	5	—	2.5	
Photo studios						
Camera room, stages	10	—	5	—	2.5	
Darkrooms	10	—	20	—	10	
		cfm/ft² floor		L/s · m² floor		
Duplicating & printing rooms		—	0.5	—	2.5	Installed equipment must incorporate positive exhaust & control (as required) of undesirable contaminants (toxic or otherwise).
Educational Facilities		cfm/person		L/s · person		
Classrooms	50	25	5	12.5	2.5	
Laboratories	30	—	10	—	5	Special contaminant control systems may be required for processes or functions including laboratory animal occupancy.
Training shops	30	35	7	17.5	3.5	
Music rooms	50	35	7	17.5	3.5	
Libraries	20	—	5	—	2.5	

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION (cont.)
3.2 Institutional Facilities (cont.)

	Estimated occupancy, persons per 1000 ft² or 100 m² floor area. Use only when design occupancy is not known.	Outdoor Air Requirements				Comments
		Smoking	Non-smoking	Smoking	Non-smoking	
Hospital, Nursing & Convalescent Homes						Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency.
		cfm/bed		L/s · bed		
Patient rooms	10	35	7	17.5	3.5	
		cfm/person		L/s · person		
Medical procedure areas	10	35	7	17.5	3.5	
Operating rooms, deliver_ rooms	20	—	40	—	20	Procedures generating contaminants may require higher rates.
Recovery & intensive care rooms	20	—	15	—	7.5	
Autopsy rooms	20	—	100	—	50	Air shall not be recirculated into other spaces.
Physical therapy areas	20	—	15	—	7.5	

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION (cont.)
3.3 Residential Facilities (Private dwelling places, single or multiple, low or high rise)

	Outdoor Air Requirements		Comments
			Operable windows or mechanical ventilation systems shall be provided for use when occupancy is greater than usual conditions or when unusual contaminant levels are generated within the space.
	cfm/room	L/s · room	
General living areas	10	5	Ventilation rate is independent of room size (General living areas through Baths, toilets)
Bedrooms	10	5	
All other rooms	10	5	
Kitchens	100	50	Installed capacity for intermittent use. (Kitchens, Baths, toilets)
Baths, toilets	50	25	
	cfm/car space	L/s · car space	
Garages (separate for each dwelling unit)	100	50	
	cfm/ft² floor	L/s · m² floor	
Garages (common for several units)	1.5	7.5	

Table 3 OUTDOOR AIR REQUIREMENTS FOR VENTILATION (cont.)
3.4 Industrial Facilities

Occupational safety laws in various states usually regulate process ventilation requirements. The following list gives the requirements for the occupants only, assuming that the ventilated air is of a quality equal to or exceeding at limits listed in Section 6.1. Air of this quality may be included as part of the process ventilation.

	Outdoor Air Requirements				Comments
	Smoking	Non-smoking	Smoking	Non-smoking	
	cfm/person		L/s · person		
High Activity level (2.5 met)*	35	20	17.5	10	Mining, foundry, etc.
Medium Activity level (2.0 met)	35	10	17.5	5	Automotive repair, assembly line, etc.
Low activity level (1.5 met)	35	7	17.5	3.5	Laboratory work, light assembly, etc.

*1.0 met = sedentary activity level = 18.4 Btu/hr · ft² body surface (58.2 W/m²).

APPENDIX C

TYPICAL AMPERAGE MEASURING DEVICES

Hand Held Clamp-on Meters

These devices are used for instantaneous readings of amperage only. To calculate kilowatts accurately, voltage must be measured also. This list is based on data from the "TRANSCATALOG" handbook of calibration, test and measurement instrumentation, TRANSCAT Company, Box D-1, Rochester, N.Y. 14606, phone 800-828-1470. This equipment is typical. There are many other manufacturers.

A) Current Gun # 7334E
   Price: $295.00

   Amperage: 200A or 500A maximum

   Typical Accuracy: +- 0.75% full scale to 100A
   +- 3.0% of reading 100A to 200A

   Display: 3 1/2 digit LCD

   Power Supply: 4 size AA batteries

   Remarks: DC or AC measurement. 3/4" maximum jaw capacity.

B) 60 Hz clamp on Meter, #7405E-60
   Price: $169.00

   Amperage: 0.1 to 999A

   Typical Accuracy: +- 2 percent, +- 1 digit

   Display: 3 LED's, 0.27"

Power Supply: 4 size AA batteries

Remarks: AC Amps, AC Volts, or ohms measured. 1.4" maximum jaw capacity.

C) Clamp-on Wattmeter, #7411E

Price: $389.00

Amperage: High range 0.1 KW to 199.9 KW
Low range 0.01 KW to 19.99 KW

Typical Accuracy: +- 2 percent of reading, +- 1 digit

Display: 4 digit LCD

Power Supply: 9 V battery

Remarks: Input current 1000 amps maximum. Calculates true watts, single phase or three phase wye or delta. 1 1/4" maximum jaw capacity.

D) AC Power Meter, #7325E

Price: $925.00

Amperage: 2-200 KW

Typical Accuracy: +- 1 percent of reading + 0.5 percent of range

Display: 4 digit LCD

Power Supply: 4 size AA batteries

Remarks: Measures true RMS Volts, amps, watts. For single phase and balanced three phase circuits. 1" maximum jaw capacity.

Electric Power/Demand Analyser

These devices are used for recording of electric energy and demand usage. They are intended for submetering to determine time varying power requirements. Outputs are volts, amps, power factor, kilowatts, kilowatt-hours, kilowatt-amps, and kilowatt-amps reactive.

Price: $2530.00 basic unit

$260.00 300A or 1000A Clamp-on CT

$895.00 3000A Clamp-on CT

Voltage: 60-600 volts, 0.06-500 Mega volts

Accuracy: +- 0.4 percent of reading
+- 0.1 percent of full scale

Amperage: 0.5-10A, 0.001-10 Mega amps

Accuracy: +- 0.4 percent of reading
+- 0.1 percent of full scale

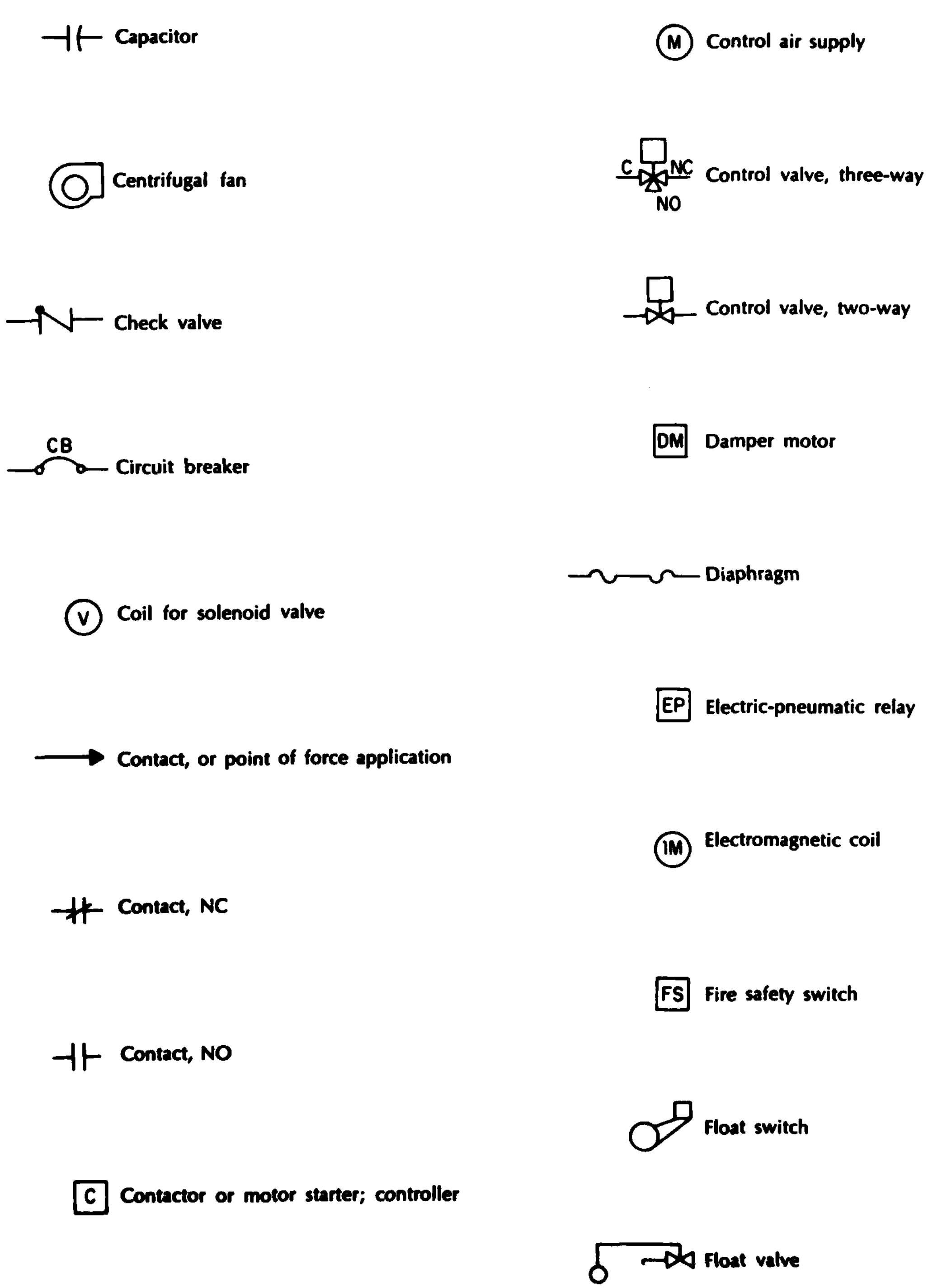
Power (KW) 30-6000 Watts
0.001-999.9 Tera Watts

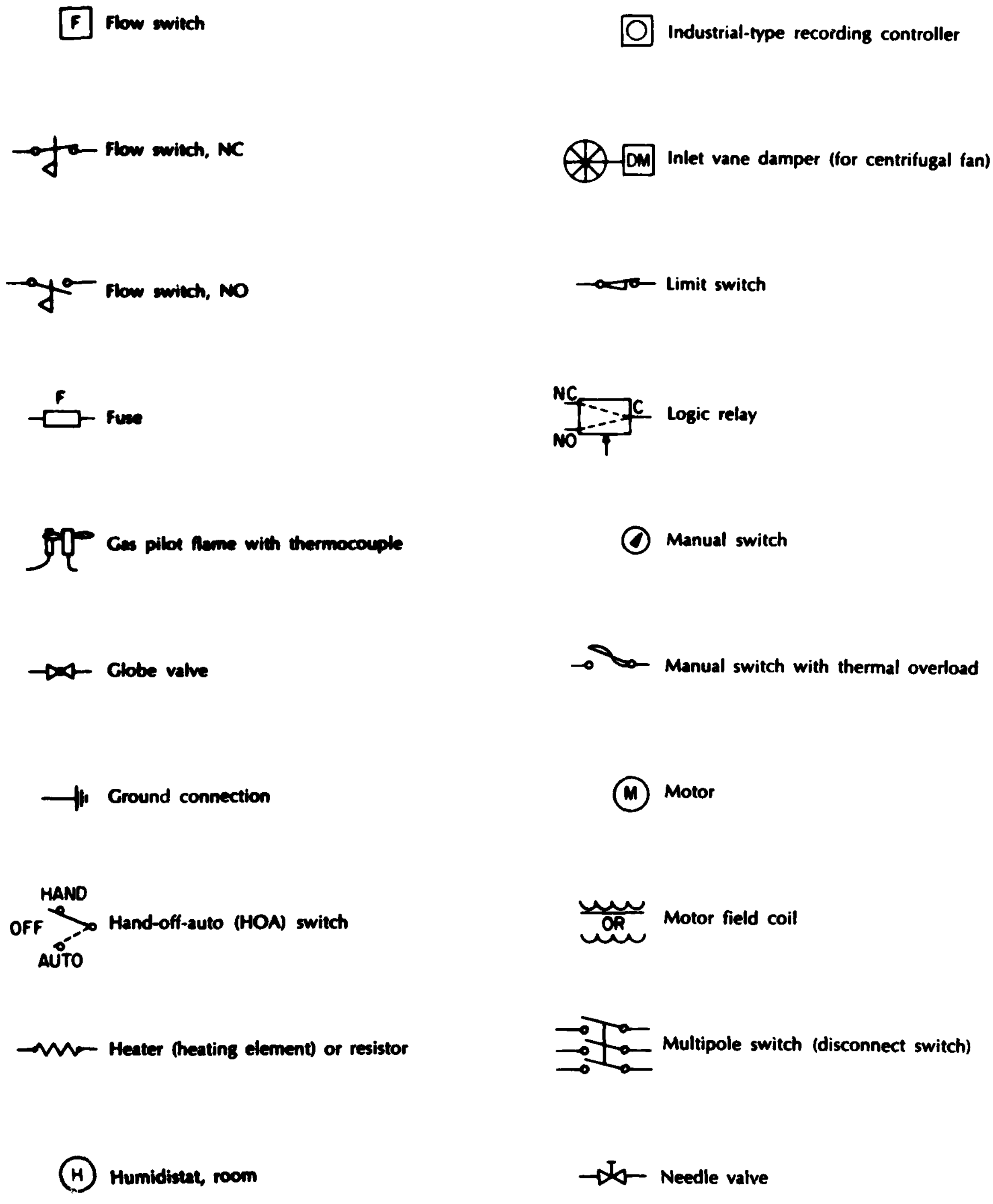
Accuracy: +- 0.8 percent of reading
+- 0.2 percent of full scale

Features: Automatic printout
16 character display
5 x 7 dot matrix printer
calendar

APPENDIX D

CONTROL SYMBOLS


Capacitor
Centrifugal fan
Check valve
CB
Circuit breaker
V
Coil for solenoid valve
Contact, or point of force application
Contact, NC
Contact, NO
C
Contactor or motor starter; controller
M
Control air supply
C
NC
NO
Control valve, three-way
Control valve, two-way
DM
Damper motor
Diaphragm
EP
Electric-pneumatic relay
1M
Electromagnetic coil
FS
Fire safety switch
Float switch
Float valve


F
Flow switch
Flow switch, NC
Flow switch, NO
F
Fuse
Gas pilot flame with thermocouple
Globe valve
Ground connection
HAND
OFF
AUTO
Hand-off-auto (HOA) switch
Heater (heating element) or resistor
H
Humidistat, room
Industrial-type recording controller
DM
Inlet vane damper (for centrifugal fan)
Limit switch
NC
C
NO
Logic relay
Manual switch
Manual switch with thermal overload
M
Motor
OR
Motor field coil
Multipole switch (disconnect switch)
Needle valve

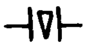

Opposed-blade damper (for modulating control)


Overload actuator

Overload contact


Parallel-blade damper (for two-position control)


Pilot light, color indicated by initial


Plug valve


Point of solid contact, as to a device case or baseplate


Pressure gage


Pressure regulator (pressure-reducing valve)

Pressure switch or sensor


Pressure switch, NC

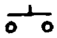

Pressure switch, NO


Propeller fan and motor

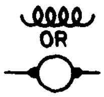
Proportioning controller, solid-state


Pump


Pushbutton, normally closed (PB, NC)

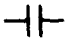

Pushbutton, normally open (PB, NO)

Relay



Relay coil


Relay or starter contact, NC

 Relay or starter contact, NO

 Relief valve

 Resistor

 Resistor, variable

Reversing relay

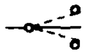
Sequencing controller

Smoke detector

 Solenoid valve; solenoid valve, two-way

 Solenoid valve, three-way

 SPDT switch

 SPDT switch with center-off position

 Spray nozzle

 Spring (where identified as such)

 SPST switch

Static pressure controller

 Steam trap

 Thermal expansion valve, thermostatic expansion valve

 Thermal switch, NC

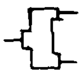
 Thermal switch, NO

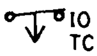
 Thermometer, remote-bulb or insertion type

Thermostat, insertion type

Thermostat, remote-bulb, duct or pipe, or insertion type

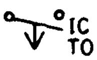
Thermostat, room


Three-pipe control valve



Time-delay switch, NC, instantaneous open after energizing, timed close after deenergizing

Time-delay switch, NC, timed open after energizing, instantaneous close after deenergizing



Time-delay switch, NO, instantaneous close after energizing, timed open after deenergizing

Time-delay switch, NO, timed close after energizing, instantaneous open after deenergizing


Transformer


Transformer coil

Wiring terminal with identification

APPENDIX E

GLOSSARY

Appendix E: Glossary

Algorithm: A set of well defined rules or procedures for solving a problem or providing an output from a specific set of inputs.

Analog to Digital Converter: A circuit or device whose input is information in analog form and whose output is the same information in digital form.

Architecture: The general organization and structure of hardware and software.

ASCII: American Standard Code for Information Interchange. An 8-bit coded character set to be used for the general interchange of data among information processing systems, communications systems, process control systems, and associated equipment. Various character/graphic subsets are discussed in FIPS PUB 15.

Asynchronous Transmission: Data transmission in which each character contains its own start and stop bits.

Automatic Temperature Control (ATC): A local loop network of pneumatic or electric/electronic devices which are interconnected to control temperature.

Background Programming: A feature of computer hardware to provide a means of writing, testing, and debugging a software program on the computer at the same time the computer is performing other "Real Time" programs.

BASIC: An acronym for Beginners All-Purpose Symbolic Instruction Code, a high-level, English-like programming language used for general applications.

Baud: A unit of signalling speed equal to the number of discrete conditions, or signal events, per second.

Bit: An acronym for binary digit. The smallest unit of information which can be represented. A bit may be in one or two states, represented by the binary digits 0 and 1.

Boostrap: A technique or device designed to bring a computer into a desired state by means of its own action.

Appendix E: Glossary

Buffer: A temporary data storage device used to compensate for a difference in data flow rate or event times, when transmitting data from one device to another.

Bus: A circuit path (or parallel paths) over which data or instructions are transferred to all points in the computer system. Computers have several separate busses: the data, address, and control busses are those of greatest importance.

Byte: Eight bits.

Central Memory: Core or semiconductor memory which communicates directly with a CPU.

Central Communication Controller (CCC): A computer that performs data gathering and dissemination from and to the FIDs, as well as providing limited backup to the CCU.

Central Processing Unit (CPU): The portion of a computer that performs the interpretation and execution of instructions. It does not include memory or I/O.

Central Control Unit (CCU): A process control digital computer that includes a CPU, central memory, and I/O bus.

Character: One of a set of elementary symbols which normally include both alpha and numeric codes plus punctuation marks and any other symbol which may be read, stored, or written.

Clock: A device or a part of a device that generates all the timing pulses for the coordination of a digital system. System clocks usually generate two or more clock phases. Each phase is a separate, square wave pulse train output.

Command Line Mnemonic (CLM): A computer language consisting of a set of fixed, simplified English commands designed to assist operators unfamiliar with computer technology in operating the EMCS.

Command Line Mnemonic Interpreter (CLMI): Software used to implement the CLM language.

Appendix E: Glossary

Compiler: A language translator which converts source statements written in a high level language into multiple machine instructions. A compiler translates the entire program before it is executed.

Control Point Adjustment (CPA): The procedure of changing the operating point of a local loop controller from a remote location.

Control Sequence: Equipment operating order established upon a correlated set of data environment conditions.

Crowbar: An electronic circuit which can rapidly sense an over voltage condition and provide a solid-state low impedance path to eliminate this transient condition.

Data Environment (DE): The sensors and control devices connected to a single FID/MUX/IMUX (IMUX only in small and micro systems) from the equipment and systems sampled or controlled.

Data Transmission Media (DTM): Transmission equipment including cables and interface modules (excluding MODEMs) permitting transmission of digital and analog information.

Deck: In HVAC terminology, the air discharge of the hot or cold coil in a duct serving a conditioned space.

Demand: The term used to describe the maximum rate of use of electrical energy averaged over a specific interval of time and usually expressed in kilowatts.

Demultiplexer: A device used to separate two or more signals previously combined by compatible multiplexer for transmission over a single circuit.

Diagnostic Program: Machine-executable instructions used to detect and isolate component malfunctions.

Direct Digital Control (DDC): Sensing and control of processes directly with digital control electronics.

Digital to ANalog (D/A) Converter: A hardware device which converts a digital signal into a voltage or current proportional to the digital input.

Appendix E: Glossary

Direct Memory Access (DMA): Provision for transfer of data blocks directly between central memory and an external device interface.

Disk Storage: A bulk storage, random access device for storing digital information. Usually constructed of a thin rotating circular plate having a magnetizable coating, a read/write head and associated control equipment.

Distributed Processing System: A system of multiple processors each performing its own task, yet working together as a complete system under the supervision of a central computer, to perform multiple associated tasks.

Download: The transfer of digital data or programs from a host computer to another data processing system such as central computer to microcomputer.

Executive Software: The main system program designed to establish priorities and to process and control other programs.

Facility Engineer: Person in charge of maintaining and operating the physical plant. In the Army it is the Facility Engineer (FE), in the Navy is the Public Works Officer and in the Air Force is the Base Civil Engineer.

Failover Control Board: A bus switch to transfer the communications function from CCU to CCC in the event of CCU failure, or the communications function from CCC to CCU in the event of CCC failure.

Fall-Back Mode: The pre-selected operating mode of a FID when communications cease with the MCR or the operating sequence of each local control loop when the FID to which it is connected ceases to function.

Firmware: A procedure for accomplishing arithmetic operations where the instruction set is resident in ROM or PROM.

FORTRAN: An acronym for FORmula TRANslation. A high-level, English-like programming language used for technical applications.

Appendix E: Glossary

Hardware: Equipment such as a CPU, memory, peripherals, sensors, and relays.

Initialize: To set counters, switches, and addresses to zero or other starting values at the beginning of or at prescribed points in a computer program.

Input/Output (I/O) Device: Digital hardware that transmits or receives data.

Interactive: Functions performed by an operator with the machine prompting or otherwise assisting these endeavors, while continuing to perform all other tasks as scheduled.

Interpreter: A language translator which converts individual source statements into machine instruction by translating and executing each statement as it is encountered.

Interrupt: An external or internal signal requesting that current operations be suspended to perform more important tasks.

Large Scale Integration (LSI): The technology of manufacturing integrated circuits capable of performing complex functions. Devices of this class contain 100 or more logic gates.

Line Conditioning: Electronic modification of the characteristic response of a line to meet certain standards. The characteristics include frequency response, signal levels, noise suppression impedance, and time delay.

Line Driver: A hardware element which enables signals to be directly transmitted over circuits to other devices some distance away.

Local Loop Control: The controls for any system or subsystem which exist prior to the installation of an EMCS and which will continue to function when the EMCS is non-operative.

Machine Language: The binary code corresponding to the instruction set of the CPU.

Appendix E: Glossary

Memory: Any device that can store logic 1 and logic 0 bits in such a manner that a single bit or group of bits can be accessed and retrieved.

Memory Address: A binary number that specifies the precise memory location of a stored word.

Microcomputer: A computer system based on a microprocessor and containing all the memory and interface hardware necessary to perform calculations and specified transformations.

Microprocessor: A central processing unit fabricated as one integrated circuit.

MODEM: An acronym for MOdulator/DEmodulater. A hardware device used for changing digital information to and from an analog form to allow transmission over voice grade circuits.

Multi-Tasking: The procedure allowing a computer to perform a number of programs simultaneously under the management of the operating system.

Non-Volatile Memory: Memory which retains information in the absence of applied power (i.e.; magnetic core, ROM, and PROM).

Object Code: A term used to describe machine language.

Operating System: A complex software system which manages the computer and its components and allows for human interaction.

Optical Isolation: Electrical isolation of a portion of an electronic circuit by using optical semiconductors nd modulated light to carry the signal.

PASCAL: A "structured programming" high level computer language.

Point: Individual connected monitor or control devices (i.e., relay, temperature sensor).

Predictor/Corrector Program: Applications software which allows continuous prediction of a future value and subsequent correction based on actual measurements.

Appendix E: Glossary

Program: A sequence of instructions causing the computer to perform a specified function.

Protocol: A formal set of conventions governing the format and relative timing of message exchange between two terminals.

Random Access Memory (RAM): Volatile semiconductor data storage device in which data may be stored or retrieved. Access time is effectively independent of data location.

ROM, PROM, EPROM, EEPROM: Read-Only-Memory, Programmable ROM, Erasable PROM, Electronically Erasable PROM. All are non-volatile semiconductors memory.

Real Time: A situation in which a computer monitors, evaluates, reaches decisions, and effects controls within the response time of the fastest phenomenon.

Register: A digital device capable of retaining information.

Resistance Temperature Detector (RTD): A device where resistance changes linear as a function of temperature.

SHF: Sensible Heat Factor, the ratio of the sensible heat to the total heat.

Software: A term used to describe all programs whether in machine, assembly, or high-level language.

Throughput: The total capability of equipment to process or transmit data during a specified time period.

Volatile Memory: A semiconductor device in which the stored digital data is lost when power is removed.

Zone: An area composed of a building, a portion of a building, or a group of buildings affected by a single device or piece of equipment.

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ASO CO (Code PWB-7), Philadelphia, PA
ASU PWO, Bahrein
BUMED Code 3212, Washington DC
CINCLANTFLT Code N47, Norfolk, VA
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CNET Code N1083 Pensacola, FL
CNM Code MAT-04, Washington, DC; Code MAT-O8E, Washington, DC
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NAS CO (AOT), Whidbey Island, Wa; CO (Code 18.1), Bermuda; CO (Code 18100); CO (Code 18100), Cecil Field, FL; CO (Code 18100), Chase Field, Beeville, Tx; CO (Code 18100), Fallon, NV; CO (Code 1815), Corpus Christi, TX; CO (Code 1824), Lakehurst, NJ; CO (Code 182H), Key West, FL; CO (Code 18300), Memphis 84, Millington, TN; CO (Code 18330), Lemoore, CA; CO (Code 183U), Miramar, San Diego, Ca; CO (Code 184), Moffett Field, CA; CO (Code 18700) Whiting Field, Milton, FL; CO (Code 189720), Brunswick, ME; CO (Code 18F), Jacksonville, FL; CO (Code 70), Glenview, IL; CO (Code 70), Marietta,

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NATL BUREAU OF STANDARDS Thermal Anal Gp, Wash, DC
NATNAVMEDCEN Code 43, Energy Conserv (PWO) Bethesda, MD
NAVACT CO (Code A171P), London, UK
NAVACTDET PWO, Holy Lock UK
NAVAIRDEVCEN CO (Code 8323), Warminister, PA
NAVAIRPROPTESTCEN CO (Code PW-3), Trenton NJ
NAVAIRTESTCENT Code CT06, Patuxent River, MD
NAVAL HOME SCE Gulfport, MS
NAVAVIONICFAC Code B/732
NAVCOASTSYSCEN CO (Code 352), Panama City, FL
NAVCOMMAREAMSTRSTA CO (Energy Conserv), Naples, It.
NAVCOMMAREAMSTRSTA Code 41, Norfolk, VA
NAVCOMMSTA CO (Code 20) San Diego, CA; CO (Code 314), Stockton, CA; CO (Code 401), Nea Makri, Greece; CO (PWD), Exmouth, Australia
NAVCOMMU PWO, Thurso, Scotland
NAVCOMMUNIT CO (Code 50), East Machias, ME
NAVDET OIC (Energy Conserv), Souda, Bay, Crete
NAVEDUTRACEN CO, Code 44, Newport RI
NAVELEXSYSCOM ELEX 1033 Washington, DC
NAVFAC CO (APOWO), Pacific Beach, WA; CO (Code 04) Coos Head, Charleston, Or; CO (Code 05) Centerville Beach Fernadale, CA; CO (Code 300), Antigua; CO (Code 50A), Brawdy Wales, UK; CO (Energy Conserv), Big Sur, CA
NAVFACENGCOM Alexandria, VA; Code 03 Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code 04 Alexandria VA; Code 04T2 (Knapp), Alexandria, VA; Code 04T2B (McGrath), Alexandria, VA; Code 04T7B (Stickley), Alexandria, VA; Code 05, Alexandria, VA; Code 05D1 (Bersson), Alexandria, VA; Code 08, Alexandria VA; Code 09M54, Tech Lib, Alexandria, VA; Code 11, Alexandria, VA; Code 111 (Mitchum), Alexandria, VA; Code 111 Alexandria, VA; Code 1112E (Tayler), Alexandria, VA; Code 1113, Alexandria, VA; Code 111B (Hanneman), Alexandria, VA; Code 111B Alexandria VA
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NAVSECSTA Code 540, Washington DC
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NAVSUBASE CO (Code 803), Groton, CT; PWO Bangor, Bremerton, WA
NAVSUPPACT CO (Code 413), Seattle, WA; CO (Code 81), Mare Island, Vallejo, CA; CO (Code N52), New Orleans, LA; CO (Energy Conserv), Naples, Italy
NAVSUPPBASE CO (Energy Conserv) Kings Bay, GA
NAVSUPPFAC CO (Energy Conserv) Diego Garcia I; Code 02, Thurmont, MD
NAVSUPPO CO (APWO), La Maddalena, Italy
NAVSURFWPNCEN Dahlgren Lab, WW-02 Dahlgren VA
NAVTELCOMMCOM Code 05, Washington DC
NAVUSEAWARENGSTA CO (Code 073E2), Keyport, WA
NAVWPNCEN Commander (Code 2635), China Lake, CA
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PACMISRANFAC CO (Code 7031), Kekaha, HI
PMTC Commander (Code 6200-3), Point Mugut,, CA
PWC CO (Code 1003), Oakland, CA; CO (Code 100E), San Diego, CA; CO (Code 100E3), Oakland, CA; CO (Code 153), Guam; CO (Code 30), Pearl Harbor, HI; CO (Code 601), Subic Bay; CO (Code 610), Pensacola, FL; CO (Code 613), San Diego, CA; Code 100A, Great Lakes, IL; Code 116, Seattle, WA; Code 154 (Library), Great Lakes, IL; Code 600A Norfolk, VA; Library, Code 120C, San Diego, CA; Library, Guam; Library, Norfolk, VA; Library, Oakland, CA; Library, Pearl Harbor, HI; Library, Pensacola, FL; Library, Subic Bay, R.P.; Library, Yokosuka JA; NAS Pensacola, FL
SPCC CO (Code 763), Mechanicsburg, PA
SUPSHIP ADMINO, San Francisco, CA; Code 901
USAF AFRCE/CR (Walton), Dallas, TX; AFRCE/ER (Burns), Atlanta, GA; AFRCE/M-X (Stevens), Norton AFB, CA; AFRCE/WR (Lowry), San Francisco, CA
USAFE HQ DEE (EMCS Mgr), Ramstein AFB, Germany
USNA Code 170, Annapolis, MD
FRANKLIN INSTITUTE M. Padusis, Philadelphia PA
LAWRENCE BERK LAB Window & Lighting Prog. Berkeley, cA
LOS ALAMOS SCI LAB Solar Energy Gp, Los Alamos, NM
MIT Cambridge MA (Rm 10-500, Tech. Reports, Engr. Lib.)
UNIVERSITY OF WASHINGTON Insti. for Envir. Studies
PG&E Library, San Francisco, CA
SANDIA LABORATORIES Library Div., Livermore CA
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