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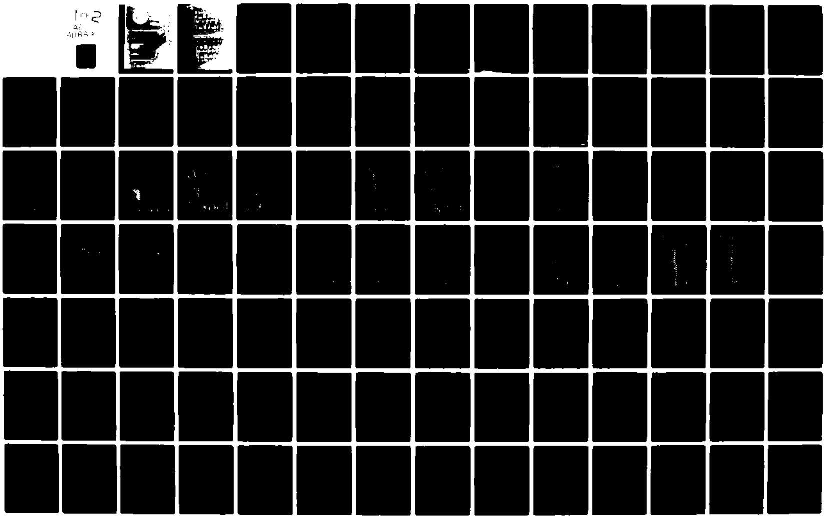

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This report contains guidelines for using microprocessor-based equipment to control energy in buildings. Energy conservation control strategies are discussed and simplified energy savings calculations explained. The results of a survey of currently available equipment suitable for use as energy controllers is included as well as selection guidance for which class of equipment will provide the needed features.

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CONTENTS

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.

I. INTRODUCTION

This report contains a Microprocessor Based Equipment Guide. This guide was developed for the Naval Civil Engineering Laboratory, Port Hueneme, California under contract number N62583-81-MR-593.

This report has been designed to aid the public works engineer in the analysis and modification of existing buildings to reduce both fuel consumption and operating costs. The report offers an approach to identifying, analyzing, and recommending action on the options available to reduce energy use in most existing buildings. Besides a review of the principles of energy use and conservation, the report provides a step-by-step methodolgy for assessing and improving the year-round energy performance of buildings, and guidance in selecting equipment to implement these improvements. Through a careful application of the procedures described in this report, the energy conservation engineer should be able to make an accurate assessment of the opportunities for reducing the energy consumption of existing buildlings. A cost benefit analysis provides the opportunity to make implementation decisions based on projected energy savings, investment costs, operational changes, and payback periods.

In addition, a survey of currently available Solid State and Microprocessor Based control equipment suitable for use in single building or small clusters of buildings was made and the results of this survey are tabulated in Section 5. A list of manufacturers addresses and telephone numbers is contained in Appendix C. To effectively use this manual, an undestanding of buildings and the mechanical equipment used to heat and cool them is helpful. Two publications that will assist in this understanding are:

Total Energy Management - published by the National Electrical Manufacturers Association

Energy Conservation with Comfort - published by Honeywell

Information on how to obtain these documents is contained in Appendix A, Table A.3.

All equations used in this report use the English system of units (^{o}F, pounds, DFM, etc.).

II. ENERGY MANAGEMENT

Energy conservation has become an increasingly vital task in recent years. Federal agencies have been charged by Executive Order 12003 with reducing the energy consumption by twenty percent in the buildings under their control.

Efforts to comply with this requirement have ranged from delamping and replacement of obsolete equipment to the installation of large scale computer based central control systems. The entire program comes under the collective term "Energy Management".

Energy management, as the term implies, is a systematic, ongoing strategy for controlling a building's fuel-consumption patterns in such a manner as to reduce the waste of energy and dollars to the absolute minimum permitted by the climate in which the building is located, as well as by the condition of the building, its functions, occupancy schedules, and other factors. In short, an effective energy management program establishes and maintains a balance between a building's annual functional energy requirements and its annual actual energy consumption -- no more, no less.

The goal of energy management is the effective and efficient use of energy. Buildings consume energy in their normal operations. Energy is required to provide lighting, to power office equipment, and to provide heating and ventilation for occupant comfort. Each of these areas offers the potential for energy conservation. This manual will concentrate on the mechanical heating, ventilating and air conditioning (HVAC) equipment.

One of the major aspects of an energy management program is proper control of a building's mechanical equipment. Most mechanical systems are controlled by mechanical timeclocks, pneumatic control circuits, electric control circuits, or some combination of these devices. While these devices provide an acceptable level of control for most applications, their limitations do not allow the most energy efficient operation. This is especially true for older equipment. Often the energy savings due to improved controls will provide sufficient cost savings to justify the replacement of obsolete equipment. Even with newer equipment, control modernization will often be economically feasable. Solid state electronics have made tremendous advances in the past few years in terms of the cost/capability ratio. Microprocessors have been developed which bring increased intelligence and capabilities to the control field. It is now possible, using these microprocessors, to scan sensors and to gather information such as temperature, humidity, and equipment status and to use this information to control equipment. In fact, it is now possible to obtain many of the features of large, computer based control systems in microprocessor based "stand alone" control devices suitable for use in a single building. The continuing downward trend in price for this hardware will make these applications increasingly attractive.

The report describes the capabilities of the new microprocessor based control devices and provides some guidance in how to apply them.

III. CONTROL STRATEGY DESCRIPTIONS

Before attempting to analyze a building for its energy conservation potential, two concepts must be defined. A mechanical system is defined as a group of mechanical devices which operate together to perform a common task. Individual items of equipment within a system are not considered to operate independently of one another; however, each system can be controlled independently of other systems in a building.

Mechanical systems will vary in configuration and details from building to building but all equipment serves one basic purpose; the maintenance of a set of desired conditions. In maintaining these conditions the equipment consumes energy. The key to reducing this energy consumption is intelligent control of the mechanical equipment. Various control strategies can be applied, depending on the installed equipment. While the details of implementation may vary, the energy conservation effects of these strategies will be similar.

A control strategy is defined as a specific operational procedure. A strategy generally consists of several independent activities, such as temperature measurement, linked by some form of logic to accomplish a specific purpose. It is important to realize that a control strategy affects an entire system and not just a particular component of the system. If consideration is given only to the operation of an individual element, say a motor, instead of to the total system of which that element is a part, operational problems may occur due to improper operation of other local controls and interlocks. This makes effective energy control and reduction difficult, if not impossible.

These strategies may be accomplished in a variety of ways depending on the particular hardware used to accomplish them, rather than the strategy itself. Therefore, it is possible to identify individual control strategies. The following paragraphs will identify the control strategies considered in this guide. These represent the most common strategies available from manufacturers today. While additional strategies can be identified and may provide some additional energy savings, those listed will most certainly provide the bulk of the potential savings.

SCHEDULED START/STOP

Scheduled start/stop consists of the starting and stopping of equipment based on the time and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. This is the simplest of all control strategies to install, maintain, and operate. It also provides the greatest potential for energy conservation if systems are currently being operated unnecessarily during unoccupied hours. HVAC systems using this strategy generally include a temperature sensor in a space which overrides the shutoff strategy if the temperature drops below a certain level.

OPTIMUM START/STOP

An additional feature of the scheduled start/stop of mechanical systems described above is optimum start/stop. Mechanical systems serving areas that are not occupied 24 hours per day should be shut down during the unoccupied hours. Traditionally, the systems are restarted before occupancy to cool or warm the space to comfort conditions. Under scheduled start/stop this is performed on a fixed schedule selected to meet worst case conditions, independent of existing weather or space conditions. The optimized start/stop strategy adjusts the start and stop times of the equipment to minimize the energy required to provide the desired environmental conditions during occupied hours. This strategy automatically evaluates the *thermal inertia* of the structure, the capacity of the system to either increase or reduce temperatures in the facility, start-up and shut-down times, and weather conditions to accurately determine the minimum hours of operation of the HVAC system necessary to satisfy the thermal requirements of the building.

DUTY CYCLING

The duty cycling strategy consists of stopping a piece of equipment for short periods of time during normal operating hours. This strategy is usually only applicable to HVAC systems. Its operation is based on the theory that HVAC systems seldom operate at peak output; thus 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 this shutdown. Although the interruption does not reduce the required net space heating or cooling energy, it does reduce energy input to constant auxiliary loads such as fans and pumps. This strategy also reduces outside air heating and cooling loads since the outside air intake damper is closed while an air handling unit is off. Systems are generally cycled off for some fixed period of time, say 15 minutes, out of each hour of operation. The off period length and its frequency should be adjustable. The off period length is normally adjusted for a longer duration during moderate seasons and shorter duration during peak seasons. Duty cycling does produce additional wear on belts and motor starting circuits. Further, it may affect building air balance between building zones if more than one air handler is in use. Analysis of these potential problems may preclude use of this strategy in certain cases.

DEMAND LIMITING

This strategy consists of stopping electrical loads to prevent setting a high electrical demand peak and thus increasing electrical costs where demand oriented rate schedules apply. There are many complex schemes for accomplishing this. They all generally monitor the electrical demand continuously. Based on the monitored data, demand predictions are made by the control equipment. When these predictions exceed preset limits, certain scheduled electrical loads are shut off by the controller to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the strategy's requirements. Generally, the loads to be shed are HVAC items. The reasoning used in the duty cycling discussion holds here also: allow a slight temperature drift in the space by shutting off the HVAC equipment. Utility rate schedules, which include "time of day" pricing, offer additional savings opportunities. Running of certain equipment, such as water well pumps, during off peak hours has significant impact under that type of schedule and should be thoroughly investigated.

Demand limiting is generally not applicable to single buildings as demand is not usually metered at this level. Instead the electrical consumption and demand are measured at a facility's main feeder and only the composite demand for the facility is recorded. Because of this, demand limiting is not analyzed in this manual. If demand limiting appears to be a viable strategy, further information is available in the Standardized EMCS Energy Savings Calculations Manual, available from the Naval Civil Engineering Laboratory at Port Hueneme, California.

DAY/NIGHT SETBACK

The energy required to maintain space conditions during the unoccupied hours can be reduced by changing the temperature set point for the space, depending on the climatic conditions. This strategy would apply only to facilities that are not occupied 24 hours per day. Normally, where applicable, this strategy would reduce the space temperature from the 65° winter inside design temperature to a 50° or 55° space temperature during the unoccupied hours or allow it to increase from the 78° inside condition during the summer.

ECONOMIZER

The utilization of an all outside air economizer control strategy can be a cost effective energy conservation strategy, depending on the climatic conditions and the type of mechanical system. Where applicable, the economizer control strategy uses outside air to satisfy all or a portion of the building's cooling requirements. Outside air is introduced through the mechanical system and return air is exhausted instead of the normal recirculation. A dry bulb economizer compares the outside air temperature to a fixed value, selecting outside air whenever it is below the switchover point.

ENTHALPY

An enthalpy control strategy uses a more sophisticated decision making algorithim than an economizer. The enthalpy, or "total heat" content of both the outside air and the return air is determined by measuring the dry bulb temperature and the relative humidity of each air stream. The air stream having the lowest enthalpy is selected for use. This allows the enthalpy economizer control strategy to achieve greater savings by taking advantage of the outside air stream a greater portion of the time.

The evaluation of economizer and entholpy control strategies is a complex process requiring many calculations. It is best accomplished using computer simulation. The Standard EMCS Energy Savings Calculations Manual describes both recommended computer techniques and a manual calculation procedure to approximate these savings.

VENTILATION AND RECIRCULATION

The thermal load imposed by outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements for a facility, depending on the geographical location. This strategy controls the outside air dampers when the introduction of outside air would impose a thermal load and the building is unoccupied. This strategy would be used during warm up or cool down cycles prior to occupancy of the building and would also apply in certain facilities that require maintenance of environmental conditions for proper operation of electronic equipment, even though the buildng is unoccupied. During those times, the outside air dampers would be closed.

The evaluation of this strategy is also beyond the scope of this manual. The Standardized EMCS Energy Savings Calculations Manual contains a recommended procedure for evaluating this strategy.

HOT DECK/COLD DECK TEMPERATURE RESET

Mechanical systems such as dual duct systems and some multizone systems use a parallel arrangement of heating and cooling coils commonly referred to as hot and cold decks for the purposes of providing heating and cooling mediums simultaneously. Generally speaking, both heated and cooled air streams are mixed to satisfy the individual space thermal requirements. In the absence of optimization controls, these systems can waste energy because the final space control merely mixes the two air streams to produce the desired result. While the space conditions may be acceptable, the greater the difference between the temperatures of the two streams, the more inefficiently the system will operate. This strategy can select the individual areas with the greatest heating and cooling requirements, establish the minimum necessary hot deck and cold deck temperatures based on these extremes, and minimize the inefficiency of the system. The goal is to reduce the temperature difference between the two air streams to the minimum value which will still meet the space conditions.

A variation of the hot and cold deck multizone system is the air handler equipped with a cold deck and a bypass section at the mechanical system and individual heating coils in the reheat position downstream from the unit. The system operates with a constant cold deck temperature which is, in turn, mixed with the bypass air in an effort to satisfy individual zone requirements. Air supplied at temperatures below the individual space requirements is elevated in temperature by the reheat coil in response to signals from an individual space thermostat. Selection of the space with the greatest cooling requirements and resetting the cold deck discharge temperature in response to these requirements minimizes the energy used for reheat. Again the strategy is to minimize the temperature differences.

CHILLED WATER TEMPERATURE RESET

The energy required to generate chilled water in a reciprocating or centrifugal electric driven refrigeration machine is a function of a number of equipment characteristics including the temperature of the chilled water leaving the machine. Because the refrigerant suction temperature is a direct function of the leaving water temperature, the higher the two temperatures, the lower the energy input per ton of refrigeration. Chilled water temperatures are selected for peak design times and, in the absence of strict humidity control requirements, can usually be elevated during most operating hours. Depending on the operating hours, size of the equipment, and configuration of the system, energy savings can be effected by resetting the chilled water temperature to satisfy the greatest cooling requirements. Generally, this determination is made by the position of the chilled water valves on the various cooling systems. The positions of the control devices supplying the various cooling coils are monitored and the chilled water temperature is elevated until at least one control device is in the maximum position. Other control schemes may be used to satisfy different system configurations. Care must be taken not to exceed the chiller manufacturer's recommended limits when applying this strategy.

CHILLER DEMAND LIMIT

Centrifugal water chillers are generally equipped with a manually adjustable control system which limits the maximum current, and thus power, the machine may use. An interface between the control device and this control circuit allows the controller to reduce the limit setting in a load shedding situation and thus reduce the electric demand without completely shutting down the chiller. The method of accomplishing this function varies with the specific manufacturer of both the water chiller and the controller. The principle of operation is the same, however. When the chiller is selected for load shedding, a single stop signal is transmitted to the interface which then reduces the chiller limit adjustment by a fixed amount. <u>EXTREME CAUTION MUST BE EXERCISED WITH APPLICATION OF THIS STRATEGY</u>. Often, the actual setting of the chiller limit adjustment is not resettable or even detectable by the controller. Incorrect interface and control can cause the refrigeration machine to operate in a surge condition, ultimately causing considerable damage to the equipment.

CONDENSER WATER TEMPERATURE RESET

Another parameter affecting the energy input to a refrigeration system is the temperature of the condenser water entering the machine. Conventionally, heat rejection equipment is designed to produce a specified condenser water temperature such as 85° at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain this specified temperature at conditions other than peak design. To optimize the performance of the condenser water system, however, these controls can be reset when outdoor temperatures will produce lower condenser water temperature. Where applicable, this strategy will reduce the energy input to the refrigeration machine.

All control strategies which affect chiller operation require extreme caution in their application to avoid damage to the equipment. The complexity and interrelation of these strategies puts them outside the scope of this manual. For further information consult the Standardized EMCS Energy Savings Calculations Manual.

IV. SAVINGS ANALYSIS

The first step in improving a building's energy performance is a physical survey of existing conditions. This survey may range from a simple walk through a small building to a detailed study for a large, mechanically complex building. However, all surveys require a certain minimum amount of information. The building's characteristics and operating schedule should be determined, paying special attention to areas such as computer rooms which require special conditions. In addition, the existing mechanical plant should be carefully surveyed to determine what systems are present. The equipment should be studied paying particular attention to the presently installed controls. At this time, all defective existing controls should be identified and repaired. No purpose is served in adding additional devices to a defective control system.

In the case of larger, more complex buildings, the survey should identify the equipment serving the various "zones" of the building. Occupancy schedules for each of these zones should be determined if there is a variation. Energy consumption records should be obtained wherever possible for study and evaluation. Patterns in the facility's energy consumption may point to energy conservation opportunities. Procedures and guidelines for performing such a survey may be found in the Standardized EMCS Energy Savings Calculations Manual and in manuals available from the commercial controls firms.

Armed with the survey data, the second step in the analysis procedure is to select control strategies appropriate to the installed equipment. Not all strategies are applicable to every mechanical system. In addition, operating constraints of the facility may eliminate some that are physically possible. Normally Scheduled Start/Stop and Optimum Start/Stop can be applied to all systems. Night Setback and Setup are also generally applicable. The amount of setup and setback will depend on the building's mission. The applicability of other strategies will depend on the mechanical systems present. Engineering judgement must be exercised to select the appropriate strategies for each building. Additional guidance in selecting appropriate strategies may be obtained from the publications listed in Appendix A, Table A.3.

The third step in the analysis is an estimation of the energy and cost savings associated with the control strategies being considered. Control strategies can be considered and analyzed on an individual basis. This approach to analysis allows a standard evaluation procedure to be developed for each strategy. These standard procedures may then be applied to various mechanical systems. Using the procedures outlined in this guide, estimates of the possible energy savings may be obtained for the most common control strategies. These potential energy savings and information on the cost of energy at a given location will yield the potential cost savings of a proposed control strategy.

One caution must be observed when using these procedures. Because each analysis is considered independently, no effort is made in the procedures to account for the interactive effects of one strategy on another. Engineering judgement and common sense must be employed when estimating savings for systems for which more than one strategy is being considered.

An estimate of the costs of implementing the identified control strategy is just as important as estimating the energy savings. This Guide contains pricing information for equipment obtained from various manufacturers. All prices represent quotes obtained for a base unit to an end user, quantity of one, and were valid as of August 1981. Because of the rapidly changing price structure of these devices, these prices should be used only for preliminary calculations. Local equipment representatives should be contacted for current pricing information as part of the project planning. An allowance for installation labor and other job conditions will also be required.

This information must be evaluated in a logical manner to allow intelligent decisions to be made on the allocation of monetary resources. The Energy Conservation Investment Program (ECIP) economic analysis procedure meets these requirements. An ECIP analysis produces three indices of merit: the E/C ratio (millions of BTU saved per thousand dollars of investment); the S/I ratio (life cycle dollar savings divided by the life cycle costs); and the simple payback period. These criteria may be used to evaluate, and rank alternative projects and to allocate funds for their implementation. The ECIP analysis procedure is designed to accommodate all types of energy conservation projects. The full analysis procedure is far more complicated than is warrented by the scope of the average project addressed by this manual. As a result, a simplified economic analysis procedure for control projects has been derived from the full ECIP Guidelines. Instructions for the simplified analysis for controls may be found in Appendix B.

Procedures for estimating the savings resulting from implementation of selected control strategies are presented in the remaining pages of this section. The energy savings aspects of these strategies are identified and a method of estimating these savings is identified. Not all strategies are discussed in this section as some require complex calculations or computer techniques to evaluate. For information on these strategies, consult the Standardized EMCS Energy Savings Calculations Manual.

Values for the various constants used in the equations presented in this manual and additional information may be found in Appendix A of this volume.

Scheduled Start/Stop

The savings attributable to this function are composed of three elements - the savings of heating energy during unoccupied hours, the reduction in ventilation air, and the shutdown of constant auxilliary loads such as fans and pumps. Each of these components must be estimated separately and then added to produce the savings attributable to this function.

Energy savings during unoccupied hours of the heating season are primarily the heating energy saved by reducing the space temperature and eliminating the ventilation air.

These savings are estimated using the following equation:

Heating BTUs saved =
(Building Thermal Transmission Factor) x (Building Surface Area) x (Night Time Temperature Reduction) x (Hours/Week Temperature is Reduced) x (Weeks/Year in Heating Season)

The yearly heating energy savings from ventilation reduction may be estimated using the following equation:

Heating BTUs Saved =
(Additional Hours/Week Equipment will be Off) x (Weeks/Year in Heating Season) x (Unit Capacity in 1000's of CFM) x (Percent of
Outside Air) x (A Conversion Factor of 1.08)* x (Space Temperature - Average Outside Temperature)

*This factor has the units $\frac{\text{MIN BTU}}{\text{hr ft}^3 \ {}^\circ\text{F}}$

Yearly Cooling savings are estimated in a similar fashion:

Cooling BTUs saved/year =
(Additional Hours/Week Equipment will be Off) x (Unit Capacity in 1000 CFM) x (Percent Outside Air) x (BTUs/Year of Required Cooling Energy)

Auxilliary savings result from turning off various motors when the equipment is not functioning. These savings are in kilowatt hours and are estimated as follows:

Auxilliary Savings =
(Additional Hours/Week Equipment is Off) x (Weeks/Year Equipment is used) x (A Conversion Factor of .8)*

*The value .8 is a worst case power factor for an electric motor

Optimum Start/Stop

After a period of reduced temperature the heating system must be started prior to occupancy to bring the space to normal conditions. Simple scheduled operation provides enough time to meet the demands of the worst case situation. Optimum start/stop will automatically adjust the starting time of the heating equipment to provide the desired space conditions with a minimum of equipment operation. The savings result from a decrease in the electrical consumption of auxiliary equipment and an increased setback time. This time interval varies from day to day but is estimated to average 1/2 hour per day.

Later start of the equipment will reduce the amount of outside air which must be conditioned. The ventilation savings is only credited for the heating season as early morning temperatures are usually quite cool during the cooling season. The later start will also reduce the energy consumed by auxiliary equipment.

The equations used to estimate these savings are basically the same as for Time Scheduled Operation.

Heating BTUs Saved =
(2.5 additional Hours/Week of Equipment off Time) x
(Weeks/Year in Heating Season) x (Unit Capacity in 1000's of CFM) x (Percent of Outside Air) x (A Conversion Factor of 1.08)* x (Space Temperature - Average Outside Temperature)

*This factor has the units $\frac{\text{MIN BTU}}{\text{Hr ft}^3\ °\text{F}}$

Auxilliary Savings =
(2.5 Additional Hours/Week of Equipment off Time) x
(Weeks/Year Equipment is used) x
(A Conversion Factor of .8)*

*The value .8 is a worst case power factor for an electric motor

Duty Cycling

Duty cycling HVAC equipment saves energy in the same manner as scheduled operation. Stopping equipment operation eliminates the energy consumption of the auxiliary equipment and the need to heat or cool outside air during the off time. The reduced hours of operation will depend upon the area being served, the weather conditions and other factors, but will usually be in the range of 15-25% of the normal operating hours. The savings for the heating season, the cooling season, and the auxiliary equipment are each estimated separately and added to obtain the savings attributable to this function.

The hours/week equipment is cycled off is a function of the percent off time during normal occupied hours. It is calculated as:

Hours/Week cycled off = (Hours/Week of normal operation) x
(% off Time)

The optimum % off time must be determined by experiment and will vary from one application to anotherand may change according to season, but as a general rule of thumb, 15 to 25% is a good estimate.

Heating BTUs Saved =
(Hours/Week cycled off) x (Weeks/Year in Heating Season) x (Unit capacity in 1000's of CFM) x (Percent of outside air) x (A Conversion Factor of 1.08)* x (Space Temperature - Average Outside Temperature)

*This factor has the unist $\frac{\text{MIN BTU}}{\text{Hr Ft}^3 \text{ !F}}$

Auxilliary Savings =
(Hours/Week cycled off) x (Weeks/Year equipment is used) x (A Conversion Factor of .8)*

*The value .8 is a worst case power factor for an electric motor

Hot Deck/Cold Deck Reset

Many systems utilizing a hot and cold deck distribution system rely upon fixed coil discharge temperatures. Control is achieved at the space level by mixing the two air streams in proportion to the load, resulting in considerable energy waste. A coil discharge temperature which is reset from outside air temperature will reduce this but still results in a significant amount of mixing.

A controller capable of Hot Deck/Cold Deck Reset changes the discharge temperature of the coils in response to the worst space load. The optimum point is when the hot deck is just warm enough to satisfy the coldest space and the cold deck is no cooler than necessary to satisfy the warmest space's requirements. This point will minimize the mixing of air and thus reduce the energy consumption of the system.

The savings attributable to this function are dependent upon the average amount the discharge temperatures can be altered. This is a difficult value to estimate accurately as it depends on a large number of variables but, lacking any other input, a reasonable estimate of the savings may be obtained by using an average hot deck reset of 2°F during the heating season and 1°F during the cooling season. For the cold deck, a reasonable value is 1.5 BTU/Pound - a reset of approximately 2.5°F.

Heating BTUs Saved =

[(Unit capacity in 1000's of CFM) x (% of flow through hot deck) x (A Conversion Factor of 1.08)*] x [(Summer Reset) x (Weeks/Year of Cooling Season) x (Winter Reset) x (Weeks/Year of Heating Season)] x (Hours/Week of operation)

*This factor has the units $\frac{\text{MIN BTU}}{\text{Hr Ft}^3\ {}^\circ\text{F}}$

Cooling BTUs Saved =

(Unit capacity in 1000's of CFM) x (% of flow through cold deck) x (Reset) x (A Conversion Factor of 4.5)* x (Weeks/Year of cooling season) x (Hours/Week of operation)

This factor has the units $\frac{\text{MIN LB}}{\text{Hr Ft}^3}$

If no better estimate of the flows through the hot and cold decks is available use 50%.

V. MICROPROCESSOR CONTROLLER SURVEY

The recent advances in solid state technology and dramatic decreases in the cost of electronics has resulted in the increased application of digital technology to control devices. The increased capability of these new digital controllers has made many of the more sophisticated control functions available to the energy conservation engineer. One element of this study was a survey of available digital control devices.

A survey of a field growing as rapidly as this can never be complete. Vendors and products are constantly entering the market. Rather than trying to present an exhaustive survey, effort was concentrated on obtaining data on a representative sample of controllers spanning the range of complexities and capabilities offered. A summary of the results of this survey is presented on the following pages as Tables 1 through 7.

For ease of use the data has been organized into six broad divisions based on functional capabilities. Table 1 is a guide to the capabilities of each group. Tables 2 through 7 summarize the characteristics of the specific devices within that class. This approach allows one to quickly identify the class of controller of interest, select some typical devices and locate more detailed information.

TABLE 1

EQUIPMENT CLASS	Scheduled Start/Stop	Optimum Start/Stop	Duty Cycling	Demand Limiting	Day/Night Setback	Economizer	Enthalpy	Ventilation and Recirculation	Hot/Cold Deck Temperature Reset	Chilled Water Temperature Reset	Chiller Demand Limit	Condenser Water Temperature Reset
TIMECLOCKS AND THERMOSTATS W/TIMECLOCKS	●				●							
DEMAND LIMITERS AND DUTY CYCLERS	●		●	●								
EQUIPMENT CONTROLLERS	●	●			●	●	●	●	●	●	●	●
BUILDING CONTROLLERS	●	●	●	●	●	●	●	●	●	●	●	●
PROGRAMMABLE CONTROLLERS	●	●	●	●	●	●	●	●	●	●	●	●
MICRO SYSTEMS	●	●	●	●	●	●	●	●	●	●	●	●

CONTROL FUNCTIONS

TIMECLOCKS AND THERMOSTATS WITH TIMECLOCKS

The controllers in this class are primarily timing devices capable of performing scheduled start/stop. The thermostats with timeclocks are also capable of night setback.

Table 2 summarizes the capacity of the timeclocks as follows:

No. of Setpoints/Load means the number of different temperature settings at which the thermostat may be set for each load. At least two are necessary for night setback.

No. of Schedules/Load means the number of different daily on/off schedules per load for which the timeclock can be programmed.

No. of Switchovers/Day means the total number of on or off switches which may be scheduled for a load in one day.

TIMECLOCKS AND THERMOSTATS WITH TIMECLOCKS
TABLE 2

MANUFACTURER & MODEL NO.	[illegible]	[illegible]	[illegible] ADJUSTMENT	MANUAL OVER-RIDE	BATTERY BACK-UP	24 VOLTS A.C., 60 HZ	115 VOLTS A.C., 60 HZ	NO. OF LOADS CONTROLLED	NO. OF SETPOINTS/LOAD	NO. OF SCHEDULES/LOAD	NO. OF SWITCHOVERS/DAY	BASE PRICE	
						POWER REQUIRE.							
AMF PARAGON EC 74				●	●	●	●	4	6	2	2	$850	365 day claendar and 12 holiday capacity available as a $100 option.
PARAGON EC 403				●	●	●		2	2	7	2	$745	Unit optimizes start/stop times based on outside air temperature.
PARAGON EC 700				●	●	●		8		8	64	$1865	Expandable to 12 control circuits.
PARAGON EC 702				●	●	●		8		8		$2070	May be used to duty cycle equipment.
AUTOTRONICS, INC. AUTOPACE 7	●		●	●		●		1	4	7	4	$200	
FEDERAL PACIFIC ELECTRIC LI/TRONIC	●			●		●		1				$33	Unit changes setting based on occupancy.
HONEYWELL T8082A	●			●		●		1	2	1	6	$112	
T800A	●		●	●	●	●		1	2	2	4	$157	
JADE CONTROLS H/C - CL	●			●		●		1	8	1	4	$75	
JOHNSON CONTROLS T53 CEA	●			●	●	●		1	2	2	4	$105	
NUCLEAR SYSTEMS INC. SMARTSTART 1000	●			●	●	●		1	4	3	4	$216	

TIMECLOCKS AND THERMOSTATS WITH TIMECLOCKS
TABLE 2

MANUFACTURER & MODEL NO.	THERMOSTAT	[illegible]	CONCEALED ADJUSTMENT	MANUAL OVER-RIDE	BATTERY BACK-UP	POWER REQUIRE. 24 VOLTS A.C., 60 HZ	POWER REQUIRE. 115 VOLTS A.C., 60 HZ	NO. OF LOADS CONTROLLED	NO. OF [illegible]/LOAD	NO. OF SCHEDULES/LOAD	NO. OF SWITCHOVERS/DAY	BASE PRICE	
PRINTED CIRCUITS INTERNATIONAL COMFORT ZONE	●	●		●	●	●		1	2	3	3	$275	BASIC 4 LOAD MODEL ADDITIONAL LOAD MODULES ARE $365
PGS INDUSTRIES, INC. COMPUSTAT	●		●	●	●	●		1	4	1	4	$89	
POWER CONTROL PRODUCTS CLOCK TWO				●	●		●	4			960	[illegible]	EXPANDABLE IN INCREMENTS OF 4 TO 16 TOTAL ΔT
RANDOM ACCESS CONTROLLER	●					●		1	2	2	4	$129	
RAPID CIRCUIT RC 8000 HAC	●	●		●	●	●		1	2	1	4	$159	
[illegible] ENG. AUTOSWITCH			●	●	●		●	16	NA	7	*	$1494	*192 to 960 PER WEEK TOTAL
SIGNALINE MODEL 513				●		●		2	NA	1	2	$155	
MODEL 514 **	●					●		1	2	NA	NA	$85	** TO BE ADDED TO EXISTING THERMOSTAT AND REQUIRES EXTERNAL TIMECLOCK
SIGNALINE MODEL 524			●		●			4	NA	8	2	$497	
SOLIDYNE 7 DAY CONTROLLER				●			●	4			18	$600	DUTY CYCLING AVAILABLE AS OPTION
TEXAS INSTRUMENTS 4PA2-3 & 4PA3-1	●		●	●	●	●		1	7	2	4	$110	

TIMECLOCKS AND THERMOSTATS WITH TIMECLOCKS
TABLE 2

MANUFACTURER & MODEL NO.	THERMOSTAT	DEMAND	CONCEALED ADJUSTMENT	MANUAL OVER-RIDE	BATTERY BACK-UP	POWER REQUIRE. 24 VOLTS A.C., 60 HZ	POWER REQUIRE. 115 VOLTS A.C., 60 HZ	NO. OF LOADS CONTROLLED	NO. OF SETPOINTS/LOAD	NO. OF SCHEDULES/LOAD	NO. OF SWITCHOVERS/DAY	BASE PRICE
U.S. ENERGY KILO-WATT-CHEK 100				●			●	3	NA	1	2	$309
TORK 8800				●	●		●	8		8	72	$1800

DEMAND LIMITERS AND DUTY CYCLERS

The control equipment in this class was selected because their primary functions are either demand control or duty cycling. Most are also capable of performing programmed start/stop of equipment. The control panels are generally contained in a lockable cabinet which is designed for mounting on a wall.

The "Soft Restore" column found in Table 3 designates those controllers which are capable of sequencing the start-up of multiple loads after a power outage or after they have been shed for demand control. The controllers have a variety of means of displaying information. Most display the loads which have (or don't have) power by means of indicator lights. The "Single Display: Select. Func." refers to a meter or digital readout which registers selectable functions chosen from a dial or keypad. "No. of Adjustable Setpoints" refers to the number of different KW demand limits which may be set for different time periods of the day.

DEMAND LIMITERS AND DUTY CYCLERS

TABLE 3

MANUFACTURER & MODEL NO.	LOAD SHEDDING	DUTY CYCLING	ALARM INDICATION	FIXED INTERVAL	SLIDING WINDOW	TIME OF DAY COMPATIBLE	SOFT RESTORE	SINGLE DISPLAY; SELECT FUNCT.	STATUS DISPLAY; CONT. LOADS	% OF MAXIMUM DEMAND	CRT DISPLAY; SYSTEM PARA.	CURRENT $ IN VALUE	NO. OF ADJUSTABLE SETPOINTS	NO. OF LOADS IN BASIC UNIT	MAXIMUM NO. OF LOADS	BASE PRICE
								VISUAL DISPLAY								
ALLEN BRADLEY 1810 P	●	●	●	●		●					●		1	64	320	$20,000
BARBER-COLMAN CP-8471	●	●	●	●					●	●			1	4	8	$ 2,441
CP-8473	●	●	●	●					●	●			1	6	16	$ 2,813
CONTROL GENERAL TP 440	●	●			●	●	●	●					2	6	14	$ 7,150
CSL INDUSTRIES MP4, MP6, MP10		●				●	●						1	4	16	
MP 30	●	●	●	●		●	●		●				9	8	28	
DUPONT ENERGY ES-KWD			●		●			●					1			$ 695
DUBAFAR MODEL 1100/1150	●		●	●	●	●	●				●		1	8	32	$12,000
HONEYWELL W-7010G, W-7020G	●	●	●		●	●		●					2	10	20	$ 3,000
JOHNSON CONTROLS SERIES 1000-MODEL 8	●	●			●				●				1	8	8	$ 2,300
SERIES 1000-MODEL 310	●	●				●							N.A.	13	27	$ 2,887

DEMAND LIMITING AND DUTY CYCLING

TABLE 3

MANUFACTURER & MODEL NO.	LOAD SHEDDING	DUTY CYCLING	ALARM INDICATION	FIXED INTERVAL	SLIDING WINDOW	TIME OF DAY COMPATIBLE	SOFT RESTORE	VISUAL DISPLAY: SINGLE DISPLAY; SELECT. FUNCT.	VISUAL DISPLAY: STROBE DISPLAY; COMB. LOADS	VISUAL DISPLAY: % OF MAXIMUM DEMAND	VISUAL DISPLAY: CRT DISPLAY; SYSTEM PROG.	VISUAL DISPLAY: CHANGES IN VALUE	NO. OF ADJUSTABLE SETPOINTS	NO. OF LOADS IN BASIC UNIT	MAXIMUM NO. OF LOADS	BASE PRICE	
SERIES 1000- MODEL 363	●	●	●	●		●				●			2	8	64	$3500	
[illegible] TIME MASTER		●							●				N.A.	4	4	$1200	
TIME MASTER MINI 8		●							●				NA	8	8	$1600	
TIME MASTER 8		●							●				NA	8	8	$1700	Optional panels can expand capabilities.
PACIFIC TECHNOLOGY MODEL 810	●		●		●	●		●					4	4	60	$6,600	
MODEL 363	●	●	●		●								2	8	64	$2,500	
BASIC 4		●			●	●	●		●	●			1	4	4	$1080	
BASIC 8	●	●			●	●	●	●					1	8	8	$2500	
POWERS FREE ENERGY	●	●			●	●	●	●					1	8	8	$5,000	
POWER CONTROL PRODUCTS CLOCK TWO 4+4	●	●	●				●		●			●	●	4+4		$1259	4 LOADS DUTY CYCLED 4 LOADS FOR DEMAND CONTROL
DEMAND CONTROLLER	●		●	●			●			●			1	4	8	$483	Expandable in Increments of 2 at $161/Increment.

DEMAND LIMITERS AND DUTY CYCLERS

TABLE 3

VISUAL DISPLAY

MANUFACTURER & MODEL NO.	LOAD SHEDDING	DUTY CYCLING	ALARM INDICATION	FIXED INTERVAL	SLIDING WINDOW	TIME OF DAY COMPATIBLE	SOFT RESTORE	SINGLE DISPLAY: SELECT FUNCT.	STATUS DISPLAY: CONN. LOADS	# OF MAXIMUM DEMAND	CRT DISPLAY: SYSTEM PARA.	CURRENT KW VALUE	NO. OF ADJUSTABLE SETPOINTS	NO. OF LOADS IN BASIC UNIT	MAXIMUM NO. OF LOADS	BASE PRICE	
PROCESS SYSTEMS SENTRY 1260			●	●	●	●							1	N.A.	N.A.	$2,800	
SENTRY 1270/1280	●	●		●		●		●					1	4	32	$8,000	
SENTRY 1400	●	●		●		●		●					3	4	16	$8,000	
ROTHENBUHLER ENG. AUTOSWITCH		●				●			●				N.A.	4	16	$1,494	
SIGNALINE MODEL 501	●		●	●					●	●			1	2	8	$ 255	
MODEL 516		●							●				N.A.	4	4	$160	
SQUARE D CO. WATCHDOG EM-8	●				●	●		●	●				1	8	8	$2950	
WATCHDOG EM-24	●	●			●	●		●	●			●	1	8	24	$3960	Expandable in increments of 8 at $110 per increment.
TEXAS CONTROLS, INC. MODEL 216		●				●		●					N.A.	16	16	$1,600	
MODEL 416 (PMM)	●	●	●	●				●					1	16	40	$5,000	
TRIMAX CONTROLS POWERWATCH 400		●				●	●		●				N.A.	4		$ 800	

DEMAND LIMITERS AND DUTY CYCLERS

TABLE 3

MANUFACTURER & MODEL NO.	LOAD SHEDDING	DUTY CYCLING	ALARM INDICATION	FIXED INTERVAL	SLIDING WINDOW	TIME OF DAY COMPATIBLE	SOFT RESTORE	VISUAL DISPLAY: SINGLE DISPLAY: SELECT FUNCT.	VISUAL DISPLAY: STATUS DISPLAY: CONN. LOADS	VISUAL DISPLAY: % OF MAXIMUM DEMAND	VISUAL DISPLAY: CRT DISPLAY: SYSTEM PARA.	VISUAL DISPLAY: CURRENT KW VALUE	NO. OF ADJUSTABLE SETPOINTS	NO. OF LOADS IN BASIC UNIT	MAXIMUM NO. OF LOADS	BASE PRICE	
TRIMAX CONTROLS POWERWATCH 515		●				●	●	●	●					5	15	$1695	
TRIMAX CONTROLS POWERWATCH 515 M		●				●	●	●	●					5	15	$1995	REMOTE TELECOM-MUNICATIONS OF OPTION AVAILABLE $1150
US ENERGY CONS. SYS. KILO-WATT-CHER 100		●							●				N.A	2	2	$ 309	
KILO-WATT-CHER 400		●				●		●					N.A	4	4	$1,395	
WATT MASTER USA WATTSMAN 8800	●		●						●	●			1	8	64	$3,895	
XENCON SLC & DC	●	●				●	●		●				2+	4	200	$1,695	

EQUIPMENT CONTROLLERS

Equipment controllers are devices which optimize the startup and/or operation of various kinds of HVAC equipment. Many of these controllers also perform a night setback function. The control panels are generally contained in a lockable cabinet which is designed for wall mounting.

The "Control Point Adjustment" column found in Table 4 designates those controllers capable of changing the setpoint temperature of a system based on data acquired by the controller, such as chilled water reset of a chiller based on outside temperature. "Load Limiting" refers to capability of some chillers to perform a Chiller Demand Limit Strategy as described in Section III.

EQUIPMENT CONTROLLERS
TABLE 4

MANUFACTURER & MODEL NO.	NIGHT SETBACK/SETUP	EXTERNAL TIMECLOCK INPUT	INTERNAL TIMECLOCK	CONTROL POINT ADJUSTMENT	LOAD LIMITING	ANALOG	CONTACT CLOSURES	ELECTRONIC	PNEUMATIC	115 ± VOLTS	24 VOLTS	BASE PRICE	EQUIPMENT TO BE CONTROLLED
							CONTROL OUTPUT			POWER REQUIRED			
AMF PARAGON 403	●		●				●				●	$745	Building optimum start/stop
BARBER COLMAN AD-8042		●		●	●	●	●	●	●	●		$1,200	CENTRIFUGAL CHILLER
CP-8161-333	●	●		●		●	●	●			●	$ 215	Air Handler
CESCO SYSTEM 400			●	●	●	●	●	●	●	●		$675 $1685	Reciprocating Chiller Price depends on number of stages capable of 4 to 18.
SYSTEM 700			●	●	●	●		●	●	●		$2750	Centrifugal Chiller Multiple chiller controlled by multiple units.
SYSTEM 1500			●		●		●			●		$4800	Basic module - requires sensors & outputs appropriate to equipment controlled.
SYSTEM 3000			●	●	●	●	●	●	●	●		$6750 $9375	Multiple chillers will also start air handlers. Price varies with configuration.
CHILLITROL, INC. CHILLITROL I			●	●	●	●	●	●	●	●		$12,000	CENTRIFUGAL OR SCREW TYPE CHILLER
CHILLITROL II				●		●	●	●		●		$20,000	LEAD AND LAG CHILLERS
CHILLITROL 750A			●	●	●	●	●	●		●		$13,500	ABSORPTION CHILLER

EQUIPMENT CONTROLLERS

TABLE 4

MANUFACTURER & MODEL NO.	NIGHT SETBACK/SETUP	EXTERNAL TIMECLOCK INPUT	INTERNAL TIMECLOCK	CONTROL POINT ADJUSTMENT	LOAD LIMITING	ANALOG	CONTACT CLOSURES	ELECTRONIC	PNEUMATIC	POWER REQUIRED: 115 $ VOLTS	POWER REQUIRED: 24 VOLTS	BASE PRICE	EQUIPMENT TO BE CONTROLLED
HEAT TIMER MPC 7	●		●				●			●			Heating system.
HONEYWELL W-973	●	●					●	●		●		$1,000	AHU
JOHNSON CONTROLS C-7305	●		●				●	●		●		$1,133	HEATING & COOLING SYSTEMS
C-7610		●					●	●	●	●		$ 270	COOLING SYSTEM
CHILLER CONTROLLER				●	●	●		●	●	●		$ 554-$2,500	CHILLER
SATCHWELL DIGITAL OPTIMISER	●		●				●	●		●		$3,000-$4,000	HEATING AND COOLING SYSTEMS
TOUR & ANDERSON, INC TA 210C	●			●		●	●	●			●	$ 855	STEAM HEATING SYSTEM
TA 210U	●			●		●	●	●			●	$ 493	HOT WATER HEATING SYSTEM
OPT-II-AAC	●		●				●	●			●	$1,732	HEATING AND COOLING SYSTEMS
TA 211				●		●		●			●	$ 282	CHILLER

Column groups: CONTROL OUTPUT (ANALOG, CONTACT CLOSURES, ELECTRONIC, PNEUMATIC); POWER REQUIRED (115 $ VOLTS, 24 VOLTS).

EQUIPMENT CONTROLLERS

TABLE 4

MANUFACTURER & MODEL NO.	NIGHT SETBACK/SETUP	EXTERNAL TIMECLOCK INPUT	INTERNAL TIMECLOCK	CONTROL POINT ADJUSTMENT	LOAD LIMITING	ANALOG	CONTACT CLOSURES	CONTROL OUTPUT ELECTRONIC	CONTROL OUTPUT PNEUMATIC	POWER REQUIRED 115 ± VOLTS	POWER REQUIRED 24 VOLTS	BASE PRICE	EQUIPMENT TO BE CONTROLLED
TA 220 SERIES	●		●	●		●	●	●		●			This is a series of modular controls designed for specific equipment such as heating or cooling systems.
TRANE ABSORPTION ENERGY MANAGER			●	●					●	●		$4500	Economiser value is approximately $1000 additional.

BUILDING CONTROLLERS

This class of equipment represents devices incorporating several functions in a single panel. These devices generally include the functions of a timeclock and a demand limiter/duty cycler as a minimum. They may also include some pre-defined functions that would otherwise require an equipment controller or a programmable controller to implement. They have been termed building controllers because they are generally configured to monitor and control a sufficient number of points to control an entire building's equipment. Although these devices are designed to stand alone, some incorporate computer interfaces and may be used to gather and report data to a central control device.

BUILDING CONTROLLERS

TABLE 5

MANUFACTURER & MODEL NO.	NIGHT SETBACK	PROGRAMMED START/STOP	DUTY CYCLE	DEMAND MONITORING	LOAD SHEDDING	MANUAL OVERRIDE	PROGRAM BACKUP	ANALOG INPUTS	ANALOG OUTPUTS	BINARY I/O	BASE I/O CAPACITY	BASE PRICE	
ADV LOGICAL SOLUTIONS POWER SAVER	●	●	●	●	●		*	●		●	+	$1095 TO $4840	* 24HOUR BATTERY BACKUP + AVAILABLE IN MODELS WITH FROM 24 to 124 I/O CHANNELS
AEGIS ENERGY SYSTEM ENERGY SAVER SERIES 24		●	●	●	●	●	●	●		●	24	$4125	12 time channels 12 load shed channels
AMERICAN AIR FILTER CURRENT COURIER		●	●	●	●	●	●			●	999 MAX		System uses existing AC wiring as transmission media.
ATLANTIC ENERGY TECH AET 816	●	●	●	●	●	●	●	●		●	32	$7,000	
BARBER COLMAN NPC 8901	●	●	●	●	●	●	●	●		●		$3,900	
BOHN BEMS 2001 - 8/16		●	●	●	●	●	●			●	8	$2100	16 channel unit available for $3175. Remote communications option $350.
CESCO K - 1500	●	●	●	●	●	●	●	●		●	64 MAX	$4625	Prices for basic CPU and 8 output module additional I/O and analog modules extra.
CONTROL PAK EM	●	●	●	●	●	●	●	●	●	●	64 MAX	$5000	
CUTLER HAMMER ENERGIST	●	●	●	●	●	●	●	●	●	●	192 MAX	$5400	

BUILDING CONTROLLERS

TABLE 5

MANUFACTURER & MODEL NO.	NIGHT SETBACK	PROGRAMMED START/STOP	DUTY CYCLE	DEMAND MONITORING	LOAD SHEDDING	MANUAL OVERRIDE	PROGRAM BACKUP	ANALOG INPUTS	ANALOG OUTPUTS	BINARY I/O	BASE I/O CAPACITY	BASE PRICE	
ENERGY METHODS 1602-ST, 1602-BS	●	●	●	●	●	●				●	16	$1,750	
FUEL COMPUTER CORP FUEL CENSOR		●	●				●	●		●		$2,000	
HEAT TIMER MPC-7	●	●	●			●	●	●		●	2	$875	Designed to monitor entire building's heating operation.
HWR	●	●	●			●	●	●		●	4	$875	Designed for control of building's hot water system.
HONEYWELL W 7000	●	●	●	●	●	●	●			●	20		Computer interface available.
LEVITON CCS		●	●			●				●	256 MAX		USES POWER LINE CARRIER TRANSMISSION
MAC VICTOR MICRO 8		●	●			●	●			●	8	$1595	May be expanded in increments of 4 to 16 I/O channels.
MICROCONTROL SYSTEMS MICROL	●	●		●	●		●	●		●	128	$5,000	
NATIONAL ENERGY COMPANY SOLUTION 1000/1600	●	●	●	●	●	●	●			●	100	$4980	Solution 1600 is the same unit but capable of 1600 channels.
PACIFIC TECHNOLOGY MODEL 1664	●	●	●			●		●		●	64	$5100	

BUILDING CONTROLLERS

TABLE 5

MANUFACTURER & MODEL NO.	NIGHT SETBACK	PROGRAMMED START/STOP	DUTY CYCLE	DEMAND MONITORING	LOAD SHEDDING	MANUAL OVERRIDE	PROGRAM BACKUP	ANALOG INPUTS	ANALOG OUTPUTS	BINARY I/O	BASE I/O CAPACITY	BASE PRICE	
POWER CONTROL PRODUCTS FPMP-2	●	●	●			●	●			●	8	$1450	4 additional I/O channels available as option for $125.
POWER MANAGEMENT SYSTEMS-CE/EC	●	●	●	●	●	●	●	●	●	●	16	$13750	
ROBERTSHAW 2616 ENERGY CONTROLLER	●	●	●	●	●	●	*	●		●	16	$5095	*48 HOUR BATTERY BACKUP
SOLIDYNE 8000A		●	●	●	●	●	*	●		●	8	$1,300	*24 HOUR BATTERY BACKUP Power line carrier available.
TITUS COMMUNICATIONS ENERGY EIGHT		●	●			●	●			●	8	$ 750	
TRIMAX CONTROLS POWERMATCH 515		●	●			●	●			●		$1,995	
TRIMAX CONTROLS POWERSENSE 830		●	●	●	●	●	*	●		●	30	$4,350	*10 DAY BATTERY BACKUP
TEMPMASTER	●	●	●	●	●	●	*	●	●	●		+	*Programs reside in unit control modules +This is a complete control system and price vary depending on number & type of units installed.

PROGRAMMABLE CONTROLLERS

Most of the programmable controllers surveyed were designed with the process control market in mind. Most use a ladder diagram type programming language. The size and capabilities of those listed in Table 6 are such that they could be programmed for energy management functions. Installation of these devices is moderately complex and would require a qualified electrician.

Most of these controllers are modular in design allowing easy expansion. Table 6 breaks down the expandability of the controllers by basic unit (additional modules or cards may be inserted into the basic electrical panel) and by system (additional panels or racks may be added to the basic unit). Some of the controllers are part of a manufacturer's equipment family, allowing interchange of equipment parts among different models.

PROGRAMMABLE CONTROLLERS
TABLE 6

MANUFACTURER & MODEL NO.	EXPANDABILITY: BASIC UNIT	SYSTEM	ACCESSORY DEVICES: CRT	TAPE	PRINTER	DISK	PORTABLE PROGRAMMER	TEST SIMULATOR	PART OF EQUIPMENT FAMILY	COMPUTER ACCESSIBLE	PROGRAM BACKUP	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	BASE I/O CAPACITY	BASE PRICE	
ALLEN-BRADLEY MINI PLC-2	●	●	●	●			●		●	●	●	●	●	●	8	$2,985	
PLC-2 & PLC2/20	●	●	●	●			●		●	●	●	●	●	●	4	$3,680	
PLC	●	●	●	●			●		●	●		●	●	●	16	$7,500	
APPLIED SYSTEMS CORP ASC	●		●				●			●	●	●	●	●	2	$2,000	
CINCINNATI MILACRON MAXIMISER	●	●		●			●				●	●	●	●	8	$3,600	
CUTLER-HAMMER D120		●		●				●			●			●	50	$1,000	
DIVELBISS ICM	●	●					●	●			●			●	8	$300–$2,500	
EAGLE SIGNAL EPTAK 200	●			●	●		●	●		●					128 MAX		
ENTERTRON SK 1600	●						●					+		●	16	$600	Programmer is $600 additional. Program stored in EPROM. Expandable to 32
ESTERLINE ITC-2524		●		●			●			●	●	●		●	16	$2,000	
GENERAL ELECTRIC LOGITROL	●	●	●	●	●					●	●	●	●	●	64	$8,000	

PROGRAMMAELL CONTROLLERS
TABLE 6

MANUFACTURER & MODEL NO.	BASIC UNIT	SYSTEM	CRT	TAPE	PRINTER	DISK	PORTABLE PROGRAMMER	TEST SIMULATOR	PART OF EQUIPMENT FAMILY	COMPUTER ACCESSIBLE	PROGRAM BACKUP	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	BASE I/O CAPACITY	BASE PRICE
	EXPAND-ABILITY						ACCESSORY DEVICES									
GIDDINGS & LEWIS PC-400	●	●	●	●	●		●				●	●	●	●	104	$10000
GOULD MODICON SERIES MODEL 184	●	●	●	●	●		●		●	●	●	●	●	●	16	$7,270
MODEL 384	●	●	●	●	●		●		●	●	●	●	●	●	16	$9,135
MODEL 484	●	●	●	●			●		●	●	●	●	●	●	4	$4,245
MODEL 584	●	●	●	●			●		●	●	●	●	●	●	4	$9,520
MODEL 1084	●	●	●	●	●		●		●	●	●	●	●	●	8	$32725
LEEDS & NORTHRUP L&N 1300											●	●	●	●	24	$2,500
PROMAC ILC 400	●				●	●							+	●	16	
RELIANCE ELECTRIC AUTOMATE 35CS	●	●	●	●	●		●				●	●	●	●	64	$ 335
UDAC		●	●	●	●	●					●	●	●	●	32	$14475

+Program stored in EPROM

PROGRAMMABLE CONTROLLERS
TABLE 6

MANUFACTURER & MODEL NO.	BASIC UNIT	SYSTEM	CRT	TAPE	PRINTER	DISK	PORTABLE PROGRAMMER	TEST SIMULATOR	PART OF EQUIPMENT FAMILY	COMPUTER ACCESSIBLE	PROGRAM BACKUP	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	BASE I/O CAPACITY	BASE PRICE
	EXPAND-ABILITY		ACCESSORY DEVICES													
SQUARE D. CO. SY/MAX-20	●		●				●	●		●	●			●	4	$8,130
CLASS 8001	●	●	●	●	●		●			●	●			●	8	$13140
STRUTHERS-DUNN DIRECTOR 4001	●	●	●				●	●		●		●	●	●	8	$2,125
STRUTHERS-DUNN S-D 77/64		●								●	●	●		●	44	$2,224
TEXAS INSTRUMENTS 5TI	●	●	●				●	●	●	●					2	$1,141
PM 550	●	●	●				●	●	●	●		●	●	●	8	$6,381

MICRO SYSTEMS

This category of equipment covers a broad range of devices, from single board dedicated controllers to small distributed processing networks. This group overlaps both programmable controllers and full scale EMCS installations. The primary distinguishing characteristics of these devices is the greater flexibility of programming and the use of higher level languages. The small system is more "computer-like" than a programmable controller. As the complexity of the small system increases the class overlaps the bottom end of the true EMCS.

Small systems give the energy conservation engineer the flexibility to implement innovative control strategies. The expandability and modular nature of these devices allows the creation of a small distributed system. With proper software this system could then be tied into a full scale EMCS.

MICRO SYSTEMS
TABLE 7

MANUFACTURER & MODEL NO.	ACCESSORY DEVICES												MEMORY CAPACITY				
	CRT	TAPE	PRINTER	DISK	POWER LINE MODEM	COMPUTER ACCESSIBLE	PROGRAM BACKUP	PROGRAMS FURNISHED	STANDARD LANGUAGE	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	MINIMUM	MAXIMUM	BASE I/O CAPACITY	BASE PRICE	
ADVANCED LOGICAL SOLUTIONS TPC 2000						●			●	●	●	●	26K	26K	64	$2475	
ASI SYSTEM SOLVER 1		●	●			●	●		●	●	●	●	4k	28k	66	$ 7,000	
ANALOG DEVICES MACSYM II	●	●	●	●		●	●			●	●	●		64k	52	$ 6,990	
ANDOVER CONTROLS SUNKEEPER	●		●			●	●			●		●			96	$12,800	
SUNKEEPER/J	●		●			●	●			●		●			48	$ 8,500	
SUNLOGGER		●	●			●	●			●		●			88	$14,200	
AC 256	●		●			●	●			●		●			48	$8600	SYSTEM IS EXPANDABLE TO 256 I/O POINTS
APPLIED SYSTEMS ENERGY CONTROL SYSTEM			●			●	●	●				●	4k	20k		$ 2,000	
ATLANTIC ENERGY TECH. AET 816	●		●			●	●	●		●		●	8k	8k	32	$ 3,950	
BARBER COLEMAN MICRO/8000	●	●	●		●	●	●	●		●		●			16		

MICRO SYSTEMS
TABLE 7

MANUFACTURER & MODEL NO.				ACCESSORY DEVICES									MEMORY CAPACITY				
	CRT	TAPE	PRINTER	DISK	POWER LINE MODEM	COMPUTER ACCESSIBLE	PROGRAM BACKUP	PROGRAMS FURNISHED	STANDARD LANGUAGE	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	MINIMUM	MAXIMUM	BASE I/O CAPACITY	BASE PRICE	
CONTROL LOGIC CINCH	●					●	●		●	●	●	●	4K	28K	68	$9,000	
CONTROL PACK EM	●		●			●	●	●		●	●	●	64K	64 MAX			
CSL SYSTEM 81	●	●	●	●		●	●			●	●	●					
CUTLER HAMMER ENERGIST							●			●	●	●			192 MAX	$5400	8 digital I/O points/module 2 analog I/O points/module
DIGITEK DK-4000	●		●			●			●	●	●	●	1K	1K			
DYNABYTE, INC BASIC CONTROLLER	●	●				●	●			●	●	●	4K	16K	80	$2,985	
EAGLE SIGNAL EPTAK	●	●	●	●		●	●			●	●	●	1K	4K	28	$4,615	
ENERCON DATA MODEL 102	●				●	●				●		●			16	$3500	Unit can function stand alone.
MODEL 410			●													$1100	Central control unit for system.

MICRO SYSTEMS
TABLE 7

	ACCESSORY DEVICES												MEMORY CAPACITY				
MANUFACTURER & MODEL NO.	CRT	TAPE	PRINTER	DISK	LINE PRINTER	COMPUTER ACCESSIBLE	PROGRAM BACKUP	PROGRAMS FURNISHED	STANDARD LANGUAGE	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	MINIMUM	MAXIMUM	BASE I/O CAPACITY	BASE PRICE	
HONEYWELL DELTA 1000	●	●	●				●	●	●	●	●	●			304 MAX	$300-$1000 per pt.	Minimum system 50 pts.
IBM EMS 320	●		●		●	●	●		●	●	●	●			460	$8,500	
IPAC SERIES 3000	●	●				●	●		●	●	●	●	40K	40K	15	$1,200	
ITRAGO COMPUDAS I/10		●				●	●			●	●	●	20K	36K	648	$5,000	
JOHNSON CONTROLS JC 85/10	●		●	●			●	●	●	●	●	●	64K	64K	304 PTS MAX	1150/PT	Based on 200 pts.
JC 85/40	●		●	●			●	●		●	●	●	352K	608K	2000 MAX	1200/pt.	Based on 250 pts.
LELAND ENERGY OMNI I	●	●	●	●		●	●			●		●			28		
McQUAY GROUP ENERTECH 80	●		●			●	●	●				●			80	$20000	
PROCESS CONTROL, INC. CPC-85						●	●			●	●	●	1K	4K	88	$3,000	
QUANTUM TECHNOLOGY MICROVISORY-11	●	●	●			●	●			●	●	●			32	$22455	

MICRO SYSTEMS
TABLE 7

MANUFACTURER & MODEL NO.	CRT	TAPE	PRINTER	DISK	POWER LINE MONITOR	COMPUTER ACCESSIBLE	PROGRAM BACKUP	PROGRAMS FURNISHED	STANDARD LANGUAGE	ANALOG INPUT	ANALOG OUTPUT	BINARY I/O	MINIMUM	MAXIMUM	BASE I/O CAPACITY	BASE PRICE	
	ACCESSORY DEVICES												MEMORY CAPACITY				
MICROMATT	●	●	●				●			●	●	●			32	$24950	
TEMPERATURE SYSTEMS COMPUCON 1	●	●	●	●	●	●	●	●		●	●	●			16	$8,800	
TOUR & ANDERSON 6501	●					●	+			●	●	●	12		32		
TRINAX POWERSENSE 830			●			●	●			●		●			15	$4350	Expandable to 30 per panel.
SCIENTIFIC ATLANTA CES 1201	●		●		●	●	●	●				●			256		+Program stored in EPROM.

APPENDIX A
REFERENCE DATA

TABLE A.1
BUILDING CHARACTERISTICS

BUILDING DESCRIPTION	TTF VALUE	EXTERIOR WALL CONSTRUCTION	FENESTRATION	ROOF CONSTRUCTION
Low-rise Apartment Building	.48	1/2" lapped wood siding; 1/2" plywood sheathing; 2"x4 stud framing (16" c.c.); 2-1/4" fiberglass insulation, 1/2" Gypsum wallboard.	Single-strenght sheet; "30% sidewalls; 0% endwalls.	Asphalt shingles 1/2" plywood sheathing,3-1/2" fiberglass insulation; 1/2" Gypsum wallboard; ventilated attic; roof slope 3 in.12
Low-rise Apartment Building	.77	4" common brick; 1/2" plywood shetthing; light framing; no insulation 1/2" Gypsum wallboard	Single-strenght sheet; 30% sidewalls; 0% end walls.	Asphalt shingles; 1/2" plywood sheathing; 3" fiberglass insu lation; 1/2" Gypsum wallboard; ventilated attic; roo slope 3 in 12.
Office	.69	6" precast concrete panels.	1/4" plate; 30% all walls	4-ply built-up roofing with gravel; 2" rigid insulation; steel decking; open web joists; 1/2" softboard.
Office Building	.81	1" insulated sandwich panel with aluminum mullions; structural steel framing.	1/4" plate; 50% all walls.	Metal deck; 4" poured concrete roofing; structura steel framing; 1/2' softwood hung ceiling.
Retail Store	2.0	12" concrete block, painted both sides	1/4" plate; 60% South wall; 0% all other walls.	4-ply built-up roofing with gravel; 2" rigid insulation; steel decking; open web joists; 1/2" softboard.
School	.71	4" common brick, 1" fiberglass insulation,	Single-strength sheet; 20% all walls.	4-ply built-up roofing with gravel; 2" rigid insulation; steel decking; open web joists; 1/2" softboard.
School	1.1	4" common brick, no insulation, 4" concrete	Single-strength sheet; 20% all walls.	4-ply built-up roofing with gravel; 1" rigid insulation; steel decking; open web joists; 1/2" softboard.

TABLE A.2

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
ALABAMA								
Birmingham	41.9	16.6	80.6	32.9	0.468	0.450	0.320	1295 - 1650
Montgomery	43.5	14.1	81.1	35.3	0.373	0.694	0.287	1380 - [illegible]5
Huntsville	40.3	18.8	80.5	30.9	0.562	0.354	0.293	---
Mobile	44.7	10.4	79.4	38.4	0.262	0.788	0.263	1490 - 1895
ARIZONA								
Tucson	46.2	12.4	83.5	40.1	0.292	0.266	0.403	1180 - 1500
Flagstaff	35.6	33.4	73.5	18.6	0.169	0.405	0.477	---
Phoenix	46.4	11.4	86.0	41.3	0.266	1.387	0.396	1540 - 1960
ARKANSAS								
Blytheville	39.5	20.4	80.5	29.7	0.628	1.419	0.262	---
Little Rock	41.7	18.1	81.6	31.3	0.554	1.438	0.286	1125 - 1435
Ft. Smith	40.5	18.0	81.0	30.5	0.535	1.446	0.273	---
CALIFORNIA								
Los Angeles	50.2	8.9	72.0	32.6	0.171	0.842	0.746	1435 - 1825
San Diego	50.5	7.0	70.9	29.8	0.132	0.817	0.767	1775 - 2260
Santa Barbara	49.6	23.9	69.7	12.2	0.475	0.328	0.029	1415 - 1800
Bishop	40.2	21.3	82.2	30.4	0.640	0.900	0.399	---
Barstow	42.6	20.6	83.7	32.3	0.565	0.983	0.425	---
San Francisco	48.2	18.4	71.1	22.2	0.393	0.463	0.787	925 - 1175
Sacramento	46.1	19.4	79.9	28.4	0.459	0.832	0.511	1140 - 1450

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
COLORADO								
Denver	35.2	29.4	77.9	22.6	0.041	0.541	0.390	1065 - 1355
Colorado Springs	35.4	30.4	76.9	21.6	0.070	0.530	0.402	700 - 890
Trinidad	36.2	27.7	78.5	25.4	0.951	0.680	0.408	---
Grand Junction	36.3	27.5	80.3	23.7	0.941	0.642	0.321	---
DELAWARE								
Dover	38.4	25.2	77.5	23.6	0.806	0.007	0.271	---
Wilmington	38.2	26.0	77.5	23.7	0.837	0.928	0.283	---
FLORIDA								
Pensacola	44.7	10.4	79.4	38.4	0.262	2.139	0.270	1655 - 2105
Miami	49.3	1.6	80.4	50.1	0.032	2.878	0.080	2010 - 2560
Jacksonville	45.6	8.6	80.4	41.6	0.208	2.054	0.247	1735 - 2210
Orlando	48.5	3.0	78.5	46.2	0.063	2.267	0.189	1855 - 2360
Tampa	47.0	4.0	78.5	46.0	0.091	2.220	0.190	1890 - 2405
GEORGIA								
Atlanta	41.1	19.8	78.7	30.0	0.575	1.255	0.334	1265 - 1610
Augusta	42.6	16.0	80.7	35.1	0.439	1.610	0.323	1320 - 1680
Macon	43.3	14.5	80.3	34.8	0.387	1.542	0.301	1370 - 1740
Valdosta	45.0	10.7	80.0	38.9	0.266	1.881	0.307	---
Savannah	44.0	12.0	80.0	38.0	0.311	1.860	0.317	1465 - 1870

*** 1000 cfm to 55°F for cooling season, per hour.**
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
IDAHO								
Boise	38.1	31.4	78.8	19.7	1.014	0.554	0.332	710 - 905
Pocatello	35.1	33.3	78.6	18.8	1.183	0.471	0.322	620 - 790
Lewiston	40.2	29.7	78.8	18.9	0.892	0.531	0.343	---
ILLINOIS								
Chicago	34.2	30.0	77.0	20.9	1.095	0.776	0.249	755 - 960
Champaign	33.3	27.3	77.9	23.6	1.023	0.775	0.257	865 - 1100
Peoria	34.0	26.0	78.0	24.0	0.955	0.775	0.242	---
Rockford	32.0	29.0	77.0	21.0	1.128	0.737	0.253	---
INDIANA								
Fort Wayne	34.8	28.5	77.7	22.5	1.022	0.851	0.250	780 - 995
South Bend	34.2	29.1	77.1	21.4	1.062	0.771	0.248	755 - 965
Indianapolis	35.8	26.7	78.0	23.9	0.928	0.910	0.251	895 - 1140
Terre Haute	36.8	26.2	78.7	24.8	0.838	1.010	0.260	---
IOWA	32.1	28.0	78.4	21.9	1.086	0.824	0.253	795 - 1010
Mason City	29.8	31.1	76.7	19.7	1.283	0.865	0.255	---
Sioux City	31.2	28.9	79.0	22.2	1.149	0.809	0.246	730 - 930
Council Bluffs	32.1	27.2	78.5	23.0	1.055	0.842	0.264	795 - 1010

*** 1000 cfm to 55°F for cooling season, per hour.**
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
MICHIGAN								
Lansing	34.0	30.4	76.0	19.5	1.116	0.614	0.278	695 - 885
Grand Rapids	34.4	30.5	75.0	19.0	1.107	0.571	0.274	715 - 915
Traverse City	33.0	32.8	75.3	17.0	1.240	0.510	0.291	---
Sault Ste Marie	30.2	37.0	73.4	12.8	1.510	0.334	0.305	---
Detroit	33.8	30.5	75.8	19.2	1.126	0.660	0.257	760 - 965
MINNESOTA								
Duluth	28.0	37.0	73.5	12.7	1.598	0.334	0.311	450 - 570
International Falls	25.5	36.8	73.8	14.1	1.689	0.361	0.306	---
Minneapolis	29.3	31.0	76.8	18.8	1.296	0.613	0.259	---
MISSISSIPPI								
Biloxi	45.2	10.1	79.8	37.6	0.249	2.221	0.261	---
Jackson	43.0	14.8	81.1	35.3	0.400	1.722	0.285	1365 - 1740
Columbus	41.6	16.9	81.2	33.8	0.093	1.615	0.274	---
MISSOURI								
Kansas City	36.5	23.6	80.5	25.7	0.803	0.996	0.264	925 - 1175
Columbia	36.1	24.4	80.2	25.7	0.841	1.026	0.263	---
Springfield	36.7	23.4	79.6	26.9	0.791	1.106	0.269	920 - 1170
St. Louis	36.1	24.2	79.6	26.3	0.834	1.053	0.259	[illegible] - 1170

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
KANSAS								
Dodge City	35.9	25.4	81.4	25.6	0.880	0.805	0.309	---
Goodland	34.3	29.1	81.0	23.6	0.059	0.693	0.332	700 - 890
Kansas City	36.5	23.6	80.5	25.7	0.803	1.026	0.264	925 - 1175
Wichita	37.0	22.6	81.2	27.0	1.757	0.027	0.279	935 - 1195
KENTUCKY								
Louisville	38.4	23.5	79.9	26.6	0.751	1.080	0.274	935 - 1190
Covington	36.8	25.1	78.2	24.4	0.846	0.870	0.274	890 - 1135
Hopkinsville	38.2	22.0	79.7	28.4	0.708	1.202	0.275	---
LOUISIANA								
New Orleans	46.4	9.4	79.8	39.6	0.219	2.230	0.223	1705 - 2170
Alexandria	43.7	13.3	81.0	37.2	0.349	1.901	0.252	---
Shreveport	42.6	15.2	81.8	35.2	0.417	1.690	0.281	1375 - 1750
Lake Charles	45.5	10.4	80.4	39.2	0.253	2.153	0.218	1670 - 2125
MAINE								
Portland	34.5	33.7	74.4	15.5	1.219	0.417	0.331	---
MASSACHUSETTS								
Boston	35.1	31.1	76.0	19.8	1.105	0.661	0.293	775 - 985
Springfield	34.6	30.5	76.3	20.1	1.100	0.626	0.285	---

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
MONTANA								
Billings	34.6	32.1	78.1	18.4	1.158	0.449	0.344	620 - 790
Glasgow	27.9	33.5	77.8	17.5	1.541	0.365	0.314	---
Helena	32.9	36.0	76.1	15.5	1.365	0.350	0.344	450 - 575
Great Falls	33.8	33.8	76.6	16.9	1.248	0.390	0.347	580 - 740
NEBRASKA								
Omaha	32.1	27.2	78.5	23.0	1.055	0.842	0.409	795 - 1010
Grand Island	32.6	28.6	79.4	22.7	1.093	0.750	0.278	---
North Platt	32.4	29.7	79.1	22.0	1.142	0.642	0.301	---
NEVADA								
Las Vegas	43.7	15.6	86.8	35.4	0.409	1.211	0.409	1300 - 1655
Ely	33.4	35.0	77.7	20.2	1.308	0.489	0.355	---
Winnemucca	36.2	31.9	80.4	22.3	1.096	0.636	0.354	---
Reno	35.0	33.0	79.0	21.0	1.176	0.510	0.382	640 - 815
NEW HAMPHSIRE								
Manchester	32.0	32.0	75.0	19.0	1.244	0.567	0.293	---
NEW JERSEY								
Trenton	37.5	26.9	77.1	22.9	0.886	0.814	0.275	895 - 1135

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
NEW MEXICO								
Alburquerque	39.7	23.9	80.4	27.3	0.730	0.752	0.368	935 - 1195
Alamogordo	41.0	19.2	81.8	32.5	0.560	0.901	0.417	---
Clovis	38.7	23.1	79.9	29.4	0.731	0.783	0.413	----
NEW YORK								
Albany	33.8	30.5	76.4	19.5	1.126	0.630	0.277	710 - 905
Buffalo	34.5	31.1	75.0	18.8	1.125	0.658	0.268	715 - 915
Syracuse	34.0	30.2	76.1	19.4	1.109	0.618	0.284	735 - 935
New York City	38.0	27.5	76.0	20.0	1.891	0.814	0.296	895 - 1135
NORTH CAROLINA								
Greensboro	40.1	21.6	79.0	28.1	0.651	1.100	0.319	1010 - 1285
Raleigh	41.0	20.0	79.0	30.0	0.583	1.333	0.318	1065 - 1355
Wilmington	43.6	15.2	78.5	33.6	0.400	1.760	0.283	---
NORTH DAKOTA								
Bismarck	27.4	33.5	77.8	18.3	1.469	0.467	0.296	550 - 700
Grand Forks	24.6	34.4	76.1	16.9	1.612	0.443	0.283	---
Minot	27.2	34.7	76.4	16.2	1.529	0.386	0.308	---
Fargo	27.2	35.0	77.0	17.0	1.542	0.485	0.282	570 - 725

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
OHIO								
Cleveland	34.0	29.4	76.5	21.0	1.080	0.681	0.253	770 - 980
Dayton	36.2	25.4	78.4	24.3	0.872	0.836	0.243	840 - 1070
Columbus	37.8	25.5	77.6	23.8	0.832	0.836	0.263	835 - 1065
Toledo	33.8	29.5	76.8	21.3	1.090	0.660	0.253	755 - 960
Cincinnati	36.8	25.1	78.2	24.4	0.846	0.970	0.274	890 - 1135
OKLAHOMA								
Altus	39.5	19.5	83.2	31.2	0.600	1.189	0.303	---
Oklahoma City	38.9	20.0	81.2	29.5	0.629	1.158	0.298	1030 - 1310
Tulsa	39.0	20.2	81.7	29.7	0.633	1.288	0.294	1060 - 1350
Enid	37.9	21.6	81.9	28.4	0.702	1.195	0.293	---
OREGON								
Burns	35.7	36.3	76.5	17.3	1.266	--	--	---
Medford	41.9	30.9	78.7	21.2	0.871	0.543	0.402	715 - 910
Pendleton	40.1	29.9	78.1	20.0	0.901	0.512	0.402	---
Portland	44.0	30.8	73.5	15.8	0.798	0.362	0.507	725 - 925
Eugene	44.0	30.8	74.0	15.0	0.798	0.421	0.500	690 - 885
PENNSYLVANIA								
Pittsburg	35.1	28.2	76.0	21.9	1.002	0.707	0.281	790 - 1010
Scranton	35.2	29.7	76.2	20.1	1.049	0.642	0.281	735 - 935
Williamsport	36.4	28.9	77.2	21.0	0.986	0.685	0.275	---
Philadelphia	38.2	26.0	77.5	23.7	0.873	0.814	0.283	885 - 1130

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
RHODE ISLAND								
Providence	37.6	28.8	74.7	18.7	0.946	0.688	0.309	770 - 985
SOUTH CAROLINA								
Charleston	43.3	14.2	78.7	36.0	0.379	1.819	0.309	1400 - 1785
Columbia	43.2	16.0	79.7	33.4	0.428	1.477	0.248	1280 - 1630
Myrtle Beach	43.0	15.9	77.9	32.3	1.429	1.672	0.314	---
SOUTH DAKOTA								
Rapid City	32.6	30.7	78.8	19.6	1.174	0.495	0.347	670 - 855
Huron	28.5	31.4	78.9	20.4	1.340		0.248	615 - 780
Sioux Falls	29.2	30.4	78.0	20.5	1.274	0.643	0.266	680 - 865
TENNESSEE								
Memphis	40.5	18.9	81.1	30.4	0.561	1.436	0.271	1120 - 1425
Nashville	39.3	23.3	79.7	28.4	0.722	1.243	0.262	1055 - 1345
Knoxville	39.5	21.5	80.0	29.0	0.662	1.134	0.294	1030 - 1310
TEXAS								
Amarillo	38.1	23.0	80.4	28.4	0.743	0.819	0.355	950 - 1210
Lubbock	39.1	20.8	80.3	30.8	0.649	0.820	0.338	1020 - 1300
Dallas	42.5	15.1	82.8	34.6	0.416	1.485	0.305	1360 - 1730
San Antonio	46.0	8.9	82.7	41.3	0.211	1.778	0.289	1520 - 1935
Corpus Christi	48.1	4.8	80.3	43.0	0.103	2.560	0.196	1820 - 2320
Houston	47.0	6.0	80.3	42.0	0.136	2.236	0.214	2065 - 2630

* 1000 cfm to 55°F for cooling season, per hour.

@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
UTAH								
Salt Lake City	36.5	30.2	79.0	19.9	1.027	0.503	0.307	740 - 940
Wendover	36.7	27.7	79.7	21.6	0.936	0.601	0.322	---
VERMONT								
Burlington	31.3	33.1	74.8	16.7	1.132	0.449	0.307	---
VIRGINIA								
Richmond	40.9	20.9	77.8	26.8	0.612	1.213	0.302	1010 - 1285
Roanoke	39.8	23.4	78.9	26.3	0.713	0.916	0.346	940 - 1200
WASHINGTON								
Seattle	43.7	37.3	70.9	9.4	0.979	0.315	0.503	580 - 735
Spokane	36.6	34.8	76.1	15.6	0.990	0.705	0.309	590 - 755
WEST VIRGINIA								
Charleston	38.4	23.7	78.4	26.1	0.758	0.697	0.253	910 - 1159
Clarksburg	36.5	29.1	75.2	22.5	0.990	0.705	0.309	---
WISCONSIN								
Madison	31.5	30.7	76.9	20.2	1.210	0.697	0.253	710 - 900
Green Bay	31.1	33.0	75.2	17.5	1.312	0.581	0.270	565 - 715
Milwaukee	33.0	30.0	77.0	20.9	1.134	0.774	0.248	670 - 855

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.2 CONT'D

WEATHER DATA

STATE CITY	WINTER AVG. DB WINTER TEMP	WINTER LENGTH IN WEEKS	SUMMER AVG. DB SUMMER TEMP	SUMMER LENGTH IN WEEKS	10^6 BTU@ OUTSIDE AIR HEATING LOAD	10^6 BTU* OUTSIDE AIR COOLING LOAD	10^6 BTU* ECONOMIZER SAVINGS	EQUIV. FULL LOAD CLG. HOURS
WYOMING								
Casper	33.6	33.5	78.3	19.2	1.245	0.476	0.314	605 - 770
Cheyenne	34.4	33.9	76.0	18.3	1.230	0.438	0.364	580 - 740
Rock Springs	31.7	35.3	75.3	16.7	1.384	0.354	0.334	---

* 1000 cfm to 55°F for cooling season, per hour.
@ 1000 cfm to 68°F for heating season, per hour.

TABLE A.3

REFERENCE PUBLICATIONS

1. Energy Conservation with Comfort, 2nd Edition Honeywell.
   Available from: Honeywell Building Services Division
   Dept. 80078 Honeywell Plaza
   Minneapolis, Minnesota 55408

2. Architects and Engineers Guide to Energy Conservation in Existing Buildings, U.S. Department of Energy, DOE/CS-0132.
   Available from: Superintendent of Documents
   U.S. Government Printing Office
   Washington, D.C. 20402
   Stock number 041-018-00080-1

3. Total Energy Management, 2nd Edition, National Electrical Manufacturers Association.
   Available from: National Electrical Manufacturers Association
   2101 L Street, N.W.
   Washington, D.C. 20037

4. Stadardized EMCS Energy Savings Calculations, Navy Civil Engineering Laboratory. Available Septmeber of 1982.

5. Energy Conservation Manual, Johnson Controls.
   Available from: Johnson Controls, Inc.
   507 E Michigan Street
   P.O. Box 423
   Milwaukee, Wisconsin 53201

APPENDIX B
ECONOMIC ANALYSIS GUIDE

The ECIP Analysis procedure provides a method for evaluating and comparing various energy conservation projects. It produces three values which measure the worth of a project:

1. The E/C ratio - The ratio of the yearly energy savings to the costs of the proposed project.

2. SIR (Savings to Investment Ratio) - The ratio of the project's savings to costs.

3. The Payback Period - How long will it take for the project savings to equal its costs.

These figures of merit allow dissimilar projects to be compared on an equal basis.

The ECIP Analysis procedure, because it was designed to accommodate many different types of projects, is somewhat complicated to use. A simplified procedure which produces these same three figures of merit for the control strategies discussed in this manual has been derived from the full ECIP procedure and is presented in this section. Table 3 is a list of the basic assumptions made in preparing this simplified analysis procedure.

Figure 1 is a sample analysis form. Direction for its use are outlined below:

Line 1a - These are the estimated costs for the control equipment and its installation, escalated to the anticipated project start-up time, if appropriate.

Line 1b - Programmable controllers, small systems, and some building controllers require some time to properly program. An allowance for an engineer's time should be included if the programming will be done in-house.

Line 1c - Total of all costs associated with this project.

Project Savings

The savings from implementation of a project are estimated by following the precedures described in this manual for the various strategies. Using these savings estimates, entries are made in the appropriate section of the form.

MBTU's of Energy - The quantity of energy in millions of BTU's that will be saved annually if this project is carried out. The energy source, gas, oil, electricity, or coal will depend on the equipment involved. A project can and often does save energy from more than one source.

Cost per MBTU - This is the cost per MBTU actually paid for energy derived from a given source. If the cost of energy is not available on a MBTU basis, the values in Table 1 may be used to convert costs in more conventional units to costs per MBTU.

If the project under consideration will be programmed for other than the current fiscal year, these costs should be escalated to the planned project start time. Table 2 contains projected escalation rates. Enter the costs in the appropriate savings section of Figure 1.

First year annual savings - This is the dollar value of the estimated energy savings for the first year after the project's completion. It is calculated by multiplying the estimated energy savings by the projected energy costs.

Differential escalation present worth factor - This is a constant factor which converts the expected savings due to implementation of the project to its "present worth". The factors on the form are the proper values to use in this analysis. They account for the differences in the projected energy costs of the various sources.

Discounted Savings - This value is the "present worth" of all the savings expected to accumulate during the economic life of the project. It measures the total value of the projected savings in "today's dollars."

FIGURE 1

ECONOMIC ANALYSIS SUMMARY

ACTIVITY & LOCATION

TITLE OF PROJECT

INVESTMENT

1. PROJECT COSTS (Economic life of 15 years)

   a. Project present worth cost .... $ ________

   b. Programmer's present worth cost (if necessary) $ ________

   c. Total Project present worth cost (a+b) .... $ ________

   (Project costs should be escalated to project start-up, if appropriate)

SAVINGS

2. ANNUAL ENERGY SAVINGS:

   KWH: ________

   a. Equivalent energy: KWH x 0.0116 =

   MBTU's: ________

   b. Cost per KWH at end of program year .... $ ________

   c. First year annual dollar savings (KWH x b) ..... $ ________

   d. Differential escalation present worth factor 12.278

   e. Discounted savings (c x d)..................... $ ________

3. ANNUAL ENERGY SAVINGS

   MBTU's OF COAL: ________

   a. Cost per MBTU at end of program year .... $ ________

   b. First year annual dollar savings .... $ ________

   c. Differential escalation present worth factor 10.798

   d. Discounted savings (b x c) .... $ ________

4. ANNUAL ENERGY SAVINGS

MBTU's of Gas ________

a. Cost per MBTU at end of program year .... $ ________

b. First year annual dollar savings .... $ ________

c. Differential escalation present worth factor ... 13.112

d. Discounted savings (b x c).................. $ ________

5. ANNUAL ENERGY SAVINGS

MBTU's OF OIL ________

a. Cost per MBTU at end of program year .... $ ________

b. First year annual dollar savings .... $ ________

c. Differential escalation present worth factor 13.112

d. Discounted savings (b x c).................... $ ________

6. TOTAL FIRST YEAR ANNUAL SAVINGS

(2c+3b+4b+5b+6c) $ ________

7. TOTAL DISCOUNTED SAVINGS

(2e+3d+4d+5d+6e)................ $ ________

8. TOTAL ANNUAL ENERGY SAVINGS

MBTU (2+3+4+5) ________

COST ESCALATION

	CURRENT COST	FY-	FY-	FY-	FY-
Electricity					
Coal					
Gas					
Oil					

9. SAVINGS/INVESTMENT RATIO
(Line 7/Line 1c)............. __________

10. ENERGY/COST RATIO
(Line8/(Line 1c/1000)) .... __________

11. PAYBACK PERIOD IN YEARS*
(Line 1c/Line 7) .... __________

*If payback period exceeds 15 years (assumed economic life), project will not pay for itself.

TABLE 1

ENERGY CONVERSIONS

For purposes of calculating energy savings, the following conversion factors will be used.

Purchased Electric Power	11,600 BTU/kwh
Distillate Fuel Oil	138,800 BTU/gal
Residual Fuel Oil	Use average thermal content of residual fuel oil at each specific location.
Natural Gas	1,031,000 BTU/1000 cu.ft.
LPG, Propane, Butane	95,500 BTU/gal
Bituminous Coal	24,580,000 BTU/Short Ton
Anthracite Coal	28,300,000 BTU/Short Ton
Purchased Steam	1,390 BTU/lb

NOTES TO TABLE 1

1. Purchased energy is defined as being generated off-site. For special cases where electric power or steam is purchased from on-site sources, the actual average gross energy input to the generating plant plus distribution losses may be used but in no case shall the power rate be less than 10,000 Btu/kwh or the steam rate be less than 1200 Btu/lb.

2. The term coal does not include lignite. Where lignite is involved, the Bureau of Mines average value for the source field shall be used.

3. Where refuse derived fuel (RDF) is involved, the heat value shall be the average of the RDF being used or proposed.

4. When the average fuel oil heating value is accurately known through laboratory testing for a specific military installation, that value may be used in lieu of the amount specified in paragraph 5a.

5. Full energy credit may be taken for conversion from fossil fuels or electric power to solar, wind, RDF, or geothermal energy less the calculated average yearly standby requirement.

TABLE 2

ANNUAL ESCALATION RATES

1. Short Term Escalation

Use the escalation rates given below for extending costs and benefits in the Economic Analysis to the end of the fiscal year in which the project is programed if better local data are not available.

	FY 81	FY 82	FY 83
Design, Construction, SIOH	7.0%	7.0%	7.0%
Maint., & Rpr, O&M, Salvage	5.6%	5.6%	5.6%
Coal	10.0%	10.0%	10.0%
Fuel Oil	14.0%	14.0%	14.0%
Natural Gas & LPG	14.0%	14.0%	14.0%
Electricity and Demand Charge Reduction	13.0%	13.0%	13.0%

TABLE 3

SIMPLIFYING ASSUMPTIONS

1. All projects are control projects and therefore have an estimated economic life of 15 years.

2. Projects will not require an allowance for design costs.

3. Projects will have no salvage value.

4. Escalation rates assume a 10% discount rate.

5. Long term differential escalation rates were used to determine the "Differential Escalation Present Worth Factors" used in this analysis. These rates are:

Coal	5.0%
Fuel Oil	8.0%
Natrual Gas	8.0%
Electricity & Demand	7.0%

6. Implementation of these projects will not result in labor savings.

7. All projects fall in the Energy Monitoring and Control Systems project category.

APPENDIX C
GLOSSARY

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.

Automatic Temperature Control (ATC):

A local loop network of pneumatic or electric/electronic devices which are interconnected to control temperature.

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 of two states, represented by the binary digits 0 and 1.

Bootstrap:

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

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:

A group of eight bits.

Central Memory:

Core or semiconductor memory which communicates directly with a CPU.

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.

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 equipment.

Command Line Mnemonic Interpreter (CLMI):

Software used to implement the CLM language.

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.

Control Strategy:

A procedure for controlling the operation of heating, ventilating and air conditioning (HVAC) equipment in an energy efficient manner.

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 controller 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.

Diagnositic 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.

Direct Memory Access (DMA):

Provision for transfer of data blocks directly between central memory and an external device.

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 from 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 Navy it is the Public Works Officer.

Fall-Back Mode:

The pre-selected operating mode of a controller or the operating sequence of each local control loop when the controller to which it is connected ceases to function.

Firmware:

An instruction set resident in ROM or PROM for accomplishing a special program or procedure.

FORTRAN:

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

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) Devices:

Digital hardware that transmit or receive data.

Interactive:

Functions performed by a process where the machine prompts or otherwise assists an operator to program the device while it continues to perform all other tasks as scheduled.

Interpreter:

A language translator which converts individual source statements into machine instructions 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 tc other devices some distance away.

Local Loop Control:

The controls for any system or sub-system which will continue to function when the EMCS microprocessor controller is non-operative.

Machine Language:

The binary code corresponding to the instruction set recognized the CPU.

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 the machine language version of a program.

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 and modulated light to carry the signal.

Point:

A single connected monitor or control device (i.e., relay, temperature sensor).

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 semiconductor 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 temperature sensor based on a linear relationship between resistance and temperature.

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.

APPENDIX D

LIST OF EQUIPMENT MANUFACTURERS

Advanced Logical Solutions
7074B Commerce Circle
Pleasanton, California 94566
415-462-0150

Aegis Energy Systems, Inc.
607 Airport Boulevard
Doylestown Pennsylvania 18901
215-348-7662

Allen Bradley
Systems Group
747 Alpha Drive
Highland Heights, Ohio 44143
216-449-6700

American Air Filter
P.O. Box 35530
Louisville, Kentucky 40232

AMF Paragon
606 Parkway Boulevard
P.O. Box 28
Two Rivers, Wisconsin 54241
Attn: EMS Group
414-793-1161

AMS
P. O. Box 873
Lake Elmo, Minnesota 55042
612-439-0022

Analog Devices, Inc.
Box 280
Norwood, Maine 02062
617-329-4700

Andover Controls
York and Haverhill Streets
Building 5, Floor 5
Andover, Massachusetts 01810
617-470-0555

Applied Systems Corporation
26401 Harper Avenue
St. Clair Shores, Michigan 48081
313-779-8700

Atlantic Energy Technologies, Inc.
73 Tremont Street
Suite 926
Boston, Maine 02108
617-367-1602

Autotronics, Inc.
1399 Executive Drive West
Richardson, Texas 75081
214-238-7291

Barber-Colman Company
Controls Division
1300 Rock Street
Rockford, Illinois 61101
815-877-0241

Bohn A/C & R Division
Heat Transfer Group
Gulf & Western Manufacturing Company
Danville, Illinois 61832
217-446-3710

CESCO
1240 N. E. 175th Street
P. O. Box 55548
Seattle, Washington 98155
206-365-1234

Chillitrol Inc.
One Century Plaza
2029 Century Park East
Los Angeles, California 90067
213-553-8141

Cincinnati Milacron Company
Electronic Systems Division
Lebanon, Ohio 45036
513-494-5361

Control General Corporation
1606 Medfield Road
Raleigh, North Carolina 27067
919-851-3095

Control Logic
Nine Tech Circle
Natick, Massachusetts 01760
617-655-1170

Control Pak Corporation
23840 Industrial Park Drive
Farmington Hills, Michigan 48024
313-471-0337

CSL Industries
11040 Santa Monica Boulevard
2029 Century Park East
Los Angeles, California 90025
213-479-8581

Cutler-Hammer
Logic Device & Systems Division
4201 N. 27th Street
Milwaukee, Wisconsin 53216
414-442-7800

Digitek Inc.
5950 6th Avenue South
Suite 215
Seattle, Washington 98108
206-762-3933

Divelbliss
9776 Mt. Gilead Road
Fredericktown, Ohio 43019
614-694-9015

Dupont Energy
625 S. Good Latimer
P. O. Box 26390
Dallas, Texas 75226
214-742-7231

Dynabyte Inc.
115 Independence Drive
Menlo Park, California 94025
415-329-8021

Dynapar
1675 Delany Road
Gurnee, Illinois 60031
312-662-2666

Eagle Signal
736 Federal Street
Davenport, Iowa 52803
1-800-553-1160, Ext 8201

Esterline Company
U. S. Highway 287
Parsippany, New Jersey 07054

Enercon Data Corporation
3501 Raleigh Avenue South
Minneapolis, Minnesota 55416
612-925-9300

Enertron Industries
Ellicott Station Box 15
Buffalo, New York 14203
716-856-2242

Energy Management Systems
116 East South S'reet
South Reno, Indiana 46601

Energy Methods, Inc.
177 Main Street
W. Orange, New Jersey 07052
201-736-1811

Federal Pacific Electric Company
Environmental Conditioning Systems Division
150 Avenue C
Neward, New Jersey 07101
201-589-7500

Fuel Computer Corporation of America
419 Whalley Avenue
New Haven, Connecticut 06511
203-865-3844

General Electric Company
General Purpose Control Department
P. O. Box 2913
Bloomington, Illinois 61701

Giddings & Lewis Electronics Company
P. O. Box 348
666 S. Military Road
Fond Du Lac, Wisconsin 54935
414-921-9400

Gould, Inc.
Modicon Division
P. O. Box 83
Shawsheen Village Station
Andover, Maine 01810

Heat Timer Corporation
10 Dwight Place
Fairfield, New Jersey
201-575-4004

Honeywell
Energy Products Center
10400 Yellow Circle Drive
Minneapolis, Minnesota 55343
612-931-4015

International Energy Management
671 Spencer Street
Toledo, Ohio 43695
419-381-2000

The IPAC Group, Inc.
P. O. Box 156
Betnel Park, Pennsylvania 15102
412-831-9200

Ithaco
735 West Clinton Street
Box 818
Ithaca, New York 14850
1-800-847-2080

Jade Controls
P.O. Box 271
Montclair, California 91763
714-985-7273

Johnson Controls
507 East Michigan Street
Milwaukee, Wisconsin 53202
414-276-9200

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WA; SCE, Pearl Harbor HI; Tech Library, Vallejo, CA; Utilities & Energy Cons. Mgr Code 108.1, Pearl Harbor, HI

NAVSTA (Code 50A) Rodman, Panama Canal; Adak, AK; CO (Code 18410), Mayport, FL; CO (Code 413), Grmo, Cuba; CO (Code 52), Brooklyn NY; CO (Code ODE), San Diego, CA; CO (Energy Conserv); CO (PWD), Keflavik, Iceland; CO (PWD), Rota, Spain; CO, Brooklyn NY; Code 16P, Keflavik, Iceland; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; Maint. Control Div., Adak; Maint. Div. Dir/Code 531, Rodman Panama Canal; Maintenance Div., Rota, Spain; PWD - Engr Dept, Adak, AK; PWD - Engr Div, Midway Is.; PWD - Engr. Div, Keflavik; PWD, Utilities Div., Guantanamo Bay Cuba; PWO, Adak, AK; PWO, Brooklyn NY; PWO, Keflavik Iceland; PWO, Mayport FL; SCE, Guam; SCE, Pearl Harbor HI; SCE, San Diego CA; SCE, Subic Bay, R.P.; Utilities Engr Off. Rota Spain

NAVSUBASE CO (Code 223) Bangor, Bremerton, WA; CO (Code 803), Groton, CT; ENS S. Dove, Groton, CT; PWO

NAVSUPPACT CO (Code 413), Seattle, WA; CO (Code 81), Mare Island, Vallejo, CA; CO (Code N52), New Orleans, LA; CO (Energy Conserv), Naples, Italy; CO, Naples, Italy; PWO Naples Italy; PWO, New Orleans LA; SCE, Long Beach CA; SCE, Mare Is., Vallejo CA

NAVSUPPBASE CO (Energy Conserv) Kings Bay, GA

NAVSUPPFAC CO (Energy Conserv) Diego Garcia I; Code 02, Thurmont, MD; PWD - Maint. Control Div, Thurmont, MD; PWO, Thurmont MD

NAVSUPPO CO (APWO), La Maddalena, Italy; PWO, La Maddalena, Italy

NAVSURFWPNCEN Commander, Dahlgren, VA; Dahlgren Lab, WW-02 Dahlgren VA; PWO, White Oak, Silver Spring, MD

NAVTECHTRACEN Code N213 Orlando FL; SCE, Pensacola FL

NAVTELCOMMCOM Code 05, Washington DC; Code 53, Washington, DC

NAVUSEAWARENGSTA CO (Code 073E2), Keyport, WA; Engr. Div. (Code 083) Keyport, WA; PWO, Keyport WA

NAVWARCOL Dir. of Facil., Newport RI

NAVWPNCEN Code 24 (Dir Safe & Sec) China Lake, CA; Code 2636 China Lake; Code 266, China Lake, CA; Code 26605 China Lake CA; Code 3803 China Lake, CA; Code 623 China Lake CA; Commander (Code 2635), China Lake, CA; PWO (Code 266) China Lake, CA

NAVWPNEVALFAC Technical Library, Albuquerque NM

NAVWPNSTA (Clebak) Colts Neck, NJ; CO (Code 09221), Concord, CA; CO (Energy Conserv) Yorktown, VA; CO (Energy Conserv), Colts Neck, NJ; Code 0911, Seal Beach CA; Code 092, Concord CA; Code 092A, Seal Beach, CA

NAVWPNSTA PW Office Yorktown, VA

NAVWPNSTA PWD - Maint. Control Div., Concord, CA; PWD - Supr Gen Engr, Seal Beach, CA; PWO Colts Neck, NJ; PWO, Charleston, SC; PWO, Seal Beach CA

NAVWPNSUPPCEN CO (Code 092E), Crane, IN; Code 09 Crane IN; ENS J. Wyman, Crane IN

NAVY PAO CENTER Directory, San Diego, CA

NCTC Const. Elec. School, Port Hueneme, CA

NSC SCE, Charleston, SC

NCBC CO (Code 80), Port Hueneme, CA; CO (Energy Conserv), Davisville, RI; CO, Gulfport MS; Code 10 Davisville, RI; Code 15, Port Hueneme CA; Code 155, Port Hueneme CA; Code 156, Port Hueneme, CA; Code 25111 Port Hueneme, CA; Code 430 (PW Engrng) Gulfport, MS; Code 470.2, Gulfport, MS; NEESA Code 252 (P Winters) Port Hueneme, CA; PWO (Code 80) Port Hueneme, CA; PWO (Code 82), Port Hueneme CA; PWO - Code 84, Port Hueneme, CA; PWO Gulfport, MS; PWO, Davisville RI; PWO, Gulfport, MS, Port Hueneme CA

NCBU 416 OIC, Alameda CA

NCR 20, Code R31 Gulfport, MS; 20, Code R70

NMCB 1, CO; 1, Code S3E; 133, CO; 3, CO; 4, CO; 5, CO; 62, CO; 74, ENS Vesely; FIVE, Operations Dept; THREE, Operations Off.

NOAA (Dr. T. Mc Guinness) Rockville, MD; Library Rockville, MD

NRL Code 5800 Washington, DC; Code 6620 (Faraday), Wash., DC; PWO Code 2530.1, Washington, DC

NROTC J.W. Stephenson, UC, Berkeley, CA

NSC CO (Code 46A) San Diego, CA; CO (Code 70A), Puget Sound, WA; Code 09A Security Offr, Norfolk, VA; Code 54.1 Norfolk, VA; Code 703 (J. Gammon) Pearl Harbor, HI; SCE (Code 70), Oakland CA; SCE Norfolk, VA; SCE, Guam

NSD CO (Code 50E); PWD - Engr Div, Guam; SCE, Subic Bay, R.P.

NSWSES Code 0150 Port Hueneme, CA

NTC CO (Code NAC50F) Orlando, FL; SCE, San Diego CA

NTIS Lehmann, Springfield, VA

NUSC CO (Code 5204), Newport, RI; Code 3009 (CDR O. Porter) Newport, RI; Code 4111 (R B MacDonald) New London CT; Code 4123 New London, CT; Code 5202 (S. Schady) New London, CT; Code EA123 (R.S. Munn), New London CT; Code SB 331 (Brown), Newport RI; PWO AUTEC West Palm Bch Det. West Palm Beach, FL; PWO New London, CT; PWO Newport, RI; SB322 (Tucker), Newport RI

OFFICE SECRETARY OF DEFENSE DASD (I&H) IC Pentagon; OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR CO (Code 701) Pasadena, CA; Code 221, Arlington VA; Code 700F Arlington VA; LCDR Williams, Boston, MA; Nelson, Arlington, VA
PACMISRANFAC CO (Code 7031), Kekaha, HI; HI Area Bkg Sands, PWO Kekaha, Kauai, HI
PERRY OCEAN ENG R. Pellen, Riviera Beach, FL
PHIBCB 1 P&E, San Diego, CA
PMTC Code 3331 (S. Opatowsky) Point Mugu, CA; Commander (Code 6200-3), Point Mugut., CA; Pat. Counsel, Point Mugu CA; Security Offr, Point Mugu 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; CO Norfolk, VA; CO Yokosuka, Japan; CO, (Code 10), Oakland, CA; CO, Great Lakes IL; CO, Pearl Harbor HI; CO, San Diego CA; CO, Subic Bay, R.P.; Code 10, Great Lakes, IL; Code 100A, Great Lakes, IL; Code 101, San Diego, CA; Code 105 Oakland, CA; Code 105, Oakland, CA; Code 110, Great Lakes, IL; Code 110, Oakland, CA; Code 116, Seattle, WA; Code 120, Oakland CA; Code 120, San Diego CA; Code 120C, (Library) San Diego, CA; Code 154, Great Lakes, IL; Code 200 (H. Koubenec), Great Lakes IL; Code 200, Great Lakes IL; Code 240, Subic Bay, R.P.; Code 400, Great Lakes, IL; Code 400, Oakland, CA; Code 400, Pearl Harbor, HI; Code 400, San Diego, CA; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Commanding Officer, Guam; Code 420, San Diego, CA; Code 424, Norfolk, VA; Code 500 Norfolk, VA; Code 500, Great Lakes, IL; Code 500, Oakland, CA; Code 505A Oakland, CA; Code 600, Great Lakes, IL; Code 600A Norfolk, VA; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Code 800, San Diego, CA; Library, Pensacola, FL; Library, Guam; Library, Norfolk, VA; Library, Pearl Harbor, HI; Library, Subic Bay, R.P.; Library, Yokosuka JA; Maint. Control Dept (R. Fujii) Pearl Harbor, HI; Production Officer, Norfolk, VA; Util Dept (R Pascua) Pearl Harbor, HI; Utilities Officer, Guam
PWC-NAS NAS Pensacola, FL
SPCC CO (Code 763), Mechanicsburg, PA; PWD - Maint. Control Div, Mechanicsburg, PA; PWO (Code 120) Mechanicsburg PA
SUPANX PWO, Williamsburg VA
SUPSHIP ADMINO, San Francisco, CA
TVA Smelser, Knoxville, Tenn.; Solar Group, Arnold, Knoxville, TN
AF HQ USAFE/DEE, Ramstein GE
U.S. MERCHANT MARINE ACADEMY Kings Point, NY (Reprint Custodian)
US FORCES, JAPAN Nakahara Honshu
USAF REGIONAL HOSPITAL Fairchild AFB, WA
USCG (Smith), Washington, DC; G-DMT-3/54 (D Scribner) Washington DC; G-MMT-4/82 (J Spencer)
USCG ACADEMY Utilities Section New London, CT
USDA Forest Service Reg 3 (R. Brown) Albuquerque, NM; Forest Service Reg 6 Hendrickson, Portland, OR; Forest Service, Region 1, Missoula, MT; Forest Service, Region 4, Ogden, UT; Forest Service, Region 5, San Francisco, CA; Forest Service, Region 8, Atlanta, GA; Forest Service, Region 9, Milwaukee, WI; Forest Service, San Dimas, CA
USNA Ch. Mech. Engr. Dept Annapolis MD; Code 170, Annapolis, MD; ENGRNG Div, PWD, Annapolis MD; Energy-Environ Study Grp, Annapolis, MD; Mech. Engr. Dept. (C. Wu), Annapolis MD; PWD Suprt. Annapolis MD
TENNESSEE VALLEY AUTHORITY (Henshaw), Knoxville, TN
ALABAMA ENERGY MGT BOARD Montgomery, AL
ARIZONA Kroelinger Tempe, AZ; State Energy Programs Off., Phoenix AZ
AUBURN UNIV. Bldg Sci Dept, Lechner, Auburn, AL
BATTELLE PNW Labs (R Barchet) Richland WA
BERKELEY PW Engr Div, Harrison, Berkeley, CA
BONNEVILLE POWER ADMIN Portland OR (Energy Consrv. Off., D. Davey)
CALIFORNIA STATE UNIVERSITY LONG BEACH, CA (CHELAPATI)
CLEMSON UNIV. Col. Arch., Egan, Clemson, SC
CORNELL UNIVERSITY Ithaca NY (Serials Dept, Engr Lib.)
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LAWRENCE BERK LAB Window & Lighting Prog. Berkeley, cA

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OAK RIDGE NATL LAB T. Lundy, Oak Ridge, TN
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PORT SAN DIEGO Pro Eng for Port Fac, San Diego, CA
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UNIVERSITY OF HAWAII HONOLULU, HI (SCIENCE AND TECH. DIV.); Natl Energy Inst (DR Neill) Honolulu HI
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KINERT San Diego, CA
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