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Local Energy Monitoring And Control Analysis

Clarence L. Walker, Jr.
Data Signal Corporation
40-44 Hunt Street
Watertown, Massachusetts 02172

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This report is an overview and analysis of currently available energy management control devices for small buildings 200,000 sq ft or less. It discusses the applications of hardware and economic considerations requisite to installing control devices local to a building's mechanical system. It further discusses methods for measuring a project's economic feasibility relative to both retrofit and new construction.

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1.0 PREFACE

As a result of the recent energy crisis the Department of Defense has been mandated to reduce its energy consumption as part of the overall national plan to:

(a) Reduce inflation through conservation.
(b) Increase security through reduced dependency on foreign oil.
(c) Conserve natural resources.

In support of this stated national goal, the function of this manual is to provide Facilities Engineers and Corps of Engineers Division/District personnel with information which will assist them in the analysis, design, and evaluation of techniques and application of local control devices for energy conservation in single buildings.

2.0 INTRODUCTION

As of 1977, buildings under 200,000 sq. ft. accounted for 98.8% of all buildings federally owned. The Department of Defense owned 80% of these federal buildings, which accounted for 84% of the total gross floor area of all government buildings.

This group represents the single largest aggregate of federal buildings classified by size. As size and construction rank as two of the most influential parameters in energy consumption, the consideration of this group in any conservation program is essential.

A primary goal of this report is to document the various types of currently available local control devices, ranging from simple electro-mechanical time-clocks to microcomputerized multi-functional programmable controllers, and their applicability to energy conservation in both retrofitting and constructing this class of buildings.

2.1 Definition of Local Control Devices:

Local control devices are defined as: Any device that permits via its installation local to a controlled function (mechanical and electrical systems) the automatic control of that function. Local is defined as being located in the same building.

2.2.1 Primary Functions of Local Control Devices:

The three primary objectives of local control energy management device utilization are:

(a) Reduction of energy consumption, i.e. fuels and electricity.
(b) Increased operating efficiency of energized systems, i.e. ventilation, heating, cooling, domestic hot water, etc.
(c) Decreased maintenance cost.

Conservation of energy consumed by a building requires first the basic understanding of the various ways in which a structure utilizes energy. This includes understanding both its mechanical and electrical systems (i.e. HVAC, boiler, etc.) as well as the building's structure (i.e. doors, windows, walls, insulation) and function of conditions, i.e. temperature, humidity, ventilation, illumination, and electro-mechanical equipment.

A particular set of space conditions define a building's load requirements. "Building load" is a term describing the amount of energy required to achieve and sustain a desired indoor space condition and to operate a building's equipment.

The efficiency of an energy supply system is a function of the "distribution load", which is a measure of the specific amount of energy required at the primary source to deliver a specific amount to the "building load".

The energy utilized in a building to distribute heat, coolant, domestic hot water of ventilation is an example of "distribution load". Loads are created by inefficiencies, e.g. heat transfer from warm air ducts to colder surrounding air via poor insulation or fluid leakage, etc. Electrical systems experience losses due to poor power factor conditions, high loss transformers, and inefficient lighting systems.

Primary energy supply systems, e.g. boilers, compressors and chillers, experience losses due to such factors as stack temperature, soot, scaling, increased condensing, and condensing temperature, etc.

Local control energy management devices can be incorporated to reduce these load conditions effectively reducing energy consumption as well as increasing the efficiency of primary conversion equipment. As an example, automatic thermostatic control valves for room convectors can be used to replace manual throttling.

2.2.2 Energy Conversion Opportunities:

Areas involving mechanical systems, which provide the most effective application of local control devices for energy conservation are the following:

(a) Temperature Setback

By shutting down a building's heating or cooling equipment during specific hours the internal temperature will drift toward the ambient outside temperature. This will conserve energy. To protect equipment and maximize efficiency this drift is limited to a specific range via a thermostat with an upper and lower range.

(b) Outside Air Reduction

Although it may not be feasible to completely shut outside air intakes at any time, it is sometimes possible to utilize a minimally open position during unoccupied hours, and thus reduce the heating or cooling requirement.

(c) Shutoff Outside Air Intake

It is often possible to close outside air intakes when the building is unoccupied, even if the heating or cooling equipment necessarily remains on. This permits desired heating or cooling levels to be reached more quickly and at less energy cost, and also conserves by not producing superfluous ventilation.

(d) Lighting Control

Through sensing ambient conditions a building's lighting circuit can be automatically controlled e.g. via photoelectric cells. Thus reducing the electrical load when ambient conditions permit.

(e) Load Scheduling

Heating and cooling equipment may be programmed to be automatically shut down during times when the building is unoccupied. When this occurs, the room temperature will drift. The equipment is automatically returned to power in time to prepare the area for normal occupancy.

(f) Optimal Start/Stop

Optimal scheduling of shutoffs, timed reductions in load, and reactivations of HVAC equipment, which allowed for existing weather rather than expected extremes, would save money and energy, improve comfort, equipment utilization, and optimization.

(g) Load Cycling

Careful scheduling during normal operating hours of on and off periods for loads, planned in relation to demand, and priority designation, can reduce energy consumption considerably.

(h) Predictive Demand Limit Control

Load shedding, as this method is often called, involves determination of peak, which, when reached, will signal equipment to be shut down in a specific order to lower the predicted demand value. To accomplish this, the demand meter (billing meter) is monitored by the control system, which, when activated refers to a user-established priority list and shuts down equipment in that pre-determined order.

By forecasting the demand at the end of the demand interval, and then comparing the predicted value to an established target demand, the need or desirability for load shedding can be determined. If the forecasted demand is higher than the target value, prioritized equipment shutdown will lower the forecast. Operation of the equipment is resumed when a subsequent comparison is made and forecasted demand is no longer higher than target value.

A minimum time feature is necessary with power controllers to prevent excessive cycling. A minimum off time assures that the equipment will remain off for a fixed period before restarting. Correspondingly, a minimum cycle time requires the equipment to operate for a fixed time before shutdown.

(i) Chiller Optimization

Optimization of chiller loading allows the most efficient and economical operation of a cooling system. When multiple chillers serving a single system are proportionately loaded the incremental operating cost of each is optimized, reducing total operating cost and enabling the system to run more efficiently and thus use less energy.

(j) Enthalpy Control

Through the use, when efficient, of outside air instead of conditioned air a building may be cooled without the use of a mechanical cooling system. (see (a))

(k) Enthalpy Optimization

Optimization of the ratio of outside air to inside air to reduce the energy consumed by the mechanical equipment load. (see (a))

(l) Equipment Malfunction Detection

Just as inefficiently operating equipment wastes time and energy, even more so does malfunctioning equipment. Rather than waiting for personnel to discover malfunctions, operative failures can be quickly detected by an automatic control system. One method of implementing this feature allows a malfunction alarm to be activated if no input signal has been received from a device during a predefined time period.

(m) Run-Time Totalization

Equipment will run more efficiently, last longer, and generally use less energy when it is maintained in good operating condition. Keeping track of equipment usage and comparing it to maintenance schedules, then incorporating a preventative maintenance program is a simple, effective way to conserve energy while performing standard and desirable equipment care.

(n) Boiler Plant Optimization

Several methods are possible to improve service of and reduce full consumption in boiler plants. One method is to predict heating demand by use of weather conditions, and then adjust output water and steam conditions for optimal efficiency according to the expected demand requirements.

A second method for situations in which two boilers are in use is to fully load the most efficient of the two boilers, leaving the least efficient boiler having to provide only the balance required.

(o) Energy Cost Allocation

Determining the cost of operating individual units of equipment for specific time periods can be useful in many ways, e.g. it can help to determine priorities when deciding on shut down order, for load shedding. Simple multiplication can determine power consumption for equipment operating at only one power level; more complicated calculations and techniques are available to approximate power consumption values if the equipment runs at variable levels.

3.0 HVAC SYSTEMS

Any program of energy conservation must first address the HVAC system characteristics particular to the building in question.

3.1 Discussion of HVAC Systems:

Each HVAC system being unique, its particular characteristics which effect energy expenditure can only be identified by inspection and measurement. It will, however, have many characteristics which are common to all systems of its generic group and it is the common characteristics which are discussed in this section.

The minimum information required to understand the present operation of a system and to provide a basis for deciding which modifications are likely to prove beneficial is tabulated below. Measurement should be as nearly simultaneous as possible.

Air Flow Rates	-total outdoor air total return air total supply air trunk ducts terminal units air cooled condenser
Water Flow Rates	-through boilers through chillers cooling towers heat exchangers coils and terminal units
Temperatures	-outdoor air DB & WB return air DB & WB mixed air entering coils, DB & WB supply air leaving coils, DB & WB hot deck cold deck air at terminals conditioned areas DB & WB (typical for each functional use) boiler supply & return chiller supply & return condenser supply & return heat exchanger supply & return coil supply & return
Regrigerant Temperatures	-hot gas line suction line

Energy conservation must be approached in a systematic manner rather than considering individual items out of context. Systems do not operate in isolation, but depend on and react with other systems. It is important to recognize this interaction of systems as modification to one will cause a reaction in another which may be either beneficial or counter-productive.

Buildings frequently use a combination of system types to meet the differing requirements in interior and perimeter zones. It is common practice, as an example, to use a VAV system for interior spaces, and multi-zone system and/or radiation for perimeter spaces. There is an interface point between the interior and perimeter zones where mixing and interaction between the two different systems takes place. In cool weather, cold supply air from the interior zone can spill into the perimeter zone resulting in overcooling and shift to a heating mode of operation and in hunting with both systems cooling and overheating. To avoid this situation, increase the supply air temperature for interior zones in cold weather.

3.1.1 Single Duct, Single Zone Systems

These systems are the simplest and probably the most commonly used. They can comprise just a single supply system with air intake filters, supply fan and heating coil or can become more complex with the addition of a return air duct, return air fan, cooling coil, and various controls to optimize their performance. Basically, the system supplies air at a predetermined temperature to one zone or the entire building, the quantity of heating or cooling being controlled either by modulating the supply air temperature or by turning the system on and off. (Figure 1)

The energy output of a single duct system to meet a space load is determined by the volume/temperature differential relationship, i.e., to maintain a space temperature of 65°F, the heating load could be met by a system supplying 10,000 cfm at 105°F, or 6,000 cfm at 125°F.

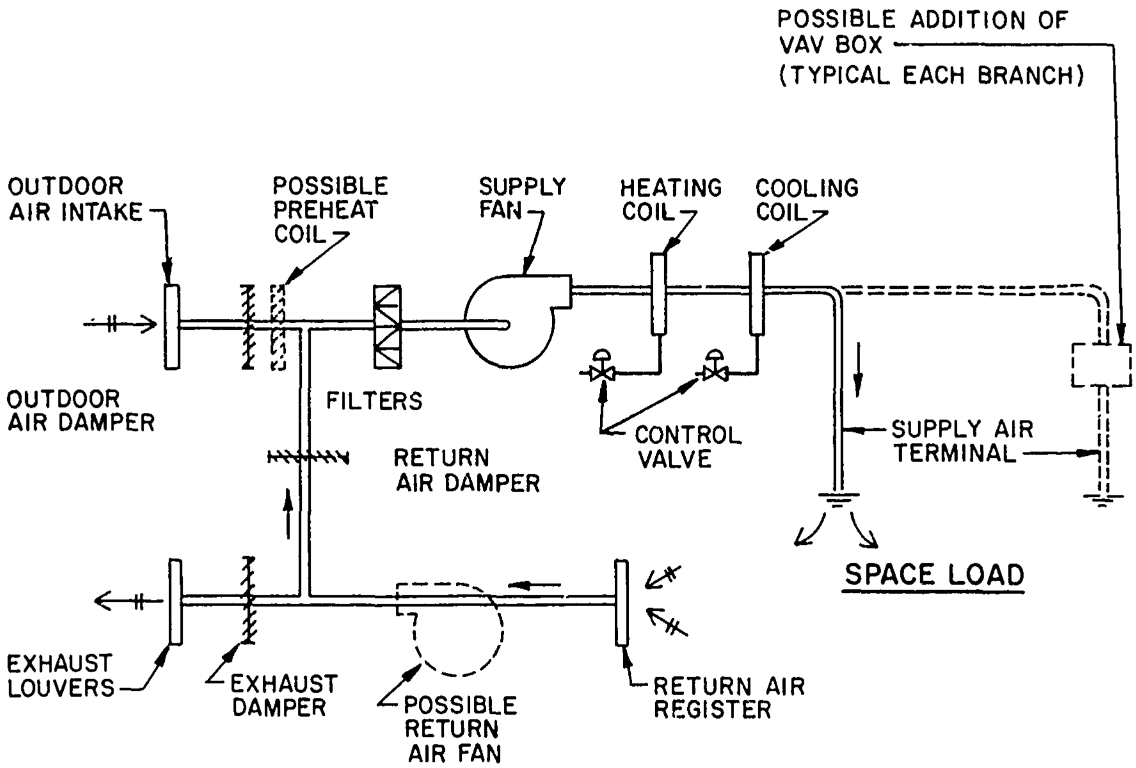
To conserve energy in a single zone, single duct system, determine from measurements the system output and the building load. In the heating mode, if the system maximum output exceeds design building load, first reduce the volume of system air as this will show the greatest energy savings, i.e., 90% of the original fan volume requires only 65% of the original fan HP. Next reduce the supply temperature; this will not conserve as much energy as reduced volume flow. Local codes regarding ventilation should be consulted.

In the cooling mode, if the system output exceeds the design building load, the saving by reduced air flow must be equated with the saving by increased air temperature as increased COP of the refrigeration equipment may yield savings which exceed the fan power losses.

Install controls on the heating and cooling coils to modulate the supply air temperature. Allow a 8-10° "Dead Zone" between heating and cooling to prevent simultaneous heating and cooling and rapid cycling. If possible, use an economizer cycle wherever the total heat of the outdoor air is favorable during occupied periods; the sensible temperature is favorable in unoccupied periods; and the size of the system makes the installation economical.

The economizer cycle can be a simple arrangement of dampers controlled by outdoor and return air DB temperature or can be a more complex system based on the total heat or enthalpy of the supply air.

Single zone single duct systems can be readily converted to VAV



Representative Single Duct System

Figure 1

Guidelines for Saving Energy in Existing Buildings ECM-2.
U. S. Department of Commerce, National Technical Information Service
PB-249-929.

by adding control boxes on each branch and substituting outlets with VAV type. Fan volume should preferably be controlled according to demand either by installing inlet guide vanes or by installing a motor speed controller. The simplest conversion to VAV is done by adding a solid state AC motor speed controller to the existing system.

3.1.2 Terminal Reheat Systems

Terminal reheat systems were developed to overcome the zoning deficiencies of single duct systems and basically comprise a single duct, single zone system with individual heating coils in each branch duct to zones of similar loads. (Figure 2)

Reheat systems were also developed to give closer control of relative humidity in selected spaces.

Terminal reheat allows each different zone to be individually controlled but wastes energy in the cooling season as all of the supply air must be cooled to a low enough temperature to meet most critical load zone but must be reheated for zones of lesser loads to avoid overcooling.

As with single duct systems, energy can be conserved by reducing the supply air volume. Many reheat systems are controlled at a fixed supply temperature of around 55° DB/55° WB. To conserve energy, fit controls to reschedule the supply air temperature upward according to demands of the zone with the greatest cooling load. If one zone has cooling loads grossly in excess of all others, the controlling thermostat should be located in that space.

The greatest quantity of energy can be saved by adding variable air volume boxes to each of the major branch ducts. Each VAV box should be controlled by a space thermostat located in its particular zone and its associated reheat coil should be provided with controls to prevent reheat until the VAV box has reduced the zone supply air volume to 50%.

In buildings where a reheat system supplies zones of different occupancy, add dampers and control valves to enable water to be shut off during unoccupied times.

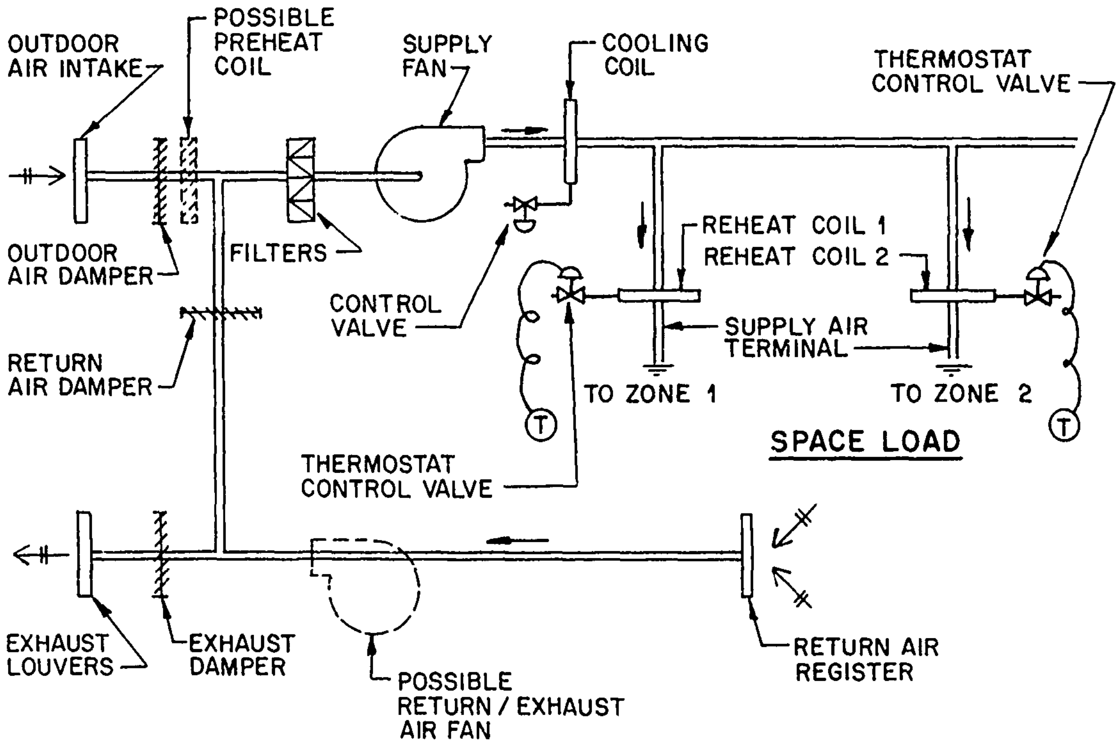
- Reduce the water flow and temperature of hot water to reheat coils.

- Use waste heat from condensate, incinerators, diesel or gas engines, or solar energy for reheat; but in all cases, raise the cold duct temperature to reduce refrigeration load.

- Modify controls to operate terminal reheat systems on a temperature demand cycle only. Caution: Control of humidity will be eliminated and zone control will be modified.

- Add or adjust controls to schedule supply air temperature according to the demands of the zone with the greatest cooling load.

- Install an interlock between the two valves to prevent simultaneous heating and cooling.



Representative Terminal Reheat System

Figure 2

Guidelines for Saving Energy in Existing Buildings ECM-2.
U. S. Department of Commerce, National Technical Information Service
PB-249-929.

- If air conditioning is needed during unoccupied hours or in very lightly occupied areas, install controls to de-energize the re-heat coils, raise the cold duct temperature and operate on demand cycle.

- Under an alteration or expansion program, install variable volume rather that terminal reheat or other systems.

- De-energize or shut off terminal reheat coils, raise the chilled water and supply air temperature of the central system and add re-cooling coils in ducts in areas where lower temperatures are needed.

3.1.3 Multi-Zone Systems

Most multi-zone units currently installed have a single heating coil serving the hot deck and single cooling coil serving the cold deck. (Figure 3) Each zone supply temperature is adjusted by mixing the required quantities of hot and cold air from these coils. With these types of units, the hot deck temperature must be sufficiently high to meet the heating demands of the coldest zone and cold deck air must be sufficiently low to meet the demands of the hottest zone. All intermediate zones are supplied with a mixture of hot and cold air wasting energy in a similar manner to reheat systems.

New model multi-zone units are now available on the market which have individual heating and cooling coils for each zone supply duct and the supply air is heated or cooled only to that degree required to meet the zone load. These new types of units use far less energy than units with common coils and where renovations are contemplated or the existing multi-zone unit is at or near the end of its useful life, replacement should be considered, using a multi-zone unit with individual zone coils.

Analyze multi-zone systems carefully and treat each zone as a single zone system and adjust air volumes and temperature accordingly.

Hot deck and cold deck dampers are often of poor quality and allow considerable leakage even where fully closed. To conserve energy, check these dampers and modify to avoid any leakage.

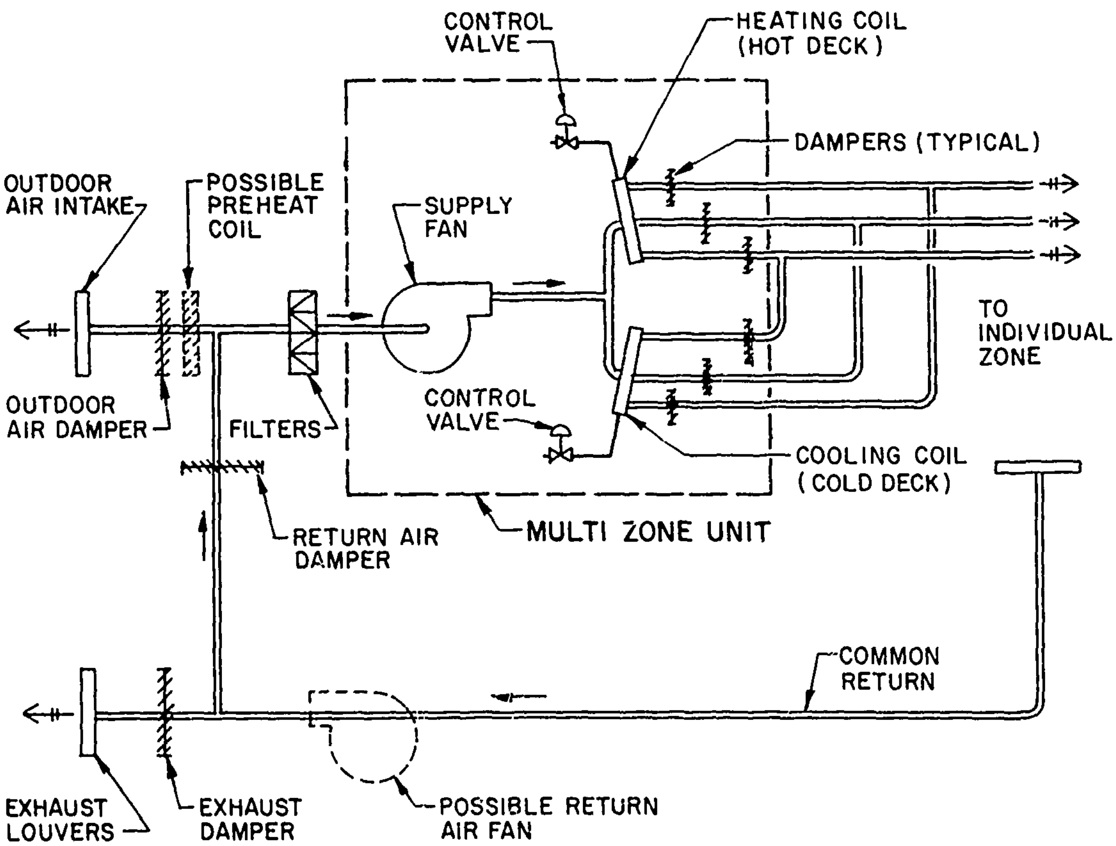
Install controls or adjust existing controls to give the minimum hot deck temperature and maximum cold deck temperature consistent with the loads of critical zones.

Where a multi-zone unit serves interior zones that require cooling all of the summer and most of the winter, energy can be conserved by converting to VAV reheat. To achieve this, blank off the hot deck and add low pressure VAV dump boxes with new reheat coils in the branch duct after the VAV box. This system works well in conjunction with an economizer cycle and reheat energy is minimized. Careful analysis, however, is required of the existing system and the zone requirements to make the correct selection of equipment.

Arrange the controls so that when all hot duct dampers are partially closed, the hot deck temperatures will progressively reduce until one or more zone dampers is fully opened and, when all of the cold duct dampers are partially closed the cold duct temperature will progressively increase until one or more of the zone dampers is fully opened.

- Install controls to shut off the fan and all heating control valves during unoccupied periods in the cooling season and shut off the cooling valve during unoccupied periods in the heating season.

- Convert system entirely or in part to variable volume by adding terminal units and pressure bypass and/or add fan coil units in specific areas requiring constant air volume.



Representative Multi-Zone System

Figure 3

Guidelines for Saving Energy in Existing Buildings ECM-2.
U. S. Department of Commerce, National Technical Information Service.

3.1.4 Dual Duct Low Velocity Systems

Dual duct low velocity systems (Figure 4) supply hot and cold air in individual ducts to the various zones of the building which are supplied with a mixture of hot and cold air to maintain the desired zone conditions. Control of mixing is normally achieved by automatic dampers in the branch ducts; the damper being positioned according to the dictates of the space thermostat. Each duct should be analyzed as a single zone system to determine whether the air volume or its temperature set point can be advantageously changed to conserve energy. Reduce the temperature of the hot duct and increase the temperature of the cold duct to that point where the heating and cooling loads of the most critical zone can just be met.

Return air is a mixture of all zones and reflects the average building temperature. In some designs of central station equipment, it is possible to stratify the return air and the outdoor air by installing splitters so that the hottest air favors the hot deck and the coldest air favors the cold deck. This will reduce both heating and cooling loads.

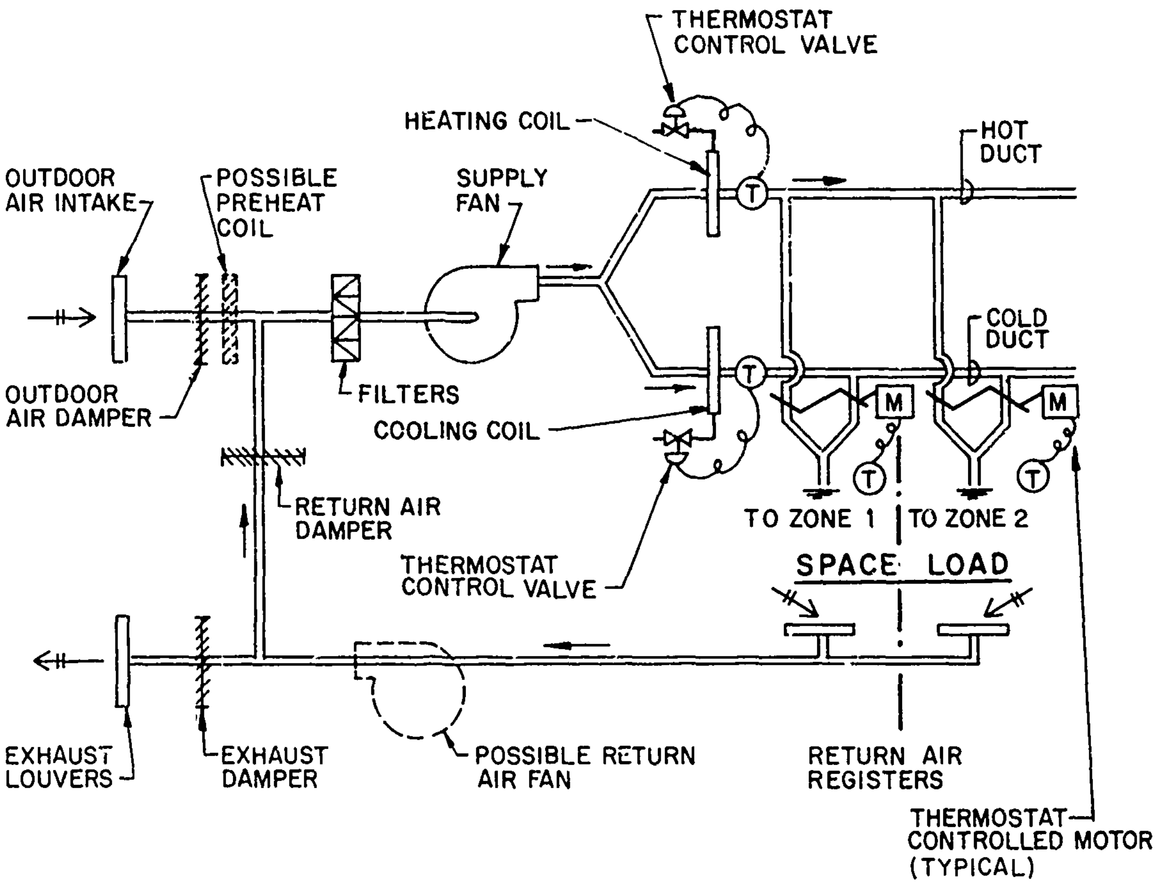
3.1.5 Dual Duct High Velocity Systems

Dual duct high velocity systems operate in the same manner as low velocity systems with the exception that the supply fan runs at a high pressure and that each zone requires a mixing box with sound attenuation. (Figure 5)

Considerable quantities of energy are required to operate the fan at high pressure and close analysis of pressure drops within the system should be made and fan pressure reduced to the minimum to operate the mixing boxes.

To reduce system pressure, lower fan speed i.e. pressure by either increasing the fan belt size or adding a speed controller in series with the fan motor.

- In conditions when there is no cooling load, install controls to close off cold air duct; de-energize chillers and cold water pumps and operate as a single duct system; rescheduling the warmer air duct temperature according to heating loads only.
- Under conditions where there are no heating loads, install controls to close off the warm air ducts; shut off hot water, steam or electricity to the warm duct and operate the system with the cold duct air only; rescheduling supply air temperature according to cooling loads.
- Replace obsolete or defective mixing boxes to eliminate leakage of hot or cold air when the respective damper is closed.
- Provide volume control for the supply air fan and reduce capacity preferably by speed reduction when both the hot deck and cold deck air quantities can be reduced to meet peak loads. Reducing the heat loss and heat gain provides an opportunity to reduce the amount of air circulated.



Representative Dual Duct Low Velocity System

Figure 4

Guidelines for Saving Energy in Existing Buildings ECM-2.
U. S. Department of Commerce, National Technical Information Service
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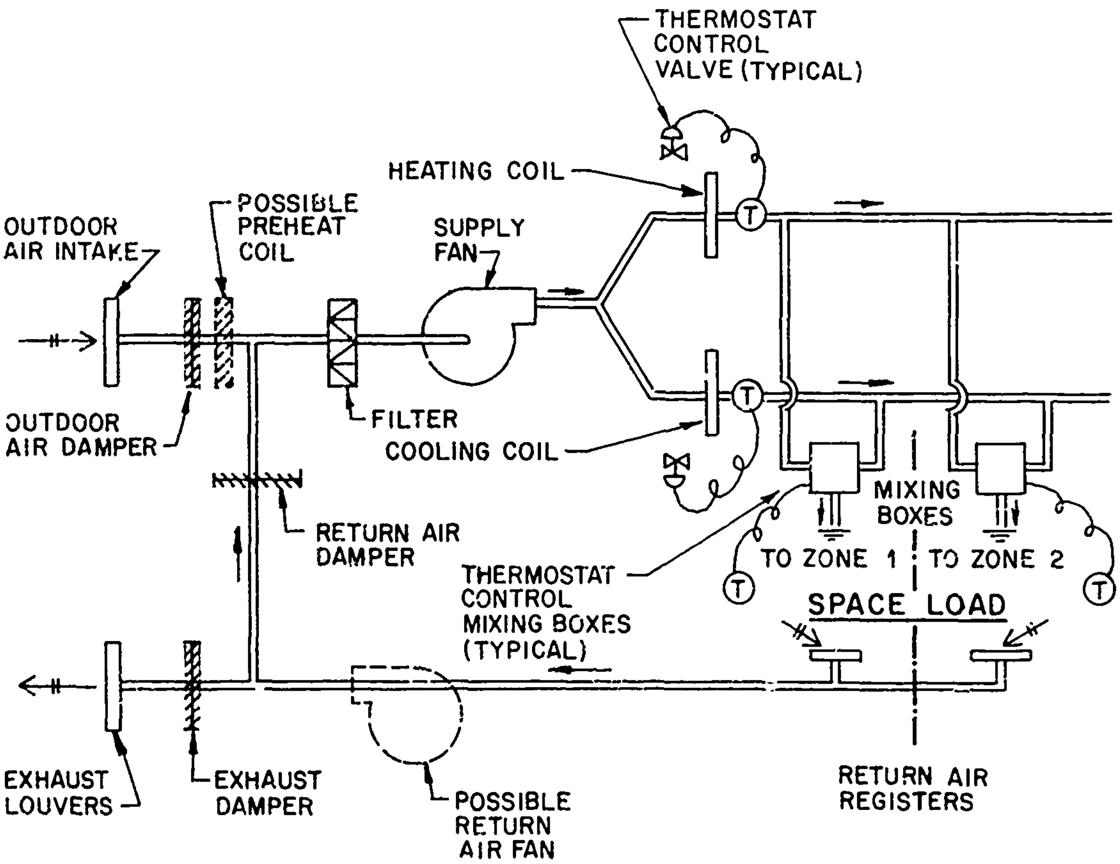


Representative Dual Duct High Velocity System

Figure 5

Guidelines for Saving Energy in Existing Buildings ECM-2.
U. S. Department of Commerce, National Technical Information Service
PB-249-929.

- When there is more than one air handling unit in a dual air system, modify duct work if possible so that each unit supplies a separate zone to provide an opportunity to reduce hot and cold duct temperatures according to shifting loads.
- Change dual duct systems to variable volume systems when energy analysis to do so is favorable and the payback in energy saved is sufficiently attractive by adding VAV boxes and fan control.

3.1.6 Variable Volume Air Systems

VAV systems are basically a modification of single zone, single duct systems to allow different conditions in multiple zones to be met by varying quantities of constant temperature air. (Figure 6) The air quantity supplied to the zone can be modulated in two different ways:

(a) Dump boxes installed in the zone supply duct modulate the amount of air through the outlets by bleeding off unused quantities of air and dumping into the ceiling void and back into the return air system. This type of VAV system maintains constant fan volume and constant flow in all the trunk ducts and can waste energy by mixing the treated dump air with the return air. This system does, however, have practical advantages when used with direct expansion cooling coils, since it maintains constant flow through the coils regardless of load, which is necessary to obtain correct operation of refrigerating equipment.

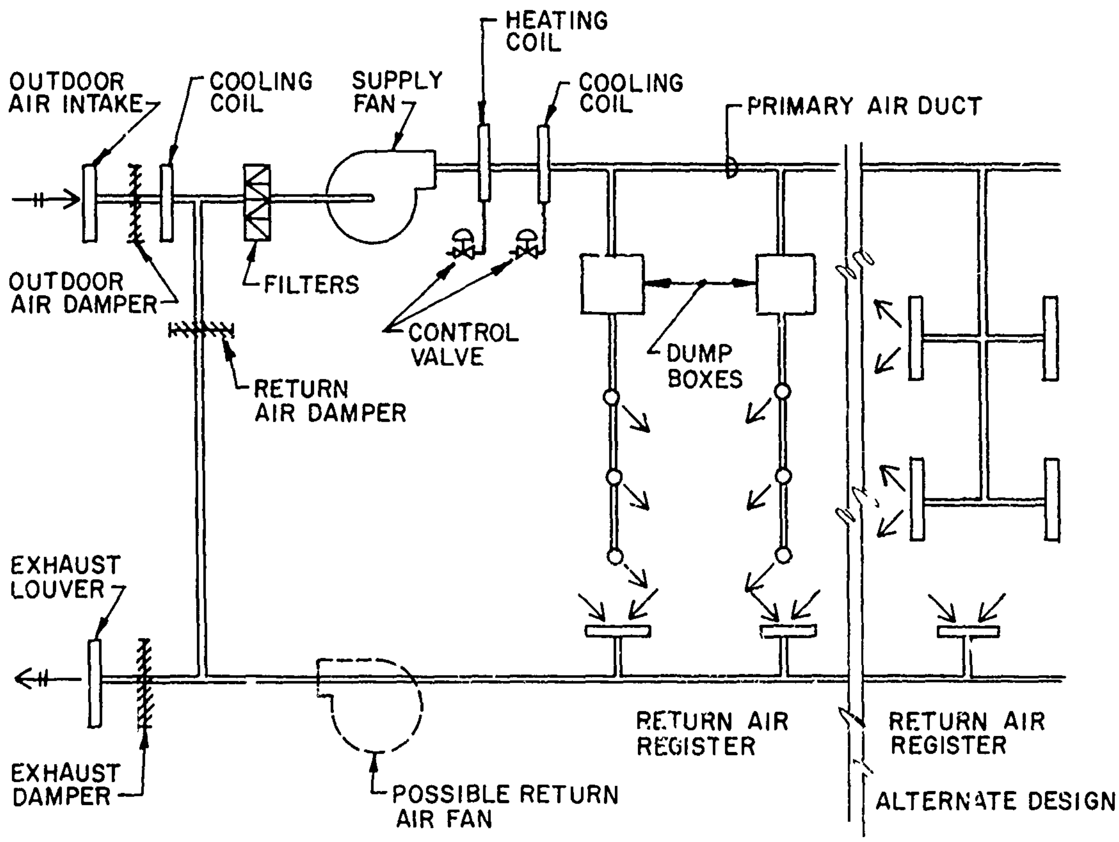
(b) The second type of VAV system is where the air volume is controlled at the outlet by closing down dampers as the zone load decreases. This type of system does, in fact, vary the total supply volume handled by the fan by increasing the resistance to air flow under light load conditions.

To conserve energy regulate the fan volume according to the demands of the system by a variable speed motor with SCR controller or by inlet guide vanes.

Provide a control to modify the fan speed up or down to maintain constant pressure in the supply duct. Reset the supply air temperature in accordance with zone loads.

- If not installed, provide either inlet vortex dampers or variable speed drive such as a multispeed motor or SCR control so that fan volume will be reduced when dampers begin to close until one or more VAV dampers is fully opened.

A constant pressure closed loop system is implemented by introducing a pressure sensor into the supply duct and feeding its output signal to a differential amplifier referenced to a constant value. The differential amplifier output signal is proportioned to the difference between the reference and pressure signals. This output signal being a function of duct pressure is fed to an SCR controller which in turn regulates the variable speed motor such that the difference between the pressure transducer signal and reference voltage is zero, effectively maintaining a constant duct pressure.



Representative Variable Volume System

Figure 6

Guidelines for Saving Energy in Existing Buildings, U. S. Department of Commerce, National Technical Information Service PB-249-929.

-Provide control to reschedule supply air temperature to a point where the damper of the variable air volume box serving the zone with the most extreme load is fully opened.

-Install control to reduce the hot water temperature and raise the chilled water temperature in accordance with shifting thermal demands.

-As with single duct variable volume systems with reheat, set control to delay reheat until cfm is reduced to minimum.

-Where possible, eliminate reheat coil and set the box to full close off.

-Variable volume with reheat systems should be operated and modified similarly to conditions described for terminal reheat.

3.1.7 Induction Systems

Induction systems are commonly used for heating and cooling perimeter zones where large fluctuations of heating and cooling loads occur. (Figure 7)

Primary air is either heated or cooled and supplied at high pressure to the induction units located within the conditioned space. Primary air is discharged from nozzles arranged to induce room air into the induction unit approximately four times the volume of the primary air. The induced air is cooled or heated by a secondary water coil. The water coil may be supplied by a two-pipe system, whereby either chilled water or heated water is available, but not simultaneously, or by a three-pipe system where separate supplies of hot water or chilled water are continuously available and after passing through the unit are mixed into a common return or by a four-pipe system, where a supply and return of hot water and chilled water are both continuously available.

The primary supply air fan operates at high pressures requiring high horsepower input. By careful analysis, reduce the primary air volume and pressure to the minimum required to operate the induction terminal units.

Induction unit nozzles may be worn through many years of cleaning and operation resulting in increased primary air quantity at lower air velocities with lower induced air volumes. Check each induction unit and either repair or replace the nozzles.

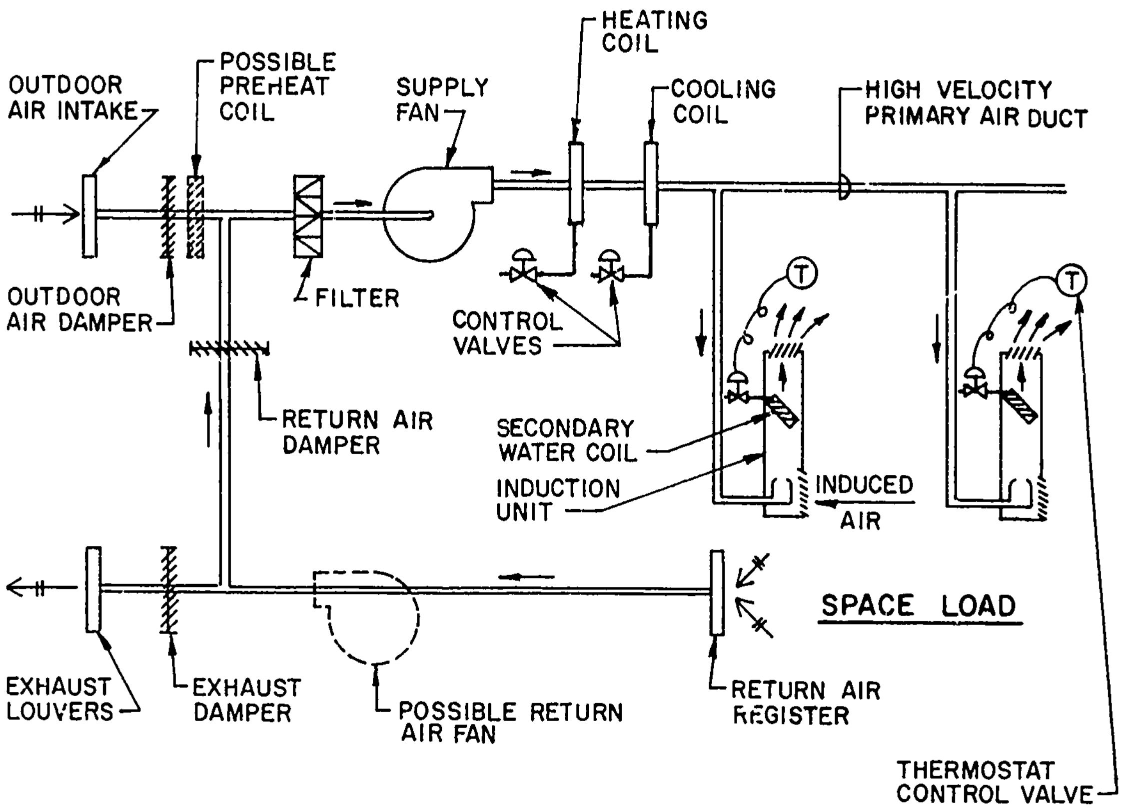
Provide controls to do the following:

(a) Set the primary air reheat schedule as low as possible without causing complaints in the occupied spaces.

(b) Lower the set point of secondary heating water temperatures in the winter and schedule according to outdoor conditions.

During maximum cooling or heating periods, reduce the secondary water flow rate to the minimum necessary to obtain satisfactory room conditions.

-Raise temperature of the primary air for cooling to reduce refrigeration load, but weigh this benefit against increased



Representative Induction Unit System

Figure 7

Guidelines for Saving Energy in Existing Buildings, U. S. Department of Commerce, National Technical Information Service PB-249-929.

cooling demand by the secondary coils.

- Reduce water temperature to the heating coils during the heating season to reduce piping loss and improve boiler efficiency.

- For night operation during the heating season, shut down primary air fan, raise hot water temperature and operate the induction units as gravity convectors.

3.1.8 Fan Coils - Unit Ventilators

Fan coil and unit ventilator performance can be improved by careful maintenance which in turn will allow energy savings to be made in the associated heating and cooling water distribution systems. Heating and cooling coils should be cleaned and air and water flow reduced to the minimum required to meet space conditions. Consider changing four-pipe heating and cooling supply systems to a two-pipe system. This will avoid changeover loss and prevent simultaneous heating and cooling within a given zone.

- For fan coils systems which have separate coils for heating and air conditioning, install a control to prevent simultaneous heating and cooling.

- Install a seven-day timer to shut down fans, close off valves, and shut off chilled water pumps, compressors and cooling towers or air cooled condensers during unoccupied periods.

- Install controls to shut off fans during unoccupied periods during the heating season and operate the fan coil unit as a gravity convector. (The same is applicable to unit ventilators as well.)

- Block off outdoor air inlets where no dampers are installed if infiltration meets ventilation requirements.

- If fan coil units are not located in conditioned areas, insulate the casings to reduce heat loss/gain.

- With three-pipe systems, set controls for minimum mixing of hot and cold water.

- Change four-pipe or three-pipe systems to two-pipe systems where possible to avoid change-over losses.

3.1.9 Water-to-Air-Heat Pumps

Air coils should be kept clean to maintain the highest possible seasonal COP. Heat pump units are normally controlled by integral thermostats which turn them on and off according to the demands of space load and these units are frequently left in operation twenty-four hours/day regardless of whether the building is occupied or not.

Add a system of on/off controls on a floor-by-floor basis using a contractor to install interposing circuitry to interrupt the individual heat pump control circuits.

-When retrofitting, install one larger unit rather than multiple smaller units for greater efficiency.

-All guidelines for condensers, compressors, evaporators, fans, pumps, piping and duct work listed in other sections are applicable to unitary closed loop water source heat pumps.

3.2.0 Air-to-Air Heat Pumps and Incremental Air Conditioning Units

The guidelines for evaporators and condensors in "Cooling and Ventilation", are applicable to these units:

-Where possible, direct the warm exhaust air from the building to the inlet of air/air heat pumps to raise their coefficient of performance. Waste heat from other processes can also be used as a heat source.

-Replace air-to-air heat pumps with water-to-air heat pumps where there is a source of heat such as ground water with temperatures above average ambient winter air temperatures.

-For incremental air conditioning units follow guidelines for fan coil units during the heating cycle.

-Install a seven-day timer to program operation of compressors in accordance with occupied-unoccupied periods.

-When replacing incremental air conditioning units which are equipped with electric heating coils, install a heat pump model instead.

3.2.1 Exhaust Systems

All the ECO's and guidelines in this section detailing methods of reducing fan power requirements by reducing flow rate and resistance apply equally to exhaust systems as well as supply systems.

Balance exhaust systems so that exhaust air flow rate does not exceed supply air flow rates of associated systems. Ideally, exhaust should be 10% less than supply to maintain a positive building pressure to prevent infiltration and to aid in temperature control.

Modulate exhaust fan volume in step with associated VAV supply fan by installing inlet guide vanes or variable speed control.

-Recirculate toilet room exhaust air through charcoal filters to reduce makeup air requirements.

-Install controls to operate toilet exhaust fans intermittently for ten to twenty minutes out of every hour and to automatically shut them off during unoccupied periods. Check local codes, this is a new design concept and is of questionable effectiveness.

-Install a motorized damper at inlet grilles and wiring from damper to light switches to reduce the air quantity when toilet rooms are unoccupied. Modulate fan volume according to load by monitoring pressure in the main exhaust stack.

- For new installations or when existing fans and/or motors are replaced, provide variable speed control or inlet vane control to operate in accordarce with static pressure.

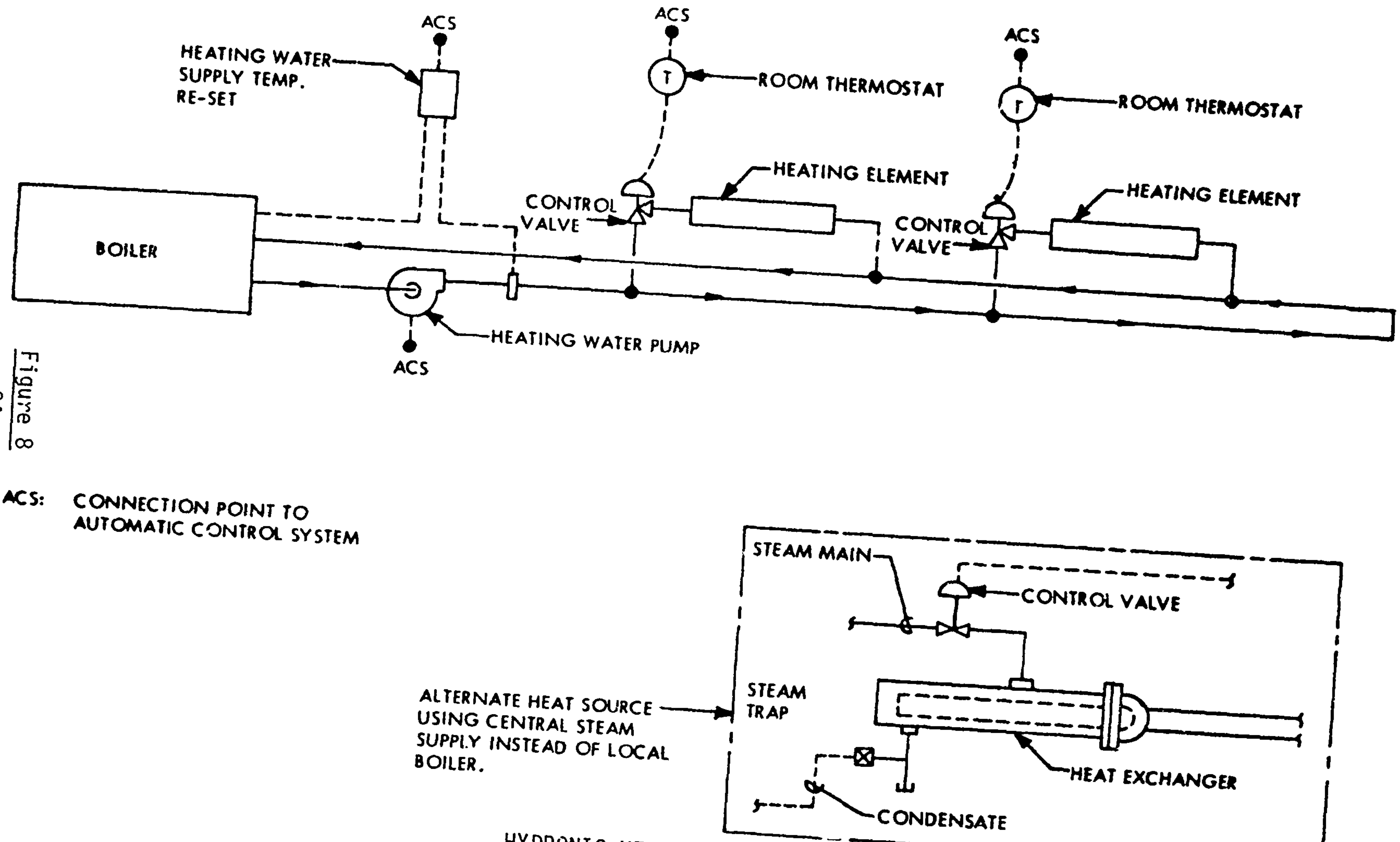
- Shut off supply fans which serve only as makeup air for toilet rooms and install new door louvers or cut off the bottom of the door to permit air from conditioned areas to migrate into the toilet rooms as makeup for the exhaust system. Set maximum capacity to provide one cfm per square foot of toilet area.

3.2.2 Hydronic Heating System

Hydronic heating systems (Figure 8) consist of a boiler, hot water supply loop, and a series of room heating elements connected in parallel to the hot water supply loop. The room heating elements transfer heat to the room air by natural convection. A circulation pump provides forced flow of water through the supply loop.

A typical application af a hydronic heating system would be in a residence or barracks building. Occasionally, several buildings in a cluster will be served by steam from a central boiler plant to take advantage of a more efficient boiler design or size. In such a case, each building would be connected to the steam supply main and to the condensate return main. The individual building boiler would be replaced by a steam to water heat exchanger.

Control points for a hydronic heating system consists of individual room controls and system controls. Individual room controls consist of thermostats which activate off/on flow control valves on the individual radiators. System controls consist of a heating water supply temperature thermostat and a start/stop control device for the heating water flow pump. Self-powered thermostatic valves are available for individual unit control.



HYDRONIC HEATING SYSTEM

Energy Monitoring and Control Systems (Report Update 1978). U. S. Army, Facilities Engineering Support Agency, Fort Belvoir, Virginia.

Figure 8

4.0 Local Control Devices

To effectively utilize the variously described HVAC distribution control schemes proposed in the previous section an understanding of currently available local control devices and their applicability is essential.

This chapter will discuss various state-of-the-art local control devices i.e. both analog and digital.

A comprehensive coverage of microprocessors shall preceed discussion of microcomputer digital control devices and their range of complexity.

4.1 Definition of Controller:

An instrument that holds a process or condition at a desired level or status as determined by comparison of the actual value with the desired value.

Controllers can be analog or digital, and can be electronic as well as mechanical. A digital cortroller acquires the actual value of the condition in digital form and compares it to the desired value contained within the controller. A detectable difference between the two will cause the generation of a signal to eliminate the difference. Digital controllers can consist of either discrete logic or a computer composed of large scale integrated circuits.

4.2 Classification of Local Control Devices:

With the advent of expensive energy, coupled with recent advances in cost-effective large scale integration of electronic circuits, a wide variety of local control devices have become available for energy conservation applications.

These devices range from electronic time clocks to programmable microcomputers.

This chapter will attempt to cover this broad range of available devices by categories of function, complexity, application, and cost.

Other chapters will detail specific LCD application to common HVAC systems and discuss their requirements and effect relative to control methods, expandability, seasonal adaptation, etc.

Local control devices generally fall into five categories of classification. These are:

(a) Non-Adaptive Non-Programmable (Presetable) Single Function Controllers

(b) Adaptive Non-Programmable (Presetable) Single Function Controllers

(c) Non-Adaptive Programmable Limited Function Controllers

(d) Adaptive Programmable Limited Multifunctional Controllers

(e) Adaptive Programmable Universal Controllers

Electro-mechanical time delay relays, time clock activated switches, thermostats, etc. fall into the category of Non-Adaptive Non-Programmable local control devices. These devices generally provide for single function user control and include mechanical, electromechanical as well as electrical circuits, which provide basic ON-OFF switched outputs only.

4.3 Categories of Local Control Devices:

The local control devices under consideration are:

4.3.1 Non-Adaptive Non-Programmable (Presetable) Single Function

-Time Delay Relay
Thermostatic Valves
Springwound 7-Day Timers

4.3.2 Adaptive Non-Programmable (Presetable) Single Function

-Weather Compensated Thermostats
Weather Compensated 7-Day Set-Back Thermostats
Light Compensated Thermostats
Light Compensated Illumination Controllers
Enthalpy Controllers (Economizer Cycle)

4.3.3 Non-Adaptive Programmable Limited Function

-Programmable Timers (Microprocessor Based)

4.3.4 Adaptive Programmable Limited Multifunction

-Demand Controllers (Microprocessor Based)
Programmable Controllers (Microprocessor Based)

4.3.5 Adaptive Programmable Universal

-Full Capacity Programmable Microcomputers (Energy Management)

4.3.6 Non-Adaptive Non-Programmable (Presetable) Single Function:

4.3.6.1 Time Delay Relays:

These electromechanical devices control the timing sequence of events such as compressor motors and fans. They are specifically useful in preventing power surges produced by the simultaneous activation of electrical machinery. They function essentially by being activated by a contact closure and after a preset time delay producing an independent contact closure, which can be used to activate or de-activate machinery.

4.3.6.2 Thermostatic Valves:

Thermostatic valves are mechanical controllers, presetable, temperature sensitive devices that modulate their orifice setting as a function of temperature and are used to control heat/cooling systems.

4.3.6.3 7-Day Mechanical Timers:

Spring wound mechanical timers are mechanical devices which provide timed presetable contact closures to activate or de-activate machinery. These timers, spring driven, have the advantage of not requiring resetting as a result of power failure.

4.4 Adaptive Non-Programmable (Presetable) Single Function

4.4.1 Currently available analog local control devices are simple in their construction and technology. In actuality, they represent state-of-the-art variations of standard and widely used traditional components.

These control devices represent the least complex components in the spectrum of local control devices. It is therefore fitting that our discussion of Adaptive Non-Programmable single function devices begin with analog systems.

4.4.2 Weather Compensated Temperature Control

These devices control boiler water temperature as a function of outdoor temperature. Consisting of both solid state analog and digital circuitry, these systems act as variable aquastats, effectively modulating the boiler water temperature of gas and oil fired hot water heating systems. Fuel consumption is reduced by proportioning energy use to the actual rate of building heat loss. (Figures 9, 10, & 11)

The basic system consists of a preprogrammed differential detector and two or more solid state temperature sensors, which measure outdoor temperature and system water temperature.

As the sensors send information the differential detector automatically adjusts energy usage such that circulating system water temperatures are held at the precise level needed to supply only the heat required to satisfy the room thermostat. Therefore, room temperature is no longer subject to temperature overshoot which is common to most hot water systems. The temperature deviation at the thermostat is held to within $\pm$1 F, giving constant heating comfort.

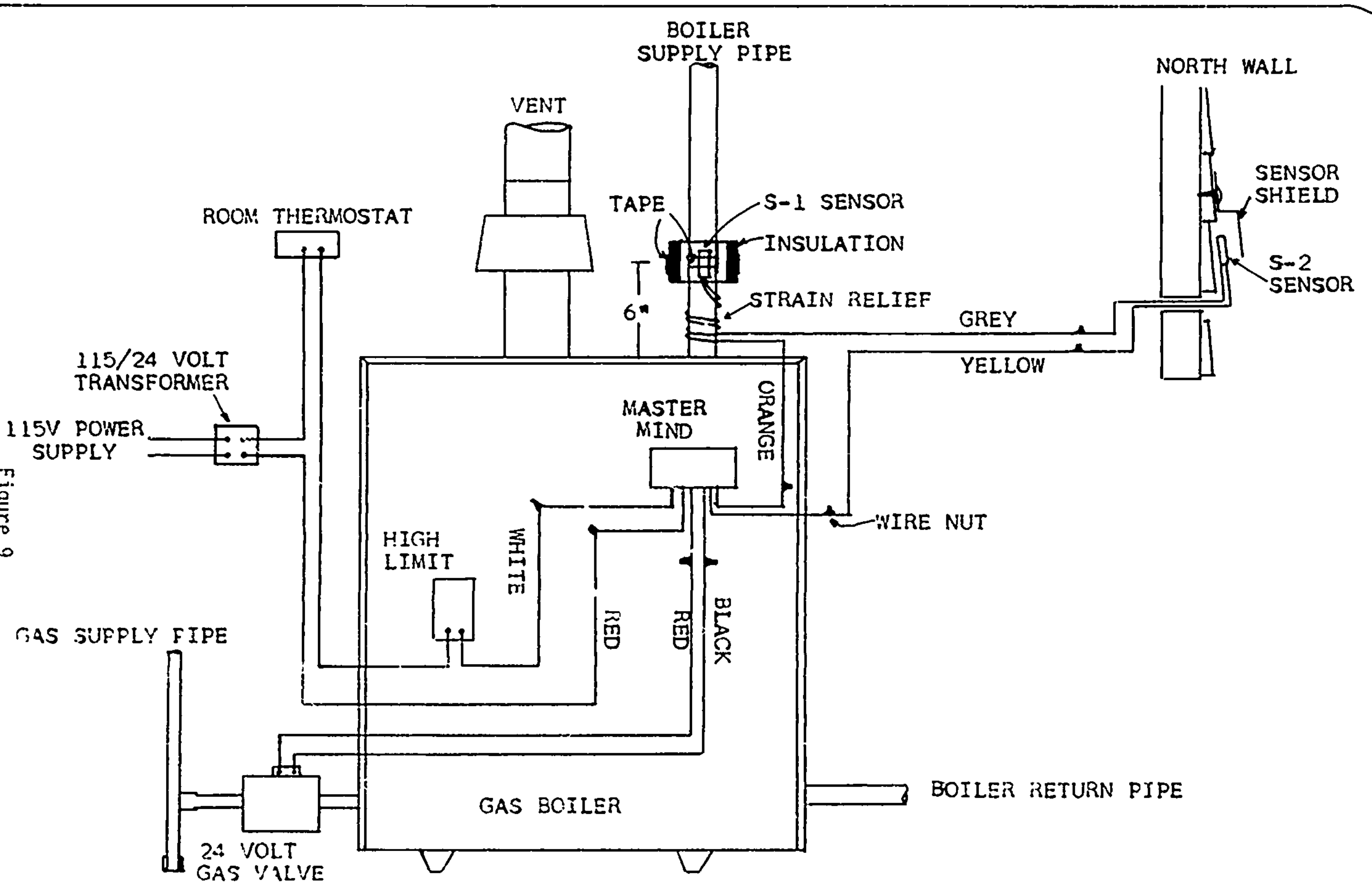
These systems shown are constant rate circulating systems. Installation plus material cost for this type system runs approximately #350 - $400.

4.4.3 Ambient Weather 7-Day Compensated Set-Back Temperature Controls

The Ambient Weather 7-Day Compensated Set-Back Temperature Controller is a variation of a Weather Compensated Temperature Control device. These systems combine both a seven day clock and a weather compensated boiler controller. Several electromechanical as well as electronic versions are available on the market.

Essentially, these devices provide for seven day daytime start-up and nighttime set-back control.

Each day of the 7-day clock is programmable for the "Building Warm-Up" time and for the desired time of "Night Set-Back". Thereafter the outdoor temperature automatically causes the adjustment of the time



WIRING DIAGRAM FOR 24 VOLT CONTROL SYSTEM

Figure 9

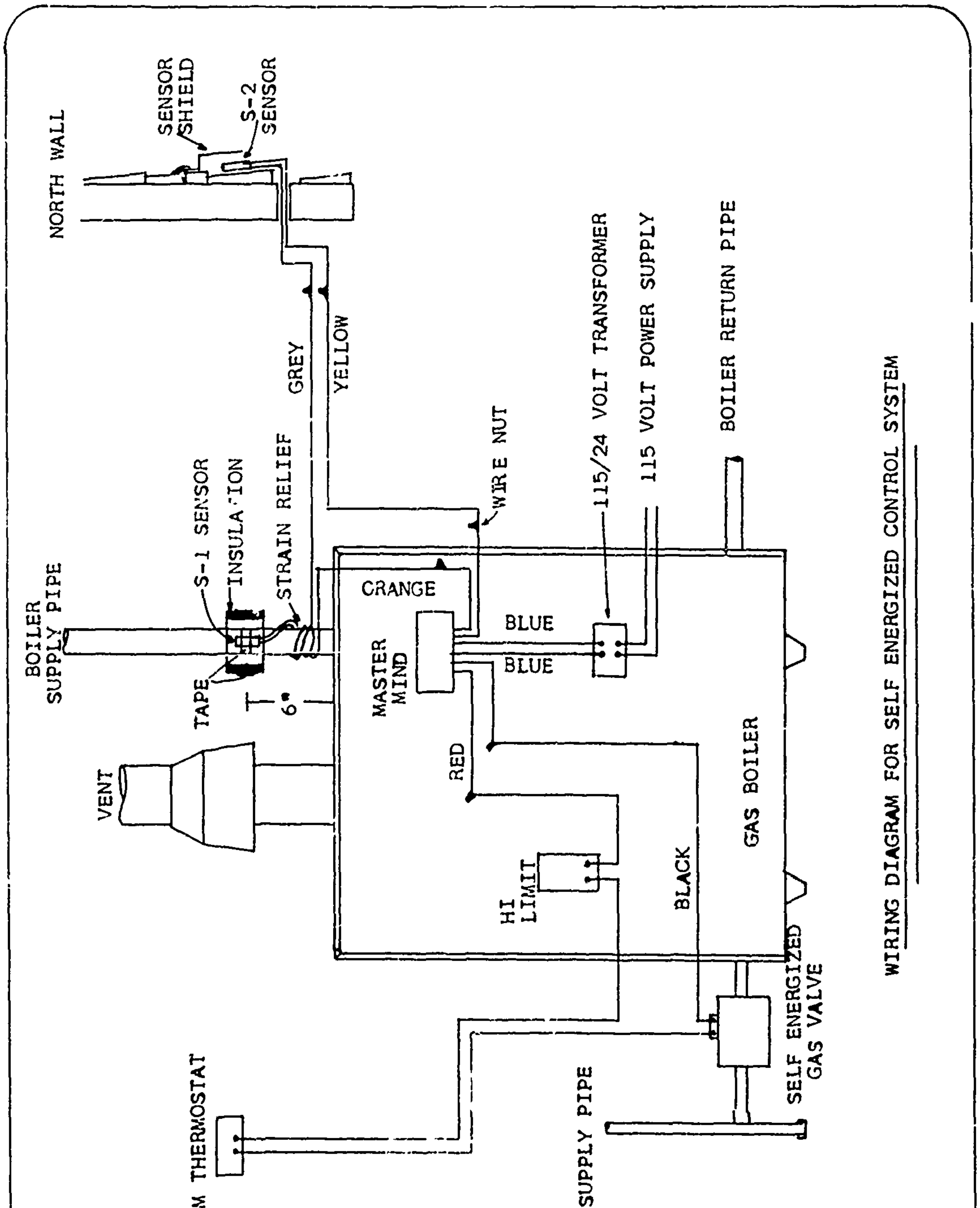
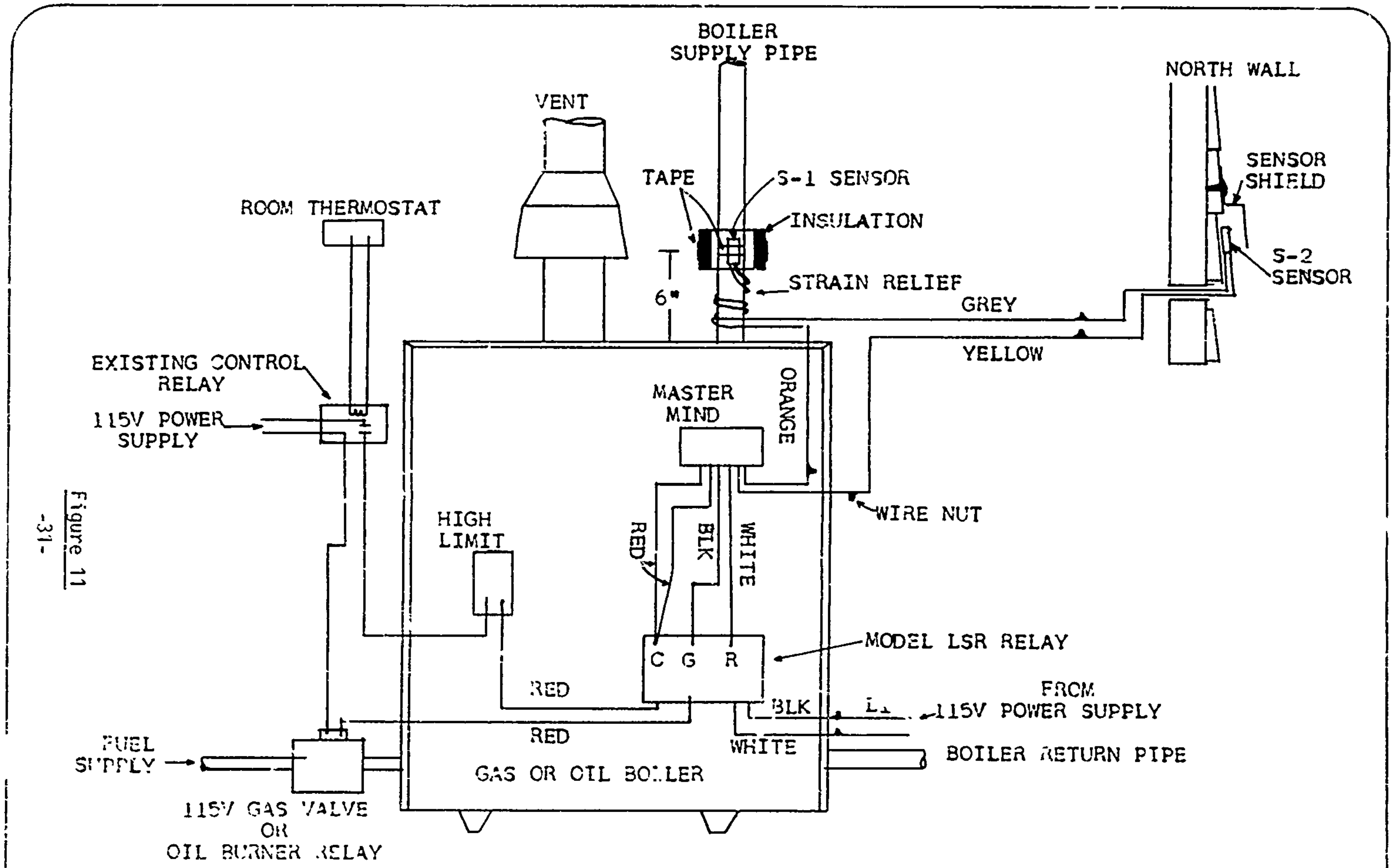
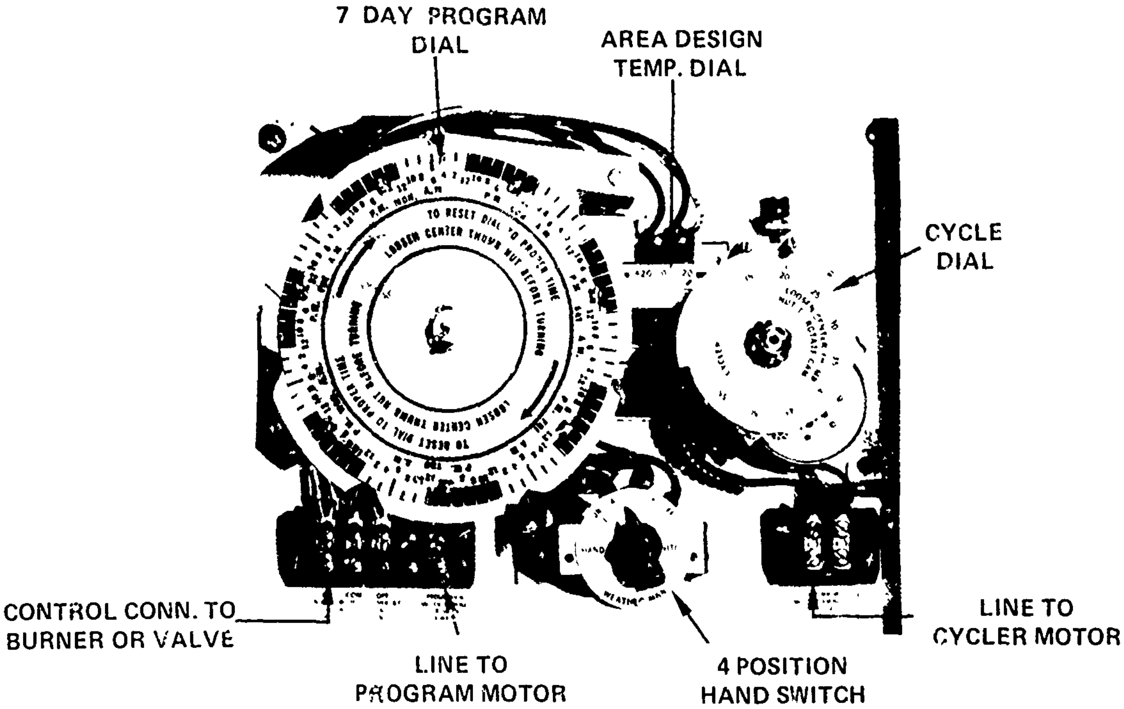

BOILER SUPPLY PIPE
VENT
ROOM THERMOSTAT
TAPE
S-1 SENSOR
INSULATION
STRAIN RELIEF
6"
NORTH WALL
SENSOR SHIELD
S-2 SENSOR
GREY
YELLOW
MASTER MIND
ORANGE
RED
HI LIMIT
BLUE
BLUE
WIRE NUT
115/24 VOLT TRANSFORMER
115 VOLT POWER SUPPLY
GAS SUPPLY PIPE
BLACK
GAS BOILER
BOILER RETURN PIPE
SELF ENERGIZED GAS VALVE
WIRING DIAGRAM FOR SELF ENERGIZED CONTROL SYSTEM

Figure 10



WIRING DIAGRAM FOR 115 VOLT CONTROL SYSTEM

Figure 11



Ambient Weather 7-Day Compensated Set-Back

Temperature Controller

Figure 12

morning warm-up occurs. Typically, on a mild day, building warm-up is started 20 minutes prior to "Building Warm" (heat on full), automatically increasing to as much as 90 minutes in cold weather. From time of morning start-up period to assure positive fast morning warm-up.

At "Building Warm" time, control of the heat flow rate is transferred to the daytime heat flow controller, continuing there until the programmed "Night Set-Back" time. This hot-shot morning warm-up makes it possible to set the day reset controller accurately to building heat loss rate, resulting in maximum energy savings throughout the day.

Additionally, these devices have programmable night temperature settings which reestablish the regular daytime rate of weather reset, cycling heat flow during setback hours, when the outdoor temperature falls below the programmed setting.

This feature prevents cold night freeze-ups and provides for morning warm-up without excessive strain on the heating system. (Figure 12)

4.4.4 Non-Adaptive Non-Programmable (Presetable) Single Function

- Ambient Light Compensated Thermostat

  Light compensated thermostats utilize photoelectric sensors to determine the level of indoor lighting as a function of building occupancy level. (Figure 13)

  By sensing the internal light level of a building or room, automatic adjustments are made requiring no clock readjustment for power outages.

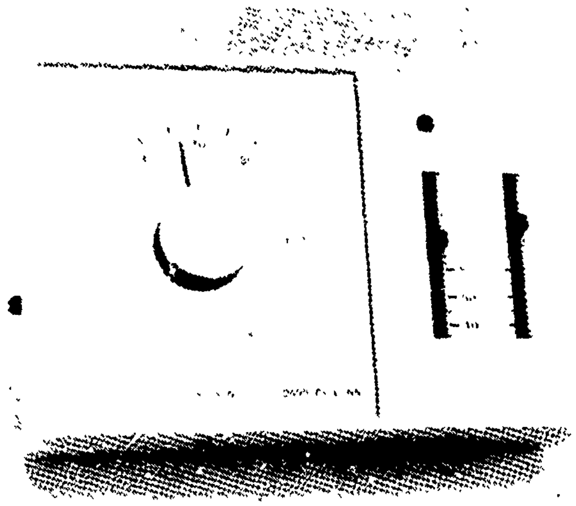
- Ambient Light Compensated Illumination Control Devices

  These devices utilize photoelectric sensors to detect both exterior and interior illumination levels. This information is used to automatically connect or disconnect interior lights to complement external ambient light conditions thereby reducing kilowatt-hour consumption. (Figure 14)

  Sensed data from photoelectric receivers is transmitted to a control module consisting of a differential amplifier, an ON/OFF delay timer, and light control output relays.

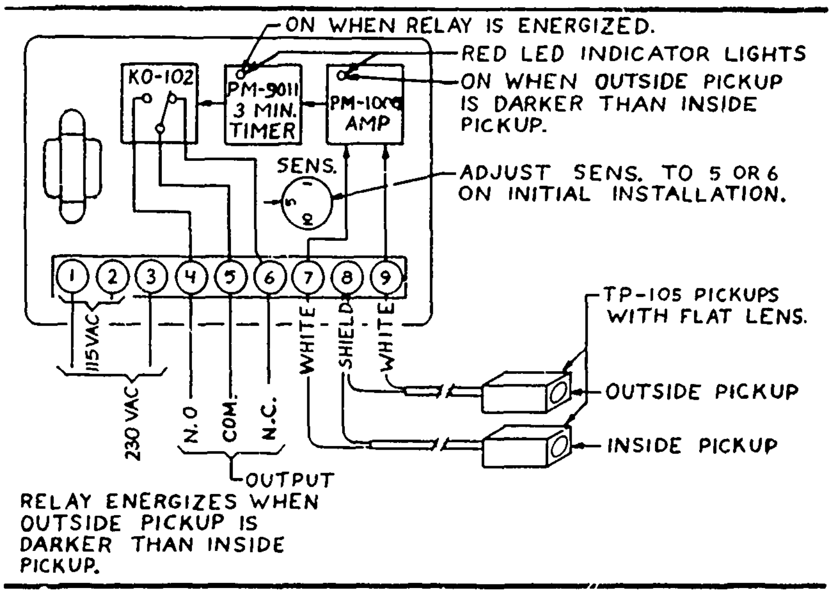
  When the light differential sensed by exterior and interior sensors reaches a pre-established threshold, e.g. exterior light sensing the differential amplifier output for a specific amount of time, the delay timer drives the light control output relays to the interior "Lights OFF" position.

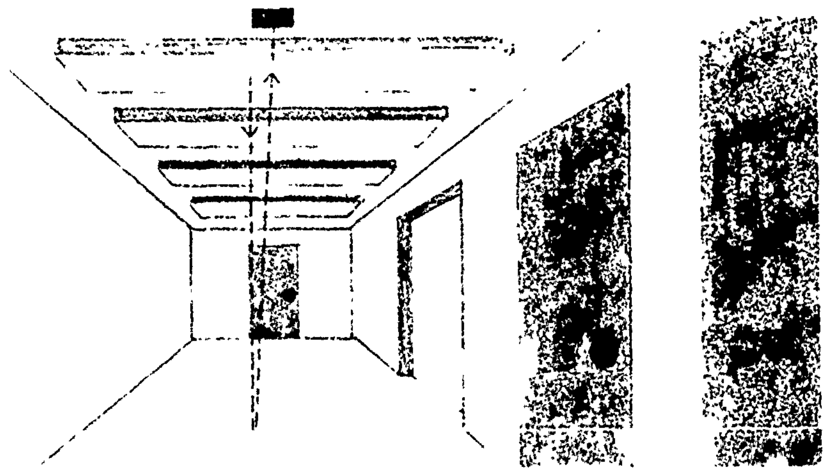
  Use of the delay timer prevents the system from responding to momentary changes in exterior light conditions, e.g. passing clouds or lightning.



Ambient Light Compensated Thermostat

Figure 13





Ambient Light Compensated Illumination
Control Device

Figure 14

The modular configuration of these devices permit their location in proximity to the actual controlled lights. This results in reduced installation cost.

5.0 Microprocessor Technology

The widespread prolific development of microprocessor technology has produced a broad spectrum of programmable devices which in their diverse functions bridge the traditional gap between computer control systems and local control devices.

The same microprocessor central processor unit which functions as the main control element for a full data acquisition and supervisory control system can function cost-effectively as the central control element for a single function timer controlled device. The development and acceptance of this new technology has produced new and effective alternatives for controlling small buildings' environmental parameters, heretofore unavailable to the small facilities engineer.

This chapter will explore the basic structure of the microprocessor and its associated circuitry, which when combined determine the limits of its capability and function, e.g. programmable timer or programmable central control microcomputer.

A definition of the terms microprocessor, and microcomputer is as follows:

(a) Microprocessor

The control and processing logic portion of any small computer generally consisting of a single integrated circuit chip, most often requiring support circuitry and memory to function with external devices. In general it contains 75% of the computational power of a small computer. (Figure 15)

(b) Microcomputer

An operational computer system which has as its computational circuitry a microprocessor in addition to all of the required interface, support, and memory circuitry. These systems are available either as single printed circuit board assemblies or as completely housed units with power supplies and associated input/output devices. (Figure 16)

5.1 Central Processing Unit/Microprocessor

Primary to any digital computer is its Central Processing Unit (CPU). The CPU or single chip large scale integrated circuit Microprocessor functions as the central control device of a computer, receiving and outputting data, manipulating data in accordance with stored instructions from memory for both arithmetic and logical operations. (See Figure 15)

(a) Microcomputer

A Microcomputer is created by interconnecting a microprocessor with memory, timing, and input/output circuitry. (See Figure 16)

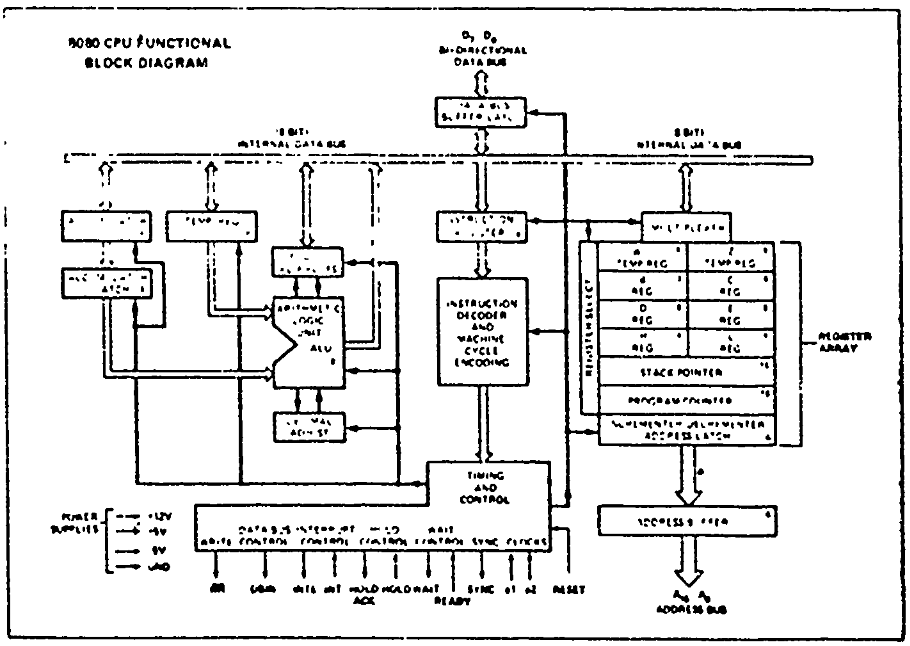
intel Silicon Gate MOS 8080

SINGLE CHIP 8-BIT N-CHANNEL MICROPROCESSOR

- 2 μs Instruction Cycle
- Powerful Problem Solving Instruction Set
- Six General Purpose Registers and an Accumulator
- Sixteen Bit Program Counter for Directly Addressing up to 64K Bytes of Memory
- Sixteen Bit Stack Pointer and Stack Manipulation Instructions for Rapid Switching of the Program Environment
- Decimal, Binary and Double Precision Arithmetic
- Ability to Provide Priority Vectored Interrupts
- 512 Directly Addressed I/O Ports

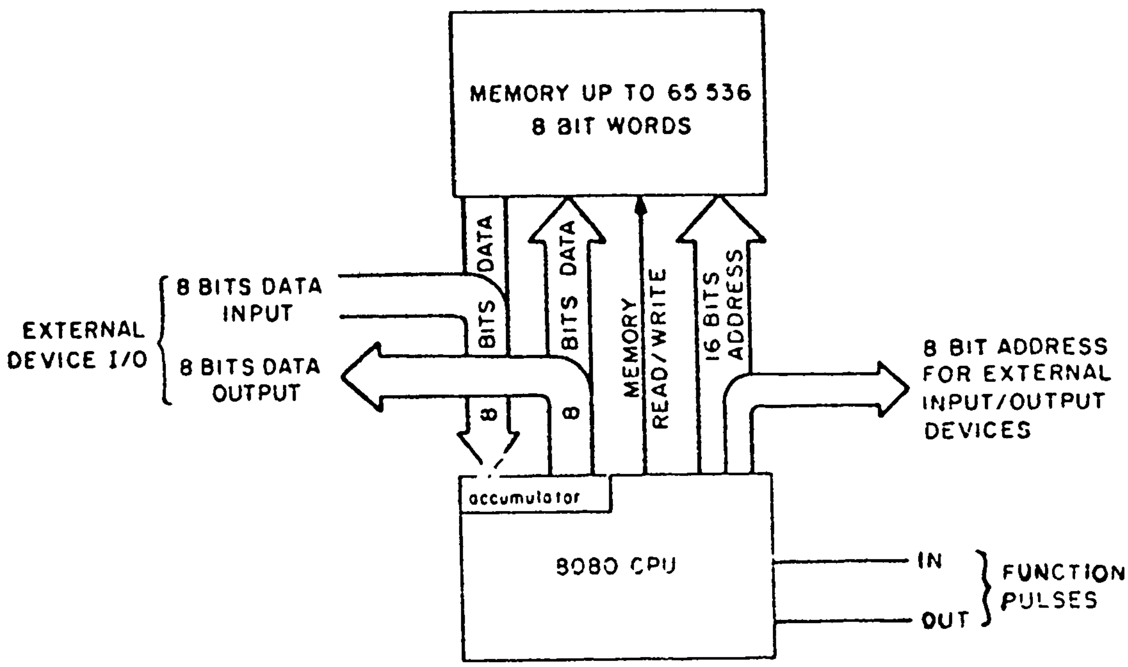
The Intel 8080 is a complete 8 bit parallel central processing unit (CPU). It is fabricated on a single LSI chip using Intel's n channel silicon gate MOS process. This offers the user a high performance solution to control and processing applications. The 8080 contains six 8 bit general purpose working registers and an accumulator. The six general purpose registers may be addressed individually or in pairs providing both single and double precision operators. Arithmetic and logical instructions set or reset four testable flags. A fifth flag provides decimal arithmetic operation.

The 8080 has an external stack feature wherein any portion of memory may be used as a last in/first out stack to store/retrieve the contents of the accumulator, flags, program counter and all of the six general purpose registers. The sixteen bit stack pointer controls the addressing of this external stack. This stack gives the 8080 the ability to easily handle multiple level priority interrupts by rapidly storing and restoring processor status. It also provides almost unlimited subroutine nesting. This microprocessor has been designed to simplify systems design. Separate 16 line address and 8 line bidirectional data busses are used to facilitate easy interface to memory and I/O. Signals to control the interface to memory and I/O are provided directly by the 8080. Ultimate control of the address and data busses resides with the HOLD signal. It provides the ability to suspend processor operation and force the address and data busses into a high impedance state. This permits OR-tying these busses with other controlling devices for (DMA) direct memory access or multi-processor operation.



Intel Corp. 1974

Figure 15



Microcomputer

Figure 16

The basic requisites therefore for a microcomputer are that:

- -It has an arithmetic/logic unit (ALU) to perform arithmetic and logical operations.
- -It has a memory.
- -It is programmable.
- -It can input and output data.

Currently, the most widely used microprocessors in general use today are 8-bit devices.

These devices incorporate an 8-bit data word. Each word is stored in memory through the use of a 16-bit memory address. 16-bits of address permit 65,536 unique memory location, which are addressable by the microprocessor.

(b) Memory

Memory consists of any component capable of storing information in the form of a logic 1 and logic 0 such that individual or group bits are accessible and retrievable.

(c) Random Access Memory (RAM)

A memory device which permits the random entering (write) and output (read) of data.

(d) Read Only Memory (ROM)

A memory device which permits the reading out of data only. Data cannot be written into it. Generally, data is stored permanently in these devices and cannot be erased even under loss of power conditions.

5.1.1 Programmable Read Only Memory (PROM)

A memory device which permits the storing of data on a permanent basis; that is to say, this device functions as a ROM. When modification of the stored data is required, this device can be erased if it is an EPROM (Erasable Programmable Read Only Memory).

The EPROM is an ultraviolet light sensitive device. Exposure of this component to an ultraviolet light source will cause the erasure of all stored data, thereby making it available for new data storage.

Another erasable ROM device is the electrically alterable read-only memory (EAROM). This device functions as a ROM. When erasure of the stored data is required a relatively high voltage is applied to this device effectively clearing memory of either all data or in some designs a particular data location, thereby permitting new data to be written into the available locations. These devices require relatively long write timing signals.

5.1.2 Memory Bus

In accessing the Memory the CPU addresses it via a memory address bus. Data is transferred between the CPU and Memory over an

8-bit in-put data bus and an 8-bit output data bus.

5.1.3 Memory Size

Memory is generally expandable in blocks of 8 bits (byte) of 1024, 2048, or 4096 words up to the capacity of the CPU to address the maximum memory address of 16 bits of all logic level "1's", which equals 65,636.

5.1.4 Accumulator

Located in the CPU is an accumulator. An accumulator is a register and associated circuitry in the arithmetic unit of the CPU in which logical and arithmetic operations are performed.

The central element of the entire microcomputer is its accumulator register; all arithmetic and logical operations occur through it. Generally, it is impossible to add memory contents of one location to that of another. All such additions or subtractions occur in the accumulator register. Additionally, for most operations input and output data must pass through the accumulator.

Data is also transferred between memory and other registers of the CPU. A register is generally a temporary storage device capable of storing one data word. These registers are usually instruction registers,general purpose registers, program counter registers, stack pointer registers.

5.1.5 Read/Write

The CPU has two input/output modes. When the read/write line is high or logical 1, data can be read into the CPU via either memory or an external input. When the read/write line is low or logical 0, data can be written from the CPU into memory or an external device.

5.1.6 Data Output

The output data bus, i.e. 8-bits of data from the CPU to the memory, is also used as an output data bus to devices external to the CPU.

Output to an external device generally requires that the accumulator in transferring data generate a specific address associated with a particular external device. The 8-bit output data bus permits 2^8 or 256 unique device codes or addresses.

Because of the speed of the CPU (u seconds), the external device must be capable of saving or capturing the momentary data provided as an accumulator's data output.

The external output device is aided in capturing data output from an accumulator by a software generated synchronization pulse from the accumulator termed a device select pulse. This pulse serves to synchronize the CPU with an external device, such that when data is presented the external device is prepared to receive it.

External devices can consist of relays, integrated logic chips, motors, voltage control circuits, etc.

5.1.7 Data Input

The input data bus, i.e. 8-bits of data from the memory to the CPU, is also used as an input data bus from external devices to the CPU.

When the CPU is prepared to capture data input from an external device, it transmits a device select pulse, which synchronizes when the input device transmits data to a buffer register within the CPU. Input devices can consist of A/D converters, relay contact closures, etc.

5.1.8 Direct Memory Access

Another input/output technique termed direct memory access or DMA permits data to be transferred directly between memory and an input/output device without first having to be processed by the accumulator.

This technique saves time relative to the transfer rate for each 8-bit data word. Each input or output device is treated as a pseudomemory location that is addressed directly with a memory instruction, instead of a data in or data out CPU instruction.

This process has particular advantages when handling large amounts of high speed data.

5.1.9 Servicing Interrupts

An interrupt is a disruption in the normal computer processing of a program in such a manner as to permit the resumption of program processing at a later period in time.

This function permits the CPU to remain in an idle state until an interrupt signal is received from an external input or output device. For more than I/O device interrupt, the microcomputer has a priority schedule for each external device; the most important having the highest priority. Use of this feature permits important data, e.g. alarms or values, to be serviced without loss or delay.

Upon servicing the interrupt the CPU returns to the program step succeeding that step which was in process when the interrupt was received.

5.2.0 System Clock

The system clock is a timing device which provides a continuous series of reference timing pulses to the microprocessor. Some systems utilize a single phase, while others require a multiphase clock (generally two phase).

A two phase clock is a timing device which provides two synchronized series of continuous pulses.

Microcomputers under software control can utilize the system clock to generate individual clock pulses, a series of pulses over a specific time e.g. timing loop or pair of start/stop pulses.

5.2.1 Software vs. Hardware

The essence of a microcomputer's functionality is the substitution of computer software for circuit hardware to execute specific control or logic operations.

Under software control a microcomputer can be used as a timed control device to perform such operations as set, clear, inhibit, start, stop, etc.

5.2.2 Computer Instruction

Programming a microprocessor involves addressing its memory and giving it instructions. Every computer system has a basic word structure (group of bits). An 8-bit microprocessor word consists of a group of 16 contiguous bits, which occupy two adjacent memory locations of 8-bits each or bytes. The length of a word defines the precision of the instruction. An 8-bit word has a resolution of .2%, whereas a 16-bit word has a resolution of .008%.

An instruction for an 8-bit microprocessor can be eight, sixteen, or twenty-four bits long. A twenty-four bit instruction would consist of an 8-bit operation (instructor) and a 16-bit memory address.

Each byte (8-bits) of a memory address i.e. 2 bytes is composed of a series of ones and zeros which are termed binary numbers. Binary numbers are represented by the absence or presence of electronic signals. A binary 0 is represented generally by a 0 voltage level. The binary 1 is generally represented by a positive +5 volt level.

5.2.3 Machine Code/Machine Language

The binary series of zeros and ones, which form an instruction for the microprocessor is termed a machine code or language.

Machine language instructions or programs are usually converted to either octal or hexadecimal code.

5.2.4 Octal Code

Octal code is created by breaking up binary machine code into groups of 3-bits, starting with the least significant bit. An example of this would be the binary word 10111001_2.

Breaking this word into groups of threes yields:

10 111 001

By adding in binary each group of 3-bits and expressing each as a decimal equivalent results in:

$$10 \; / \; 11 \quad 001 = 271_8$$

5.2.5 Hexadecimal Code

Hexadecimal code is created by breaking up binary machine code into two groups of 4-bits each. An example of this would be the binary word 1011001_2.

Breaking this word into two groups of 4-bit yields:

1011 1001

Noting the list of hexadecimal to binary number conversion, the following hexadecimal equivalent is derived. (Tables 1 & 2)

$$1011 \quad 1001 = B9_{16}$$

HEXADECIMAL TO BINARY CONVERSION LIST

Hexadecimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Table 1

BINARY to OCTAL to HEXADECIMAL to DECIMAL CONVERSION TABLE

Binary Number	Octal Number	Hexadecimal Number	Decimal Number
.00000000	000	00	0
.00000001	001	01	1
.00000010	002	02	2
.00000011	003	03	3
.00000100	004	04	4
.00000101	005	05	5
.00000110	006	06	6
.00000111	007	07	7
.00001000	010	08	8
.00001001	011	09	9
.00001010	012	0A	10
.00001011	013	0B	11
.00001100	014	0C	12
.00001101	015	0D	13
.00001110	016	0E	14
.00001111	017	0F	15
.00010000	020	10	16
.00011000	030	18	24
.00100000	040	20	32
.00101000	050	28	40
.00110000	060	30	48
.00111000	070	38	56
.01000000	100	40	64
.01001000	110	48	72
.01010000	120	50	80

Generally, machine coded instructions are written in octal rather than hexadecimal code because of its comparatively confusing use of alphabetical symbols.

Table 2

5.2.6 Mnemonic Code (ASSEMBLY Language)

The term mnemonic means "to aid memory". To aid in the remembering of computer instructions, a system of alphabetical codes are incorporated to represent actual machine code.

When used the microprocessor must first convert mnemonic code to binary for interpretation. This conversion is referred to as assembling a machine code from a MNEMONIC or SYMBOLIC CODE. Thus the name of a mnemonic code is "assembly language".

5.2.7 Instruction Set

An 8-bit machine code permits an instruction list or set of 256 unique operations.

5.2.8 Higher Languages (Compiler/Interpreter)

Other languages exist which permit the equivalent of many machine code instruction statements to be expressed as a single higher level statement. These languages require a compiler/interpreter software decoder, which converts the higher level instructions into machine code.

Two such higher level languages (compiler based), which are very popular are FORTRAN and BASIC.

Generally, the category of local control devices considered for energy management of small buildings are limited in the instruction sets to low level mnemonic (assembler) code.

5.2.9 Instruction Entry

To program the microprocessor a method of inputting instruction code is required. Microprocessor based programmable local control devices vary in their method of data entry depending upon their level of sophistication. Single function processor applications generally utilize thumbwheel switches for programming.

Microprocessors used in multifunction non-adaptive applications incorporate both built-in and portable numeric keypads along with special function keys. Activation of a special function key selects a pre-programmed set of machine code e.g. relay closures. Keypad entered data is used to set specific parameters such as time, date, priority etc.

All higher level processors provide an industry standardized communication channel. This communication channel conforms to an industry standard signal level convention which is either 20ma TTY (Teletype Compatible) or EIA-RS232-C.

The TTY signals consist of a 20ma current flow representing a binary Logic 1 and an open circuit for Logic 0.

EIA-RS232-C signals consist of a negative voltage level in the range of -3to-25 volts for a Logic 1 and a positive voltage +3to+25 volts for a Logic 0. See Table 2.

Data is presented serially i.e. one binary bit at a time. This serial presentation of data conforms to an industry standard ASCII Code (American Standard for Coded Information Interchange). The ASCII Code represents a specific character set of alpha, numeric, punctuation and special symbols.

Adaptive programmable systems generally provide a full ASCII data entry terminal. These terminals vary from keyboard entry CRT displays and teletypes to TTY compatible high speed terminals incorporating mass data storage devices such as floppy disk and tape cartridge systems.

Discussion of microprocessor adaptation will begin with its simplest application as time delay relay.

6.0 MICROCOMPUTER APPLICATIONS

6.1 Non-Adaptive Non-Programmable (Presetable) Single Function

6.1.1 Time Delay Relays

These devices represent a current state-of-the-art application of single function microprocessors. Time delay relays are utilized in mechanical systems requiring sequence control, e.g. chiller activation/shutdown, ventilation start-up, burner start-up/shut-down, etc.

Until recently, circuitry of this type was constructed of individual integrated circuit chip, utilizing integral memory and a central processor to perform mathematical and algebraic operations which duplicate the basic relay circuitry function.

The basic units can provide: ON-DELAY, INTERVAL, LATCHED INTERVAL, LATCHED ON-DELAY, ACCUMULATED DELAY.

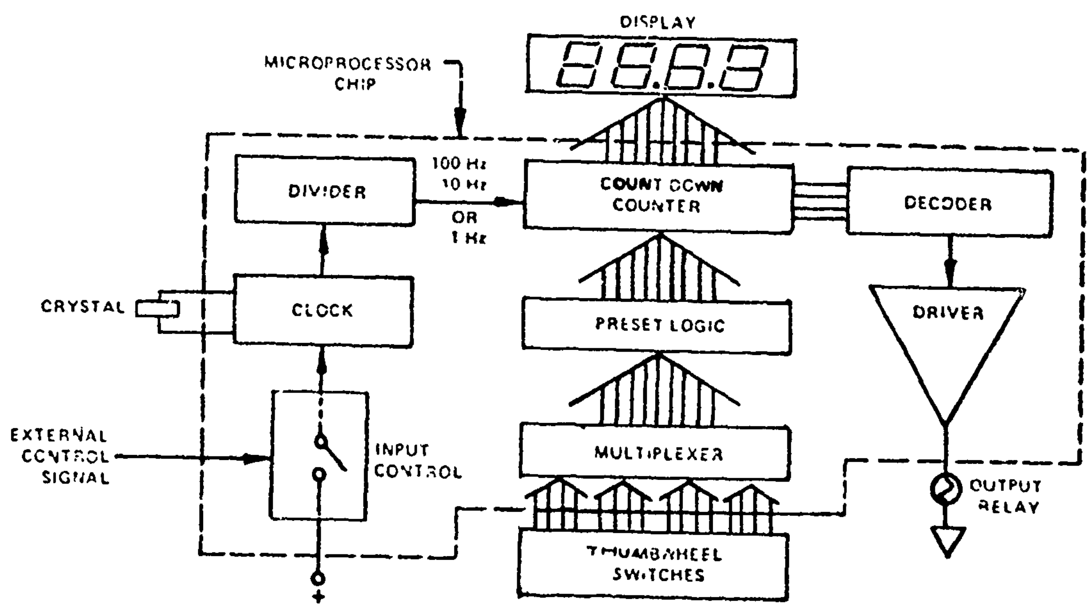
Additionally, on the ON-DELAY and INTERVAL modes, control of the relays is possible by interruption of the operating voltage or by opening and closing an external control path. In some models control can be effected by substituting an external ±5 to ±24 volt logic level. This mode permits the Time Delay Relay to be incorporated into an automatic system.

Noting Figure 17, the Time Delay Relay derives its precision timing via a quartz crystal timing circuit. This Clock-Pulse generator when activated by an external circuit closure produces a train of high frequency pulses which are then divided by a frequency divider.

The reduced frequency pulse train is then used to clock a count down counter. Counter programming is typically by means of thumbwheel switches built directly into the Time Delay Relay.

The thumbwheel switches provide logic inputs to a preset Logic Circuit which presets the countdown counter to the number of hundredths of seconds, tenths of seconds or seconds (depending on range of Time Delay Relay). This same count is displayed on a built-in digital readout.

When the Time Delay Relay is activated by an external signal, the Clock-Pulse generator is activated effectively initiating a pulse train which is then counted by the counter. With each pulse the count decreases by 2 units of time, e.g. .01, .1, or 1 second depending on the range of the relay. Upon reaching 00.00 (count-down to zero) a decoder circuit energizes an output relay driver effectively activating the relay. (Figures 18, 19, & 20)



Time Delay Relay

Figure 17

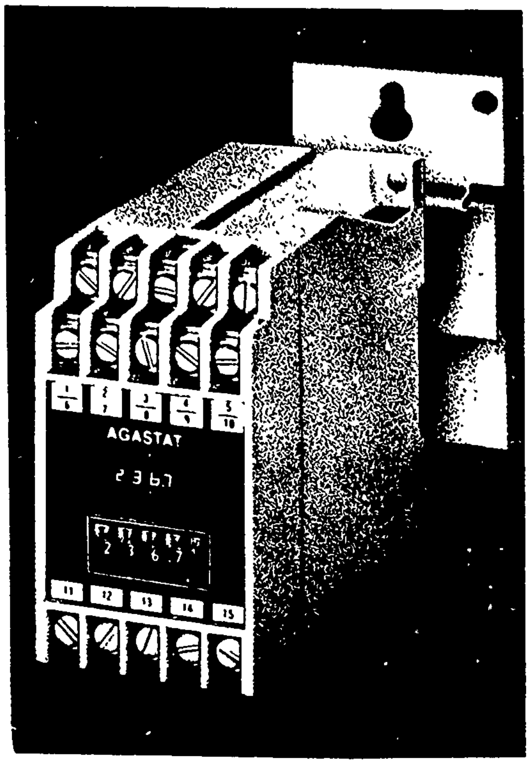
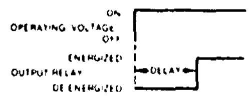


Figure 18

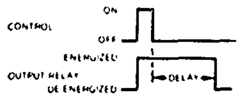
operation

Operating Modes

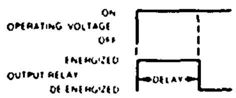
Type 1 Delay on energization/on delay (D/E)
Time delay is initiated upon application of operating voltage or closure of control path with power continuously applied If maintained output relay transfers at the end of the preset time delay If operating voltage is removed or control path is opened during the timing period time delay will revert to zero If operating voltage is removed after the timing period, output relay will release and time delay will revert to zero



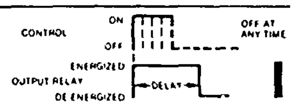
Type 2 Delay on de energization/off-delay (D/D)
Operating voltage must be applied continuously Output relay transfers upon closure of control path Time delay is initiated upon opening of control path If control path remains open, output relay releases at the end of the preset time delay If control path is reclosed during the timing period, time delay will revert to zero



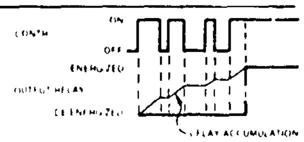
Type 3 Delay on energization with instantaneous transfer/interval delay (D/E/I)
Output relay transfers and time delay is initiated upon application of operating voltage or closure of control path If maintained output relay will reset at the end of the preset time delay If operating voltage or control path closure is removed during the timing period, output relay will release and time delay will revert to zero If removed after timing period time delay will revert to zero



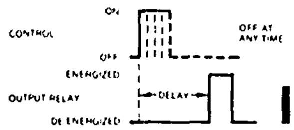
Type 4 Latching delay on energization with instantaneous transfer/latching interval (LD/E I)
Operating voltage must be applied continuously Output relay transfers and time delay is initiated upon closure of control path Once closed state of control path has no further influence until timer is reset Upon expiration of time delay, output relay releases Timer is reset by opening reset path



Type 9 Delay on accumulated energization/accumulated on delay (ACC D/E)
Operating voltage is applied continuously When the total duration that the control path remains closed in either an intermittent or continuous manner equals the preset time delay the output relay will transfer The contacts will remain in the transferred position until the timer is reset by removing the operating voltage or by opening the reset path



Type 11 Latching delay on energization/latching on-delay (LD/E)
Time delay is initiated upon closure of control path (Operating voltage applied continuously) Once closed state of control path has no further influence until timer is reset Upon expiration of time delay output relay transfers and remains in transferred position until timer is reset by opening reset path



Type 50 Pre determining Counter (ACC—D/D)
Operating voltage is applied continuously With each closure of the control path the preset number in the counter is decremented by one count The output relay transfers when the count reaches zero, and remains in this position until the timer is reset by removing the operating voltage or by opening the reset path An external contact closure rate up to 35 per second will be counted accurately

specifications

Absolute Accuracy
Absolute accuracy is the maximum range of deviations in actual delay from the thumbwheel switch setting that can occur over any number of consecutive operations taken under any combination of operating voltage and ambient temperature

When timing is initiated by means of the start input with power continuously applied, absolute accuracy includes two factors a) a scale factor, dependent on crystal accuracy or line frequency fluctuations, depending on time base selected, or b) a time offset, which is dependent on microcomputer program input circuit conditioning, and output relay operate or release time

Time Base	Operate Modes	Base	x	Scale Factor	+	Offset (Milliseconds)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Repeat Accuracy
Repeat accuracy is the bandwidth of values that will contain the delay that results from any number of consecutive operations taken at any fixed temperature and operating voltage The table below presents repeat accuracy by mode and time base and uses 3 0 milliseconds as the repeat ability of the relay operate and/or release times

It must be noted that operating a DSA timer in any mode that initiates timing by power line application with the start input strapped, requires that the repeatability bandwidth be increased by 5 0 milliseconds (± 2 5 milliseconds tolerance around midpoint)

Time Base	Operate Mode*	Repeat Accuracy (Milliseconds) Bandwidth	Tolerance
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Reset Time
0 025 second maximum This is the minimum interval between deenergization and reenergization of the TDR, or between opening and closing of the control path, or after opening the reset path, without affecting the accuracy of the TDR

Instantaneous Relay Release Time
0 025 second maximum This is the maximum interval between deenergization of the timer, and the complete transfer of its relay contacts under any combination of operating temperature and operating voltage

Relay Operate Time
0 028 second maximum This is the maximum interval between triggering and complete transfer of relay contact at any combination of operating temperature and operating voltage

Figure 19

specifications

CAUTION. Remove all sources of power before adjusting timer or removing case.

Timing Ranges and Resolution
Three ranges, field selectable at any time, by means of internal DIP switches

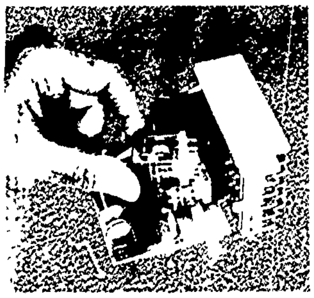
Code	Range (seconds)	Resolution (seconds)
A	01 to 99 99	01
B	0 1 to 999 9	10
C	1 0 to 9999	1

Delay Setting
Four miniature thumbwheel switches on the front of the case permit selection of the delay s^tting over the above listed ranges, with the indicated resolution

Setting and Status Indication
The Series DSA includes models with and without setting display Numerals on the delay setting thumbwheel switches indicate the delay setting in four digits
For models with display, when operating voltage is applied to the TDR, an adja cent red LED display of four ¼" illuminated digits with decimal point indicates the time delay setting while the TDR is in the ' reset state
During the countdown of the delay interval, the display indicates the time remaining before output relay activa tion After activation (and before reset-ting), the display indicates zero Models without the display are equipped with two red LED s that indicate ' ON status of the control path and the output relay respectively

External Control
Operation of the Series DSA can be controlled either by an external contact closure (with operating voltage applied), or by application of operating voltage (with control channel closed) The control channel can be activated by a relay contact, an open collector NPN transistor or by a + 8VDC nominal logic source for automatic operation when desired

Output
The Series DSA offers an unusual degree of versatility in output capabil ity It is equipped with a **timed** relay containing two form C (SPDT) contacts, and an **instantaneous** relay with one form A (SPST NO) contact and one form B (SPST NC) contact



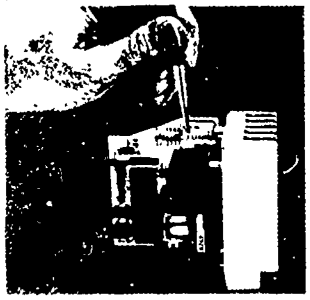
The latter relay operates at the *start* of the delay cycle Both relays are field replaceable, plug in units, as shown below left All relay contacts are rated as follows.

1/3 HP, 120/240VAC
345VA, 120/240VAC
10A, 28VDC/120VAC
Same Polarity

Operating Voltage + 10%, − 15%
115/120VAC, 50—60Hz
230/240VAC, 50—60Hz
24VDC
12VDC

Circuit Protection
Inputs are transformer isolated, and protected against external EMI/RFI influence and transients
3000 volts, 100 microseconds
2500 volts 1 millisecond
Current or voltage transients, magnetic effects, etc caused by adjacent devices, solenoids, transformers, etc , or picked up by wiring connected to the TDR, will not cause spurious opera tion or affect the function or accuracy of the TDR at any combination of rated operating conditions The control circuit is designed to ignore contact bounce in any mode of operation

Selection of Operating Modes & Conditions
Operating modes and conditions are field selectable by means of an internal 8 section DIP switch, accessible after removal of the unit's case (see illustration)



Selections are as follows

SWITCH		SELECTS
Section 1	ON*	01—99 99 seconds timing range
Section 2	ON*	0 1 999 9 seconds timing range
Section 3	ON*	1 0—9999 seconds timing range
Section 4	ON	60Hz line frequency
	OFF	50Hz line frequency
Section 8	ON	crystal time base reference
	OFF	line frequency time base ref

Sections 5 6 and 7 select the operating mode as follows

SWITCH SECTIONS 5	6	7	MODE
ON	ON	ON	Type 1 (On Delay)
ON	OFF	ON	Type 2 (Off Delay)
OFF	OFF	ON	Type 3 (Interval Delay)
ON	ON	OFF	Type 4 (Latched Interval)
OFF	ON	OFF	Type 9 (Accum On Delay)
OFF	ON	ON	Type 11 (Latching On Delay
ON	OFF	OFF	Type 50 (Counter)

*Among Sections 1 2 and 3 only one Section to be ON at any time

Power Consumption
3 6 watts, maximum Current drain at nominal voltage

	Output Relay Energized	Output Relay Deenergized
115/120VAC models	0 030 amps	0 010 amps
230/240VAC models	0 015 amps	0 005 amps
24VDC models	0 150 amps	0 050 amps
12VDC models	0 300 amps	0 100 amps

Dielectric Strength
1480 volts between contacts and circuitry and between line inputs and control circuits (except DC operation)

Operating Life
Mechanical 10,000,000 operations
Electrical 500,000 operations at rated resistive load

Temperature Range
Operating 0° to + 60°C (+ 32° to + 140°F)
Storage − 40°C to + 85°C (− 40°F to + 185°F)

Dimensions and Weight
2 18" × 3 85" × 4 94"
(55 4mm × 97 8mm × 125mm)
Approximate weight 560 grams (20 ounces)

Mounting
The Series DSA snaps directly onto a DIN track, and is supplied with an adapter plate that permits mounting on a 300 volt machine tool relay channel, *or on any flat surface*, as shown
It can also be mounted directly by 2 screws fastened through the built in mounting ears

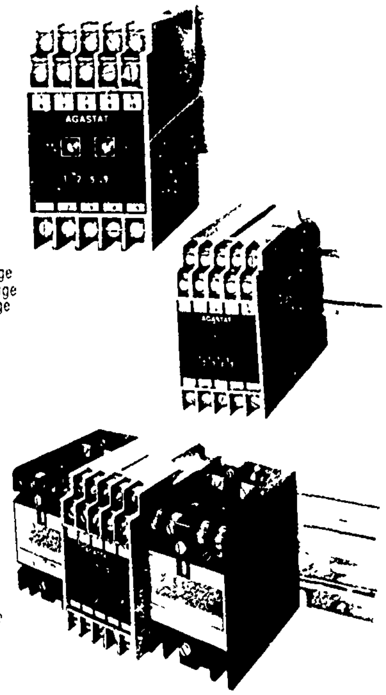


Figure 20

6.1.2 Non Adaptive Programmable Limited Function Controllers

-Programmable Timers

The Programmable Timer family of controllers are microprocessor oriented control output devices, which permit the prescheduling and cycling of electric loads. These devices provide comphrehensive control in easy to use format, through simple built-in keyboard programming by the user. (Figure 21)

Basic units generally provide 8 to 16 relays for load control. These relays control such loads as air-conditioning, lighting and fans. Program techniques using RUN/REST relationships can be established to match the requirements of each cycling load to minimize equipment wear and to achieve a desired environmental effect.

The controller printed circuit board contains all of the functional devices such as microprocessor, system clock, memory, keyboard, readout display and isolated relay drivers. Some units provide plug-in relays, others require that the user provide relays.

This approach, especially for multiple contacts, permits each relay to be located in proximity to the controlled equipment, thereby reducing control signal wiring.

Control signal wiring for the coils of each relay is usually connected to a terminal strip located in a readily accessible area inside the controller housing.

Figure 22 indicates the major subsystem components housed in the enclosure.

(a) Run/Program switch located inside of door.

(b) LED indicators and numeric displays for data monitoring and verification.

(c) Input Voltage: 117VAC

(d) Fusing

(e) Fusing

(f) Power switch

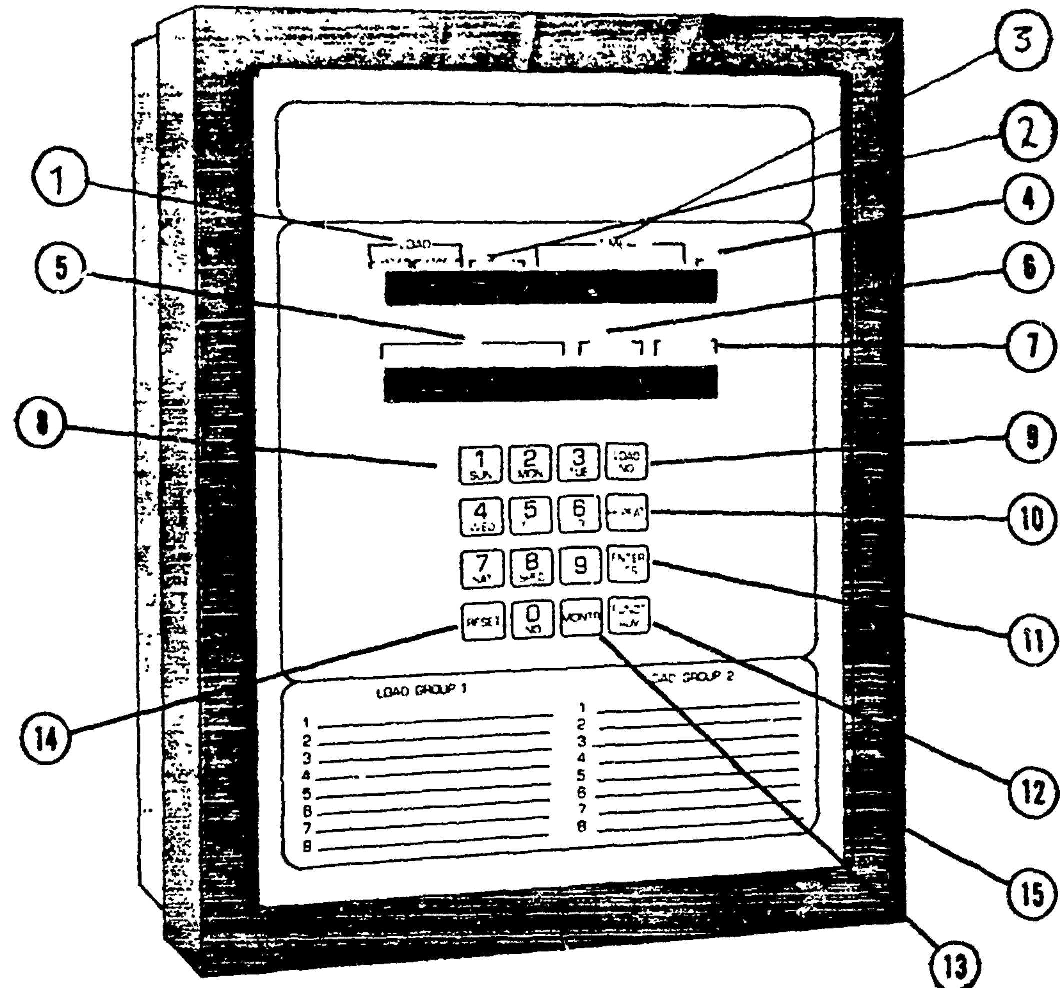
(g) Plug-in cables for ease of maintenance

(h) Battery backup

(i) Load Wiring: Barrier Strips - two terminals for each relay coil connection. (Figure 23)

Load Relays: Externally connected

(j) Load Control Switches: Provides Auto-Off-On control of circuits connected to load relays.



1. Load Group 1 or 2 is indicated by LED. Load Number within a group is indicated by digits 1 through 8.

2. Schedule is indicated by digits 1 thorugh 9.

3. Indicates the following:
   a. Time of day based on 24 hour clock.
   b. On or off times during schedule entry.
   c. Off and minimum on times for schedule entry of cycling loads.
   d. Event codes.

4. Cycling or non-cycling schedule is indicated by LED. Use NO key to toggle the display to the desired reading.

5. Day of the week is indicated by LED. Also used to indicate load status of group during Monitor mode.

6. Indicates by LED whether the schedule time displayed is on time or off time.

7. Indicates by LED whether time displayed for cycling schedules only is minimum on time or off time

8. Touchpad keys used to select load schedules and day of the week. 0/NO key also used to toggle the display to desired reading.

9. Used to access load selection program for schedule recall and entry.

10. Used to duplicate a given schedule for other days in the week, or other loads within a group.

11. Used to enter data in memory.

12. Guides operator (via flashing indicator) to next item which may be changed.

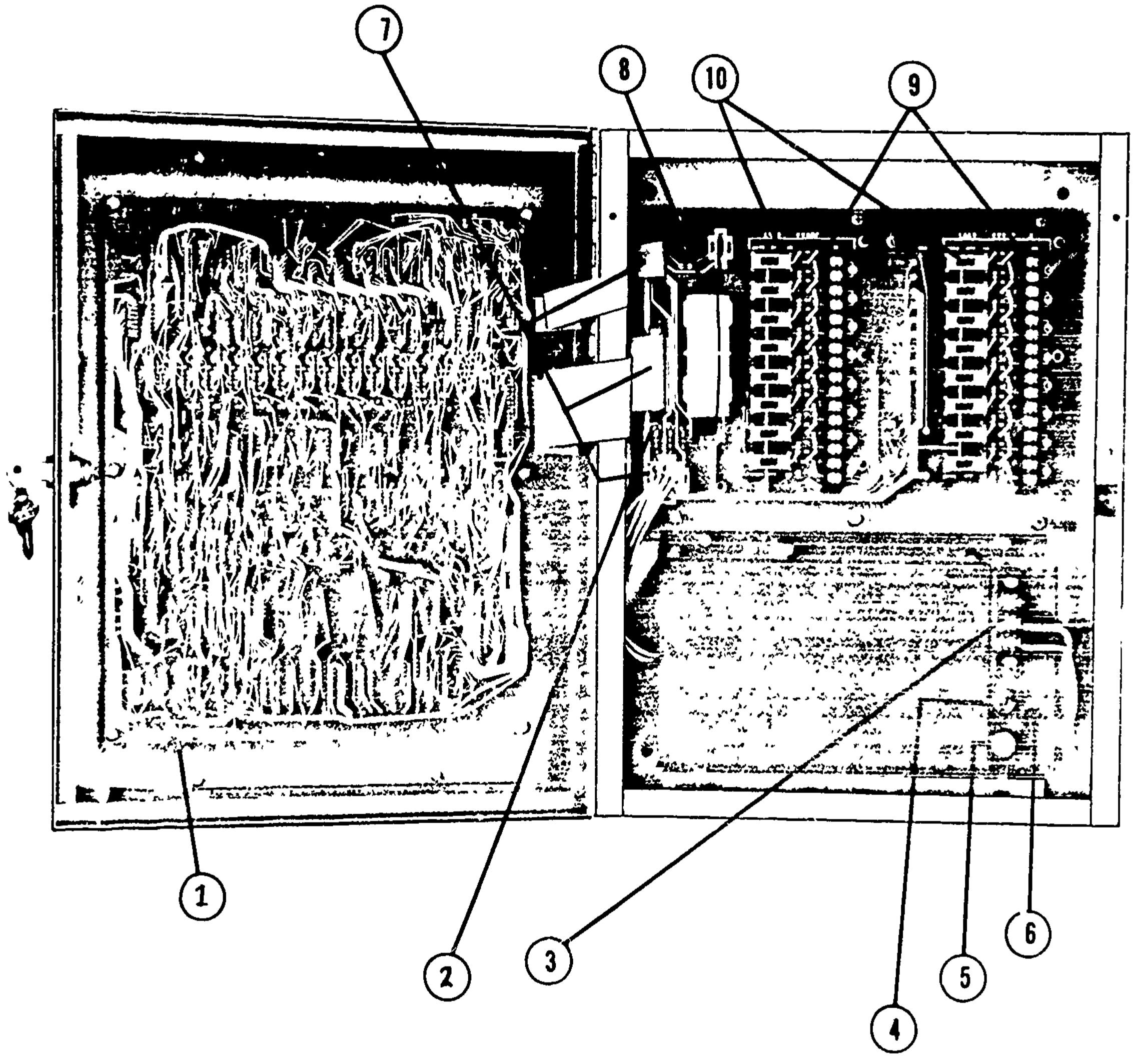
13. Used to access monitor [illegible] for observation of load status.

14. Used to reset displays and to clear event code messages.

15 Toggle switch, located inside the enclosure on the bottom of the [illegible] used to select either Run mode or Program mode

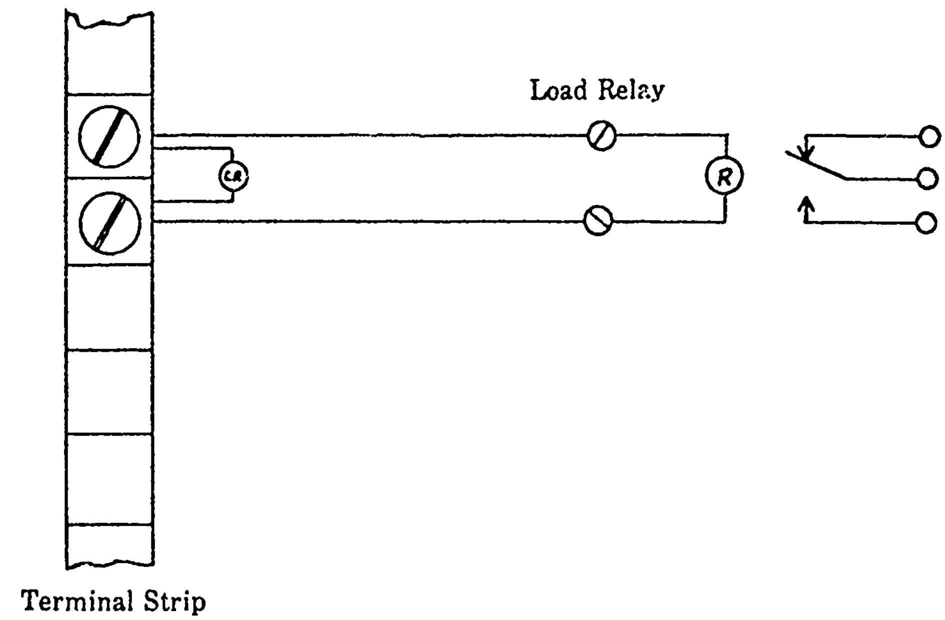
<u>Programmable Timer</u>

<u>Figure 21</u>

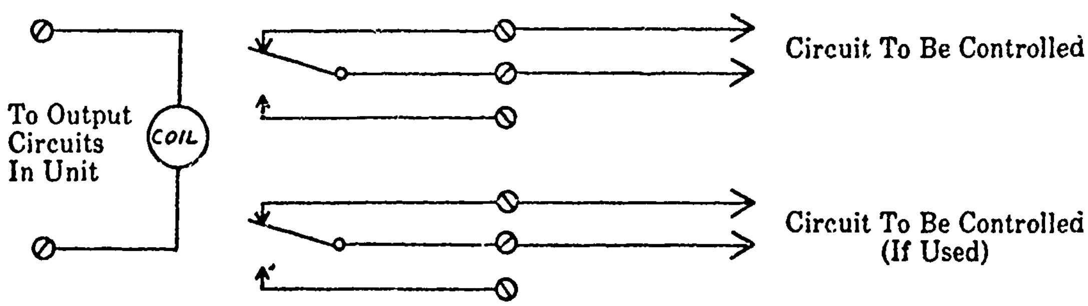


Programmable Timer

Figure 22



Relay Connection



Load Circuit

Figure 23

6.1.3 Operation and Programming

Programming is basically a matter of selecting a function key, which calls up a stored program from memory. Modification of parameters require only the entering of values; no programming knowledge is required.

Schedules are established for individual loads for each day, with each schedule consisting of an on-time and an off-time plus additional details for loads designated as cycling.

The on-time defines when the load circuit will be turned on (closed circuit), while the off-time determines when the circuit will be turned off (opened circuit). Generally these times may be from 00:00 (start of day) to 23:59 (end of day).

For cycling loads a pair of time values are entered, which define the minimum time the circuit will remain on, each time it is cycled off (off-time). The range of these times are usually 0 to 100 minutes. These times are determined as a function of the permissible cycling rates of the controlled equipment and the effect of having it off.

The number of programmable schedules (varies for different units 2-10) used for a given load for a given day depends on the number of separate running periods required as well as desired changes to cycling times. The upper range of programmable schedules per unit in general is 256.

A separate entry establishes an update time (1 to 100 minutes) which determines how many cycling loads are off at any given moment.

Override switches are usually provided for each load circuit which may be used to turn loads ON, OFF or to place them under control of the unit (AUTO).

Monitor modes and diagnostic read outs are provided to display current program status and program errors.

Units are generally housed in NEMA rated housing and are wall mounted. The units are wired through conduit knockouts located on the wall of the enclosures.

6.1.4 Power Failure

Units with stand-by battery backup are desirable. In a power failure mode units without battery backup would lose all user programmed instruction stored in RAM memory, thus requiring all such units to be reprogrammed. Additionally, depending upon the load being controlled, catastrophic failure could occur during an unscheduled shutdown or upon return of power start-up.

6.1.5 Preventive Maintenance

Units of solid state design require little preventive maintenance. Periodic inspection and cleaning of dust accumulation, which could inhibit coding and under high humidity conditions cause a short, is advised.

6.1.6 Cost Factor

Basic cost for such units is approximately $100 per point controlled, starting at approximately $1,000.

6.1.7 Adaptive-Programmable Limited Function Controllers

-Demand Controllers

An example of this class of controller is the demand controller. These devices are a level of complexity above programmable timers in that they respond to data received from the external world.

These microprocessor programmable devices are capable of performing timing, mathematical and logic calculations upon which control decisions are made.

Figure 25 depicts a typical unit suitable for small building applications. Demand controllers function as kilowatt demand limiters, effectively limiting the peak average electrical energy used during short periods of time, referred to as demand intervals (15 or 30 minutes). For additional information on kilowatt demand see page

Through the sensing of a facility's energy consumption, by means of either a current transformer and a 0-10VDC converter (see Figure 24) or a demand pulse meter which outputs signal pulses (contact closures) directly in proportion to demand, measurement of the actual power demand is possible.

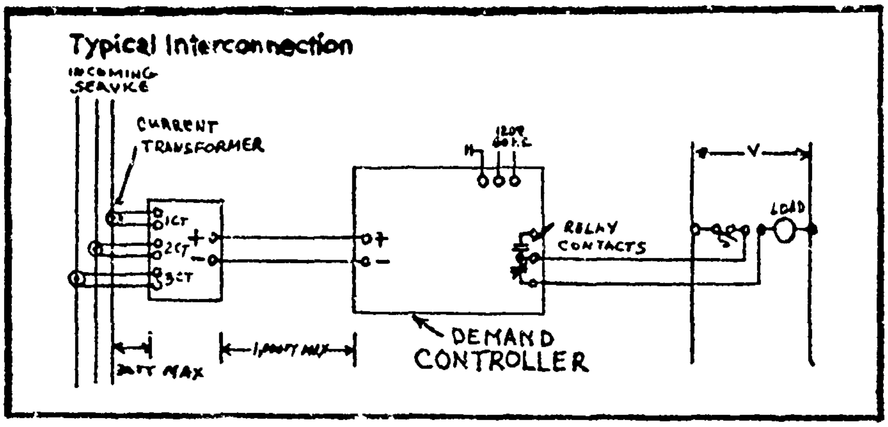


Figure 24

The demand controller upon receiving the converted demand signal information from either a converter or pulse meter (contact closure) initiates control action based on programmed instructions.

Basically, the controller begins its load shed action, when depending upon its design either a user programmed demand set point is reached or the demand load equals a controller automatically predicted demand limit (sliding window). This latter approach is more efficient.

In the sliding window mode the controller predicts a demand level based upon the average of the integrated demand and the current instantaneous KW loading. Load shed action initiates when the demand equals the demand limit.

Restore action begins when the predicted demand is less than the demand limit by a user adjustable KW value (a restore differential).

In the sliding window method the demand limit is automatically adjusted downward by a percentage of the service KW for a specific number of hours (usually days) that the controller has not taken any demand action.

Conversely the limit is increased by an equal percentage of service KW for every demand interval that the control has shed all loads and is still required to shed. Programmable levels are provided to restrict demand limit increases and decreases.

Control of loads is usually through relay contact closure. The typical unit provides from eight to sixteen relays or relay control outputs.

6.1.8 <u>Load Shed Prioritization</u>

Load priorities are programmable and in the more versatile versions provide for first-off/last-on options. This is beneficial in preventing the continuous cycling of the same devices and thereby increasing their chances of failure.

6.1.9 <u>Programmable Shed Time</u>

Adjustable maximum and minimum shed times are provided to prevent extended equipment disconnection and injurious disruption respectively.

6.2.0 <u>Programmable Timer Modes</u>

In addition to their load shedding capability some units have programmable time of day schedule control e.g. on, off, cycled and auto-demand.

6.2.1 <u>Operation and Programming</u>

As with programmable timer controllers, instructions are entered via a built-in or portable keypad.

Portable keypads prevent unauthorized entry, but most units have an operate/enter data key selected mode switch, which when left in normal "run" position deactivated the keypad.

6.2.2 Typical Instruction Set

Instruction	Keyboard Operation
Exit Rotating Display	ADV
Jump to Step 1	ADV, CE, CE
Jump to Step 14	ADV, CE, CE, 0, ADV
Jump to Any Relay	ADV, CE, CE, RELAY, NO. ADV
Reset Error or Alarm	CE

Program diagnostics are provided, the following is a typical representation:

Controller Self Diagnostics

Error Message	Description
EE01	Incorrect priority entered.
EE02	Incorrect time entered.
EE03	Time of day table full.
EE04	Load relay number not valid.
EE05	Data entry attempted in Run Mode.
EE06	Incorrect clock time entered.
EE07	KW entry missing.
EE08	Data lost in Time of Day Table - Enter again.
EE09	Duplicate entry in Time of Day Table.
EE10	Data lost in memory verify program.
EE11	Only zero entry allowed.

Override switches are usually provided for each circuit.

Units are housed typically in NEMA grade wall mountable enclosures.

6.2.3 Power Failure

Most units use battery backup and annunciate a low battery condition.

6.2.4 Preventive Maintenance

As with programmable timers, periodic inspection and cleaning is advised.

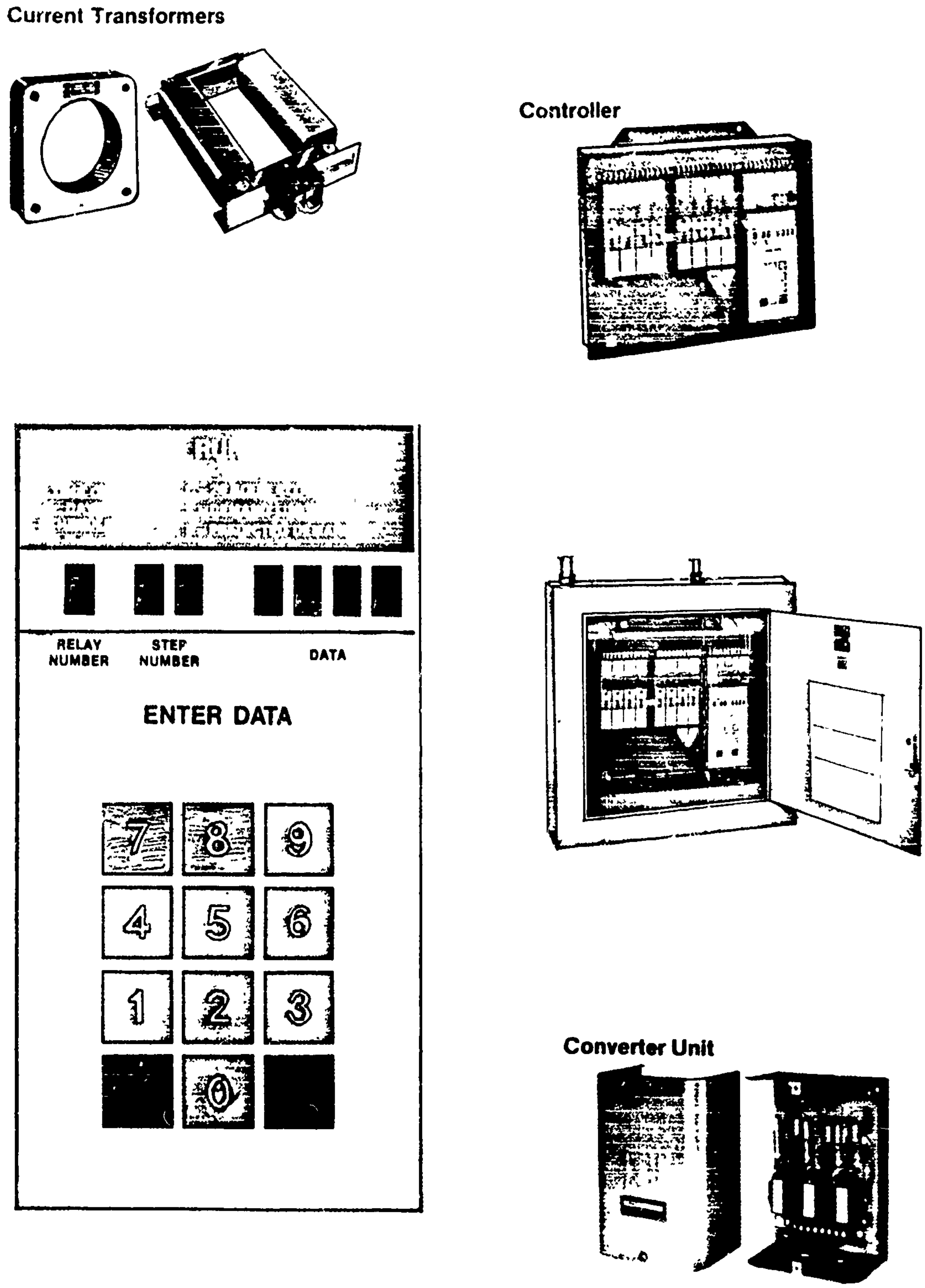
6.2.5 Optional Features:

Some units provide an RS232-C output port for direct communication with a central computer. This configuration allows the local control device for an individual building to be incorporated into a much larger centralized computer based system.

Additionally, some units have CRT and hardcopy display capability.

6.2.6 Seasonal Considerations:

Depending on a building's use and mechanical system design,



Close-up of Keyboard and Display

Figure 25

seasonal adjustments might be required of both the demand limit and cycling programs to maximize efficiency.

6.2.7 Cost Factors:

Basic cost ranges from $1,800 to $7,000 depending on the features and options required.

6.2.8 Kilowatt Demand

Demand charges are necessary for a utility to recover its fixed investment in the generation, transmission and distribution equipment required to provide for a customer's maximum demand for electrical power. Because of the fact that demand charges can make up as much as 30 percent of utility billing it is important to limit a facility's average power requirements during each demand interval (15 - 30 minutes). Most utilities measure an average or integrated demand over a fifteen or thirty minute period for billing purposes.

6.2.9 Kilowatt Demand Formula

Using a time interval of 30 minutes (0.5 hours) the formula for KW demand is:

KW demand = Kilowatt - hours/0.5 hours

Example:

If a 100 ton chiller operates at rated load (assume 1KW/ton) for thirty minutes, the integrated demand will be 100 KW (Figure 26).

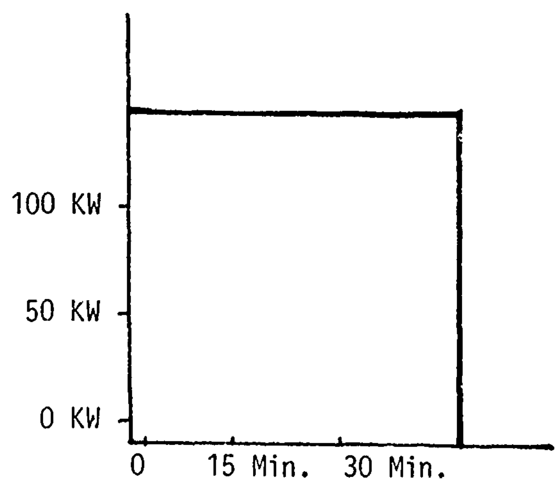


Figure 26

Any device operating for the full thirty minute demand interval at its rated load will develop a KW demand equal to its steady-state KW rating.

The energy used, kilowatthours (KWH), is computed by multiplying the KW rating by the operating time period in hours. Thus, the energy used in the example is 100 KW x 0.5 hours = 50 KWH. The demand is 50 KWH/0.5 hr. = 100 KW.

The 100 KW demand figure does not necessarily relate to a specific, single device. In fact, it seldom does since under actual conditions the energy consumed at a facility is used by numerous devices.

All the relationship really indicates is that if 50 kilowatthours are consumed in one-half hour, the integrated KW demand is 100 KW.

6.3.0 Adaptive-Programmable Limited Multifunction Controllers

-Programmable Controllers

Microprocessor based programmable controllers are in the same device class as demand controllers and differ only in their function.

6.3.1 Central Processor Unit

Programmable controllers i.e. for small scale applications are designed to perform all the functions of relay and hardwired logic control. (Figure 27)

They can also solve sophisticated control problems including arithmetic, analog/digital conversions and remote input and output.

Their I/O capabilities provide for relay control, timing and control functions to precisely control ON-OFF operations of solenoids, pump starters, motor starters and other types of control equipment.

Figure   depicts a typical small scale controller.

Typically, these units are of modular construction. CPU's are normally self-contained 8-bit machines.

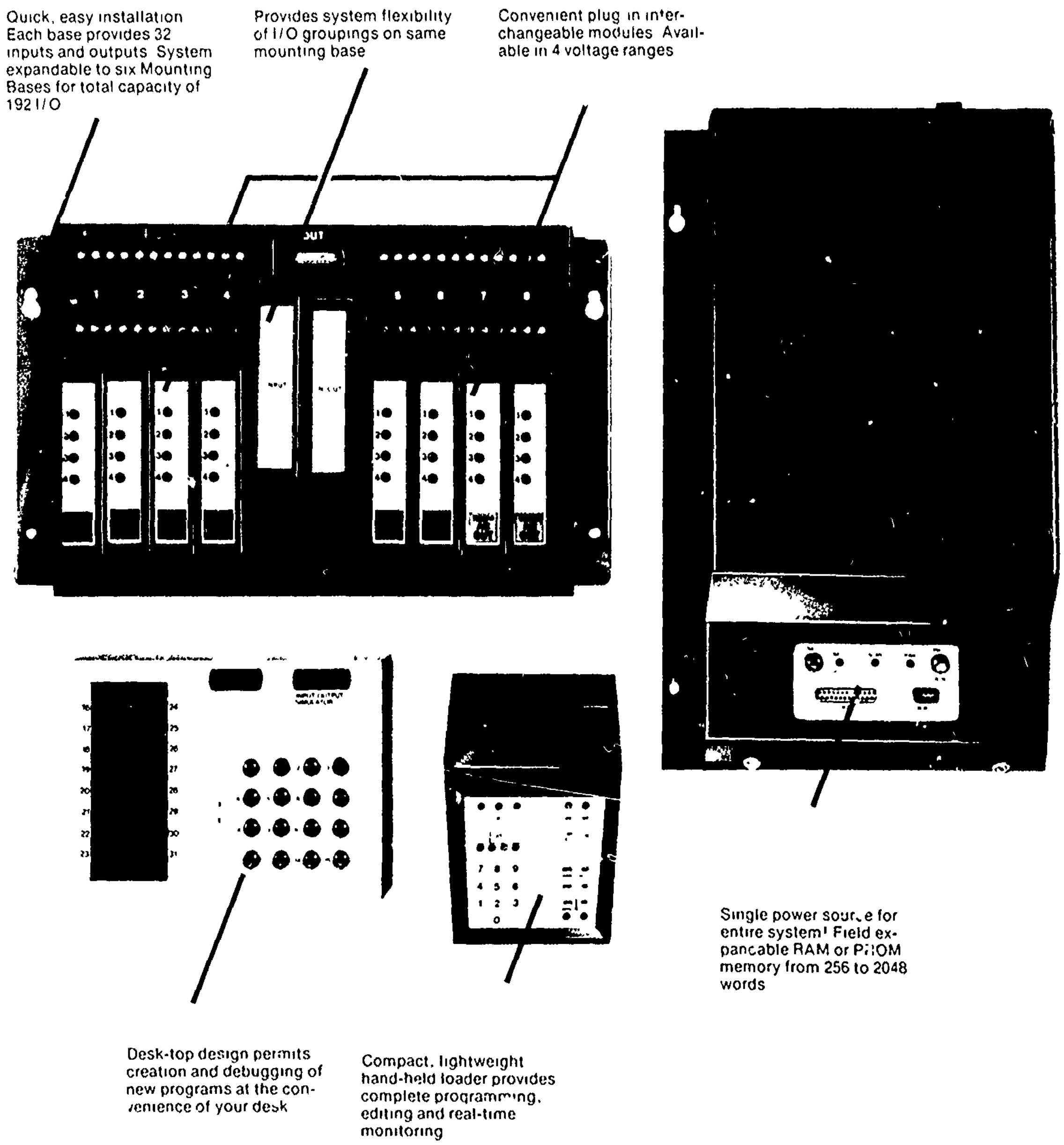
6.3.2 Memory

Memory consists of solid state read/write RAM's and READ/ONLY PROM's and EAROM's. Memory if field expandable from generally 256 to 4096 words.

The number of possible discrete inputs and outputs varies as a function of memory size, ranging from generally 8 discrete inputs and outputs to 256 each.

6.3.3 I/O System

External equipment is interfaced with the controller via plug-in modules. The I/O modules convert signals from external devices such as pushbuttons, limit switches, motor starters, solenoids, computers, thermostats, instrumentation and transducers to signals compatible with



Central Processor Unit

Figure 27

the processor. I/O modules are enclosed in protective housing.

6.3.4 Typical Module Types

(a) Discrete Input Modules:

Input = 5, 12, 24, 48, 120 and 250 volts AC or DC
4 Opto-isolated circuits per module

(b) Discrete Output Modules:

Output = 5, 12, 24, 48, 120, and 250 volts DC
120 and 250 AC

(c) Relay Output Modules:

4 per module, FORM C

(d) Analog Input Module:

Input = 0 - 5 volts, 0 - 10 volts, 1 - 5 volts
4 - 20ma and 10 - 20ma

(e) Analog Output Module

Output = 0 - 5 volts, 0 - 10 volts, 4 - 20ma and

10 - 50ma

6.3.5 I/O Racks

I/O modules are housed in a separate rack. Each rack typically can accomodate 4 I/O modules. Generally, each rack will accept all I/O module types i.e. input and output signals may be mixed on any rack. (See Figure)

6.3.6 I/O Expander Power Supply

I/O expander power supplies are required whenever system expansion exceeds the power capacity of the processor.

6.3.7 Remote Input/Output

Some programmable controllers have the capacity communicating via UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTERS TO REMOTE LINKS.

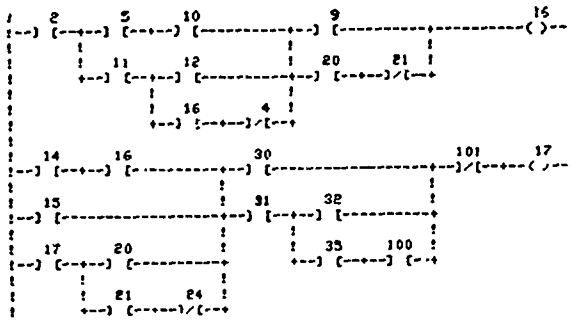
6.3.8 Read/Write Memory Loader/Monitor

Program entry is generally done through a portable terminal. (See Figure 28)

The Loader/Monitor Terminal can be a CRT with keyboard entry or a compact hand-held calculator type terminal with LED displays.

Keyboards are labled with relay symbology and I/O address entry is in decimal numbers, which greatly simplifies programming. (See Figure 28)

Programming is then a straight forward matter of directly entering relay contacts, switches, timers, output or connection points from a conventional relay ladder diagram.



Read/Write Memory Loader/Monitor

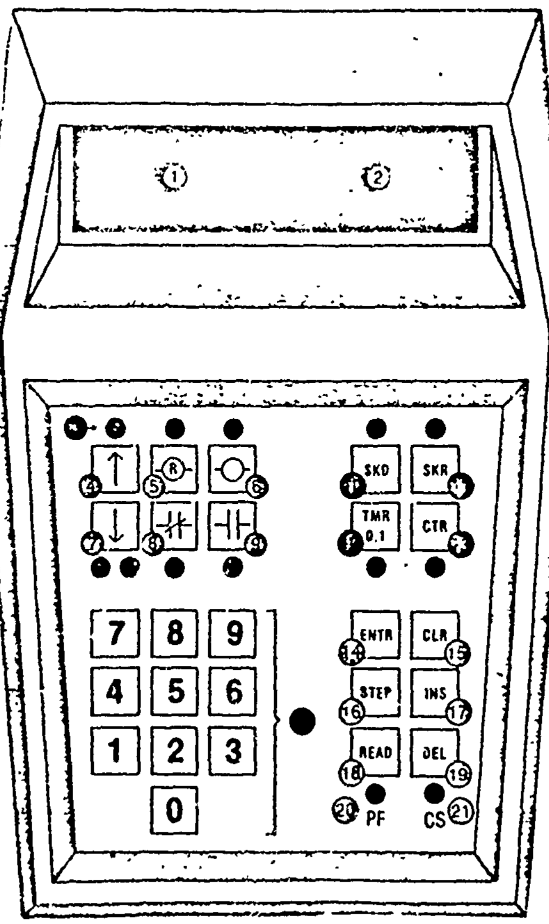


Figure 28

R/W LOADER KEY LEGEND

1. **Memory Address Display**—Displays the specified memory address up to 2047.
2. **I/O Address and Timer/Counter Display**—Displays specified I/O address (up to 255) or remaining time of timers or remaining counts of counters (maximum of 999)
3. **LED Indicators** (total 13) which illuminate after appropriate instruction key is depressed
4. **Up Arrow**—Completes parallel lines of logic in control circuit
5. **Retentive Output**—Energizes real or storage output in control program. Similar to latching-type output.
6. **Output**—Energizes real or storage output in control program. Considered a "normal" output instruction versus the "retentive" output instruction
7. **Down Arrow**—Starts a parallel logic path in control program. The Down Arrow is "packed" into the normally open or normally closed contact instruction, thus no memory words are used.
8. **Normally Closed**—Examines an input for an open condition, examines an output for a de-energized condition
9. **Normally Open**—Examines an input for a closed condition, examines an output for an energized condition
10. **Skip and De-energize**—Advanced instruction to skip one or more lines of logic and de-activate the output if it is active
11. **Skip and Retain**—Normal instruction to skip one or more lines of logic and retain the status of the output when the line of logic went into skip.
12. **Timer**—Enters timer presets at 100 millisecond resolution.
13. **Counter**—Enters counter presets
14. **Enter**—Writes previously selected data into selected memory location.
15. **Clear**—Clears Memory Address Display from present position to memory address "zero." Also used when clearing memory
16. **Step**—Increments memory address to next higher memory address and displays contents of that memory address.
17. **Insert**—Inserts displayed instruction into selected memory address
18. **Read**—Causes contents of selected memory address to be displayed.
19. **Delete**—Deletes displayed instruction in read/write memory when editing a program
20. **Power Flow**—LED indicator which shows real time indication of true power flow within a line of logic or within a parallel branch
21. **Contact (Output) Status**—LED Indicator which shows real time status of contact or output (opened or closed) presently being displayed
22. **Numeric Keys 0 thru 9**—Used for I/O address, memory address and peripheral operations

Normally open or closed contact conditions are entered or deleted by depressing the appropriate key located on the loader/monitor. LED's or print-out verify logic selection and condition.

Complete monitoring and inspection of all control circuits is performed with the R/W loader.

Any particular circuit elements address is displayable. Random search and display of any circuit element is achieved by simply numerically selecting the memory address location in which the element is stored.

6.3.9 Operation and Programming

Programs are created via the R/W loader by loading the contacts and output elements of each control circuit into the RAM memory, one at a time, starting with the first contact element in the first control circuit through to the final output element in the last control circuit.

After a control circuit program has been created and entered into RAM memory, it may be automatically copied into PROM memory using either a PROM programmer or writing directly into EAROMs. Some systems provide a one-step operation, whereby the program in RAM is automatically copied into the PROM memory. Once a control circuit program has been entered into PROM it is possible to copy it back into RAM for modification.

6.4 Optional Peripherals

To aid in the creation of new designs, simulators are provided. These permit the simulation and debugging of new programs without having to fabricate hardware.

Actual control circuit programs can be tested for proper operation before they are implemented into the control process, this greatly reduces the time and cost of start-up.

Additional peripherals are available e.g. printers, tape loaders, mass storage devices such as floppy disk and tape cassettes.

6.4.1 Training

Simulators can also be used as training tools. Personnel can be trained in such areas as programming, operations, and troubleshooting.

6.4.2 Adaptive Programmable Universal Controllers

-Full Capacity Programmable Microcomputer (Energy Management)

The adaptive programmable universal controller is a centralized microcomputerized supervisory control and data acquisition system. (SCADA) (Figure 29) These systems are only marginal cost-effective for buildings less than 200,000 sq. ft.

6.4.3 Control/Data Acquisition Functions

These devices have full input and output capability to perform demand limiting, automatic time based control, optimized start/stop, enthalpy control, lighting control and refrigeration control.

Centralized microcomputer based systems are capable of constantly monitoring such parameters as temperature, pressure, flow, level and status point information within a single facility or complex in realtime.

6.4.4 Operation and Programming

Under operator control any I/O point can be accessed for current information and action can be taken to correct or modify conditions via a computer keyboard console.

Generally alarm messages are received and processed by either or both CRT and hardcopy printers. Alarm annunciation is typically provided.

6.4.5 Event-Initiated Control

A unique series of control actions may be programmed to be triggered to occur whenever an "event" takes place.

An "event" as defined by the operator can be any change in a basic parameter e.g. set point or demand limit.

Control actions resulting from an "event" may be a set point adjustment, on or off control or a sequence of control actions with specified time delays in between.

6.4.6 Long Distance Communication

Depending upon the distances involved, modems (Modulators/Demodulators) are utilized to permit communication between the central processor and remotely located field interface devices (FID). Direct device control is via parallel interface CPU bus compatible hardware.

6.4.7 Central Processing Unit

Centralized microcomputerized systems incorporate either 8-bit or 16-bit central processing units.

Recent developments have seen the production of a 16-bit microprocessor with the equivalent power of a PDP-11/35 minicomputer, selling at a price well below that of the mini.

6.4.8 Software

To facilitate programming a compiler level language is utilized e.g. FORTRAN or BASIC. This readily permits program development at the user level.

6.4.9 Interactive Interfacing

Generally interactive programs are incorporated which require operator response to computer generated questions concerning system parameters e.g. upper/lower pressure limits, voltage levels, flow rates, etc.

6.5 Software Modification

Because of the use of higher level program languages, programmer personnel are readily available having the capability to modify existing and to develop new software packages.

6.5.1 Security

Access to programs can be limited by software to authorized personnel only, through the use of passwords and user level defined routines.

6.5.2 Maintenance Management

Additionally, central microcomputer systems permit the accumulation of run time information on major pieces of equipment and the automatic printing out of preventive maintenance instructions.

A typical system for small building applications might consist of:

(a) An 8 or 16-bit microprocessor CPU with 1K to 4K resident RAM and 2K ROM.

(b) 24K to 32K RAM (semiconductor) memory.

(c) Two serial interface boards for communicating with;

(d) One teletype compatible hardcopy printer or terminal and;

(e) One CRT computer console terminal.

(f) One mass storage device controller to interface with;

(g) One floppy disk, cassette or disk system.

(h) A variable number of parallel interface boards to permit direct computer input/output access to local external devices.

(i) A/D and D/A converters to process incoming signals and to control external equipment.

(j) One modem for communicating with remotely located field interface devices (FID).

6.5.3 Field Interface Devices (FID)

To control equipment remotely located from the central computer requires that a communications terminal be located in proximity to the equipment.

These FIDs can be intelligent or dumb terminals. Dumb terminals provide a low cost means of extending the central computer's control monitoring and analog points to remote locations. Intelligent remotes are typically programmable controllers with universal asynchronous receiver/transmitters.

6.5.4 Power Failure

To protect against power failure, three different methods are typically employed:

(a) On board memory back-up batteries.

(b) Core memory is used for RAM (non volatile memory)

(c) Uninterrupted power systems for total system supply.

- -Direct battery back-up per each voltage required
- -Inverter supplied AC voltage (converts battery DC voltage to AC).

7.0 APPLICATION OF LOCAL CONTROL DEVICES

To reduce energy consumption and to improve overall facility efficiency, local control devices can be incorporated in the following areas: (See Table 3)

7.1 Fans

(a) Control:
starting/stopping of fan motors; overriding steam or water valve controllers; operating outside air dampers as a function of outside temperature, regulating static building pressure, regulating functions based on time of day, regulating exhaust air and space humidity, etc.

(b) Monitoring:
failure to run, free protection safety, fire detectors, smoke detectors, run status, discharge and suction pressure, bearing temperature, air temperature and relative humidity, inlet vane position, motor temperature, outside air damper position, return air fan parameters, control valve position, humidifier excessive output, clogged or overflowing drain pans, building static pressure, etc.

7.2 Pumps

(a) Control:
starting or stopping as a function of time of day, controlling as a function of outside air temperature or power demand, etc.

(b) Monitoring:
pump failure, operating status, fuse failure, control power failure, motor current, manual or automatic control mode, alternator failure, bearing temperature pressure, motor temperature, water leakage.

7.3 Chiller/Refrigeration Compressors

(a) Control:
load or unloading a machine as a function of chilled water temperature, space temperature, outside temperature, power demand, time of day, cooling coil valve position, process requirement priorities, chilled water flow connected air handler CFM, space humidity and combinations of the above.

(b) Monitoring:
refrigeration failure, high pressure safety, overload safety, freeze protection safety, oil pressure safety, winding thermostat safety, operating status, head pressure, suction pressure, chilled water temperature, stages of unloading, motor current control power failure, etc.

7.4 Boilers

(a) Control:

adjusting of pressure or temperature control set points, night shutdown, limited firing during warm up, etc.

(b) Monitoring:

pressure, temperature, flame failure, high pressure safety, high temperature safety, low water safety, control power failure, operating status, power ON/OFF, feedwater control, feedwater pumps, oil or gas train operational sequencing, blowdown controls, chemical feeders, etc.

7.5 Lights

(a) Control:

as a function of time of day, occupancy and demand.

(b) Monitoring:

occupancy/light status condition.

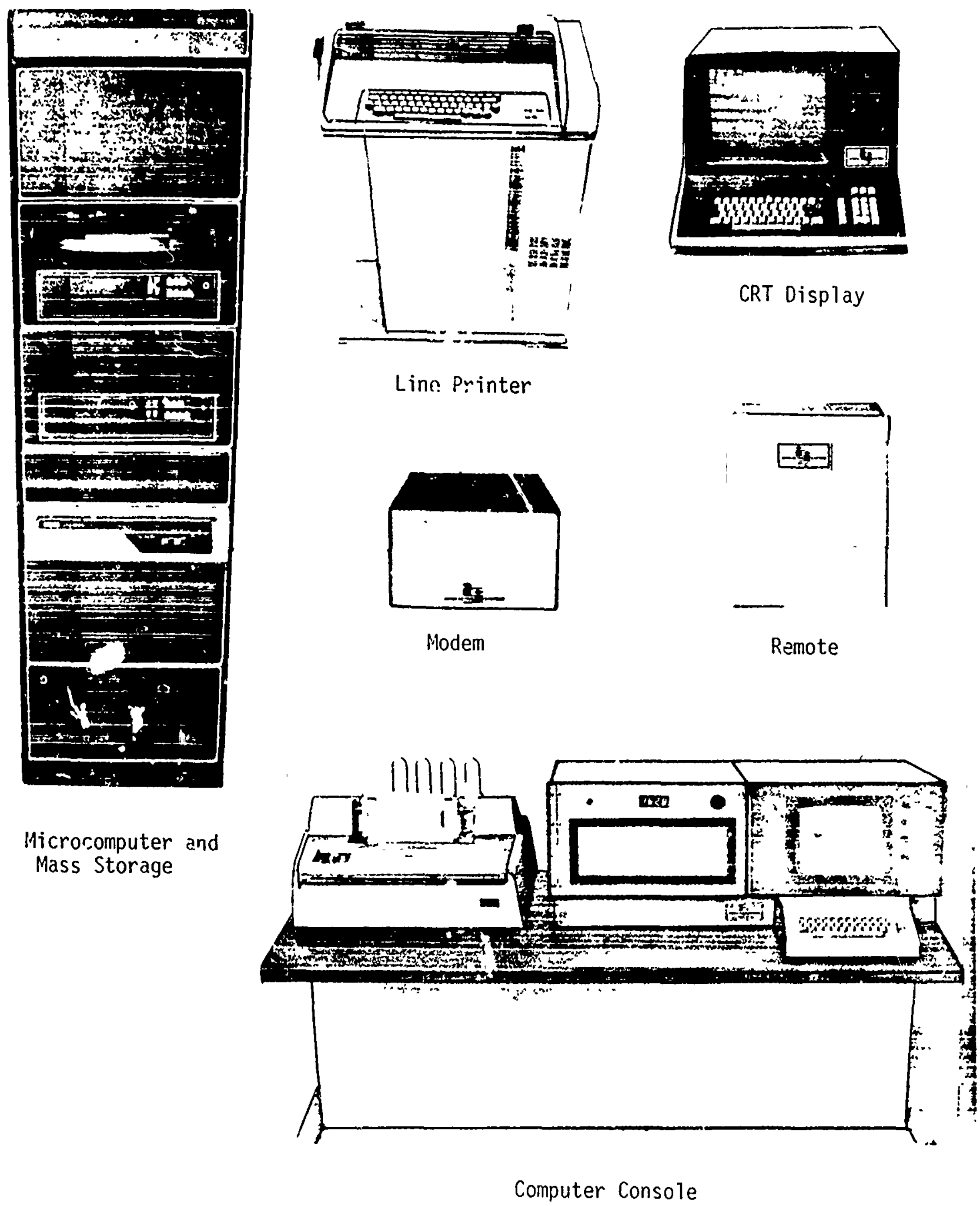

Line Printer
CRT Display
Modem
Remote
Microcomputer and
Mass Storage
Computer Console

Figure 29

Applicable Control Schemes for Various HVAC Systems

	1. Hydronic Heating System	2. Self-Contained HVAC	3. Single Zone System	4. Fan Coil System	5. Terminal Reheat System	6. Dual Duct System	7. Multizone System	8. Constant Air Volume System	9. Variable Air Volume System	10. Induction HVAC System
1	x	x	x	x	x	x	x	x	x	x
2	x			x	x		x	x	x	x
3	x	x	x	x	x	x	x	x	x	x
4	x	x	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x	x
8			x	x	x	x	x	x	x	x
9			x		x	x	x	x	x	x
10			x		x	x	x	x	x	x
11										
12			x		x	x	x	x	x	x
13	x	x	x	x	x	x	x			x
14			x		x	x	x	x	x	x
15	x	x	x	x	x	x	x	x	x	x

1. Scheduling of Loads
2. Shutoff of Outside Air Intake
3. Temperature Setback
4. Outside Air Reduction
5. Lighting Control
6. Enthalpy Control
7. Enthalpy Optimization
8. Chiller Optimization
9. Optimal Start/Stop
10. Load Cycling
11. Predictive Load Demand
12. Run Time Totalization
13. Equipment Malfunction Detection
14. Boiler Plant Optimization
15. Energy Cost Allocation

Table 3

8.0 Retrofit/New Construction Design Considerations and Implementation Requirements

8.1 Institutional Requirements/Resources

Once having determined the equipment to be controlled, a decision as to control methodology must be established. Dependent upon the mix of equipment to be controlled, consideration must be given to the possible range of control devices compatible with the following:

(a) Equipment types and quantity
(b) Equipment location
(c) Facility layout
(d) Facility operations and usage patterns
(e) Installation/construction impact

8.2 Equipment Types and Quantity

The number of different types of equipment to be controlled will effect, in the case of programmable control devices, the number of control program schemes to be developed and maintained. Also, in the case of non-controllable devices, the number of different types of equipment will effect the amount and type of spare parts to be maintained.

8.3 Equipment Location

Equipment location will in great part determine the control philosophy of an installation. Long distances will greatly effect periodic adjustment of parameters. Multi-functional programmable control devices permit readjustment to occur at fewer locations through the use of their programming keyboard as opposed to each equipment location.

8.4 Facility Layout

Conduit runs and control wire installations should be designed to have minimal effect on the facility layout.

8.5 Facility Operations and Usage Patterns

Facility operations and usage patterns, e.g. occupancy schedule, etc., will influence the number of control variables and time functions to be controlled. Environmental considerations will also effect control equipment configuration and specifications, e.g. housing, electrical noise immunity, operational temperature, etc.

8.6 Installation/Construction Impact

The impact of installing control equipment on a facilities operation must be considered in determining the most cost-effective alternative. Single function devices installed in proximity to HVAC equipment have the least effect on a facility's physical configuration.

As an example of the above consideration, use of a time-delay relay device in proximity to equipment to be controlled could decrease the amount of hook-up wire and conduit that had to be connected, when compared to a central controller. This function, dependent upon where the equipment was located and facility operations, could in some instances be of great importance.

In most cases several alternative control methods will be applicable; the most effective approach can only be determined after consideration of each alternative's total impact on the above listed items.

8.7 Operational Requirements/Resources

Additionally, the various alternatives must be weighed in light of their effect on such operational detail requirements as:

(a) Personnel - numbers, job skill requirements, training and scheduling, etc.

(b) Seasonal requirements - equipment adjustment, e.g. daylight savings time.

(c) Power failure - automatic or manual reset, e.g. time clock, etc.

(d) Maintenance/repair - failure modes, repair time, etc.

(e) Security - access to control equipment, vulnerability to unauthorized adjustments, modification to existing procedures.

(f) Specialized - air-conditioned area for central control system, power line voltage filtering for micro-based system, storage and maintenance procedures.

8.8 System Interconnect

Universal to all alternative approaches is the requirement to inter-connect equipment to control circuitry and to provide power to both. In the case of adaptive programmable limited function controllers a trunk line communications link may be required to communicate with a central control system external to the facility.

8.9 Control Signal/Communication Wiring

Figure 30 shows a typical wiring diagram of an automatic weather compensated boiler reset control. Essentially, this device is a switch (in series with an existing high limit control) that modulates the boiler water temperature as a function of outdoor temperature.

This circuit has 7 low voltage control signal wire connections and 3 high voltage connections to 120 volts AC. The low voltage signals wiring does not require conduit.

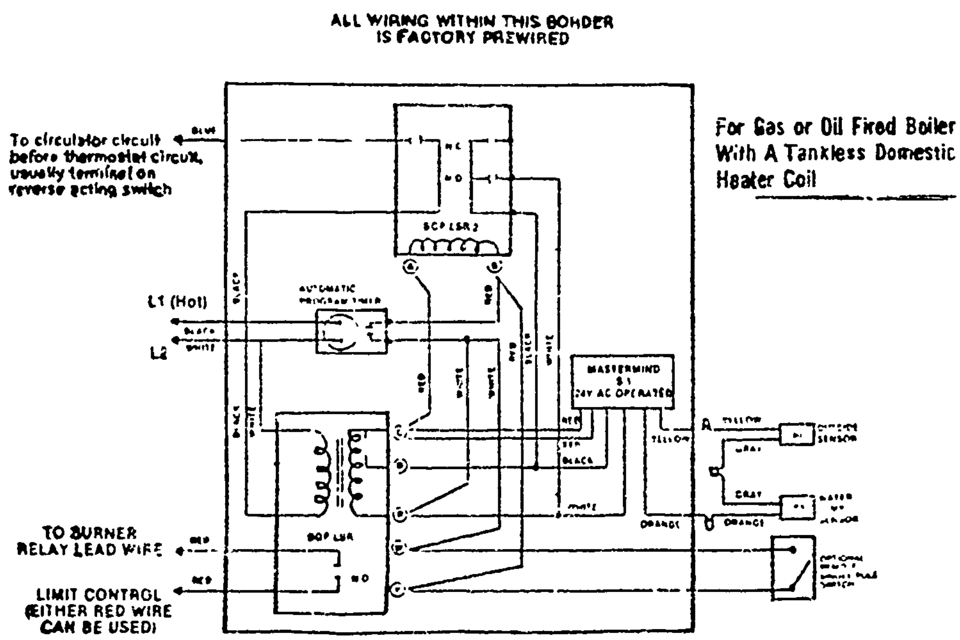
Signal wire installation is estimated at $3.50 per foot. (Table 4)

8.9.1 Branch Wiring

Branch (power circuit) wiring requires conduit and is estimated at $6.00 per foot and $10.00 per connection, or in the above case, 3 connections.

Table 4

Number of Remote Points	Number of Multi Conductor Wires in Single Cable	Installed Cost per Foot	Installation Cost per Termination
1-2	2-4	$ 3.00	$ 11.00
3-4	6-8	3.50	22.00
5-6	10-12	4.50	33.00
7-8	14-16	6.00	44.00
9-10	18-20	6.50	55.00
11-12	22-24	6.75	66.00
13-14	26-28	7.00	77.00
15-16	30-32	7.50	88.00
17-18	34-36	9.50	99.00
19-20	38-40	10.50	110.00
21-22	42-44	11.00	120.00
23-24	46-48	13.00	130.00



Control Signal Wiring Cost

Figure 30

9.0 ECONOMIC EVALUATION METHODS AND ANALYSIS

A general procedure for implementing a control system economic analysis evaluation should begin with the gathering of all the subject building's information schedule (BIS). The BIS can be found at the office of Plans and Policies in the FE shop.

9.1 Building Information Schedule

BIS information is a compilation of various parameters for each building on post. Where possible, this information should cover a minimum period of 12 months. This will provide an historical profile, which will be useful in determining energy management alternatives.

9.1.1 Baseline Consumption Figures

Because of the fact that at most Army facilities, individual buildings are not metered, studies have been performed to develop base line heating and cooling consumption characteristics for various classes of buildings. (Table 5) These figures should be used as a means of estimating consumption when actual data is unavailable.

All fuel and utility bills for an individual building, where available, should be used and recorded on an annual energy use and cost chart. (Figure 31)

9.1.2 Building Walk-Through Survey

A physical inspection of the building should be performed to determine type, performance characteristics, and possible improvements of the heating, cooling, ventilation, lighting, and domestic water systems.

The usage pattern of the building under construction should be determined as this factor has a great effect on energy consumption.

During the on-site inspection, the various opportunities for energy conservation discussed in Chapter 2 should be applied. Particular attention to system control and name plate information should be made.

The usage pattern of the building under construction should be determined as this factor has a great effect on energy consumption.

During the on-site inspection, the various opportunities for energy conservation discussed in Chapter 2 should be applied. Particular attention to system control and name plate information should be made.

9.1.3 Conservation Options Documentation

An analysis of potential savings per each conservation option should be made and recorded on a conservation option comparison schedule for each building. (Figure 32)

BASELINE ENERGY CONSUMPTION

Military Building Type	Heating Baseline Energy Consumption in Thousands of BTUs per Sq. Ft./yr.	Cooling Baseline Energy Consumption in Thousands of BTUs per Sq. Ft./yr.
E.M. Recreation Center	92	58
Theatre	193	39
Bowling Alley	36	107
N.C.O	92	123
Post Exchange	171	120
Commissary	19	24
E.M. Mess	88	139
Laundry[1]	117	0
Field House[1]	40	0
Chapel	122	36
Library	11	27
Office Building[2]	78	36
Laboratory[3]	83	66
Laboratory[4]	42	19
Barracks	28	22
B.O.Q.[5]	77	35
Machine Shop[1]	43	54
Warehouse[1]	56	41
Dental Clinic	76	43

1.) Energy savings must be treated for specific cases. Generalized figures unavailable.

2.) Energy savings based on a 132,217 square foot three story office building with five air handling units and numerous fan coil units. Two local boilers and a chiller provide heating and cooling. Brick on block construction completed 1952.

3.) Energy savings based on an 8,235 square foot single story lab building with three air handling units. Central plant heating and direct expansion cooling. Brick on block construction completed in 1942.

4.) Energy savings based on a 38,566 square foot three-story lab building with air handling units. Local gas and electric boilers provide heating. Direct expansion refrigeration provides cooling.

5.) Energy savings based on an 18,360 square foot two-story B.O.Q. building with one air handling unit. Local oil fired boiler and chiller provide heating and cooling.

Table 5

Energy Monitoring and Control Systems (Report Update 1978). U. S. Army Facilities Engineering Support Agency, Fort Belvoir, Virginia - Contract No. DAAK 70.77.C.0296.

Building Name:

ANNUAL ENERGY USE AND COST

Year	Electricity			Natural Gas		Fuel Oil		Coal		Other:	
	Maximum kW Demand	kWh Use	Cost ($)	MCF or Therm Usage	Cost ($)	# of Gallons Usage	Cost ($)	# of Tons Usage	Cost ($)	Quantity	Cost ($)

Present Cost of Energy Sources ($/Unit)

Energy Source	$/Unit	$/million Btu
Electricity	/kWh	
Natural Gas	/therm	
Fuel Oil	/gal.	
Coal	/ton	
Other:		

Year	Number of Btu's Used per year per square foot
Base Year 1973	
Present Year:	

Figure 31

Identifying Retrofit Projects for Buildings
Federal Energy Management Program
Federal Energy Administration

CONSERVATION OPTION COMPARISONS

Building	Option Number	Energy Source	Energy Savings (Units/Year)	Energy Cost Savings ($/Year)

Figure 32

9.1.4 Options Analysis

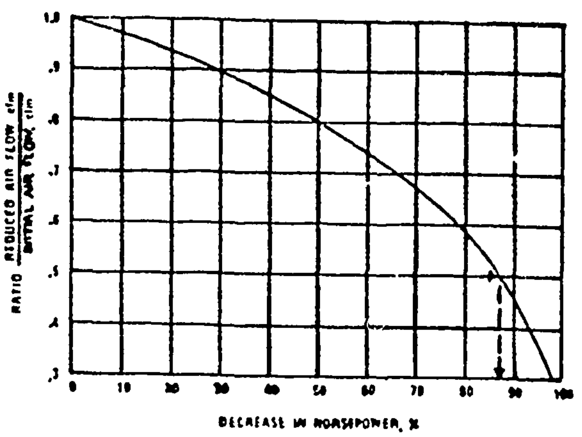
Pages 86 through 96 discuss the use of graphs and tables to assist in the analysis of particular energy conservation options.

Additional useful data is included on pages 95 through 103 as an aide in actual computation; of particular note is Table 6 on page 95.

This data is provided to aid the user in performing an Energy Conservation Investment Program (ECIP) analysis.

9.1.5 Reduce Air Volume

Air distribution systems often consume a large percentage of the total energy used in a building. By reducing the number of cubic feet per minute (CFM) delivered by the air distribution system through reduction in fan speed to the minimum level required by law, a great deal of this energy can be saved. The graph (Figure 33) shows the potential large reductions in power compared to the reductions in CFM. The vertical axis of the graph is the ratio of the reduced air flow by 50% reduced the instantaneous power use by 85.5%. This will result in lower electrical demand charges. This option should be applied to motors greater than 5 horse power. Apply this option to central air distribution systems only and not to perimeter fan coil units.



DECREASE IN HORSEPOWER ACCOMPANIED BY REDUCING FAN SPEED (Based on Law of Fan Performance)

Figure 33

Identifying Retrofit
Projects for Buildings
Federal Energy Management Program
Federal Energy Administration
Office of Energy Conservation and Environment

9.1.5.2 *Preliminary Data Collection

For this option the air flow must be measured for each fan system, If this cannot be done with in-house labor, then an HVAC contractor or consultant can do the measuring. at a cost of approximately $500/day. They will also know the legal minimums for CFM delivery. For most buildings it should not take more than a few days to accomplish the measuring and have the recommendations for lowering the air volumes.

9.1.5.3 *Energy Savings (KWH's/year)

Total decrease in horsepower x 0.75 KW/horsepower x number of operating hours/year of the fans (this calculation does not include energy savings in the heating and cooling equipment).

9.1.5.4 *Energy Cost Savings/year

Energy savings (KWH's/year) x $/KWH

9.1.5.5 *Capital Cost ($)

Once the amount of possible air reduction is know, it is a matter of slowing the fan down to the proper speed by changing the motor speed or changing the pulley. In any case, it should not be more than $1,000 for each unit unless it is extremely large. Estimates for this work can be obtained from an air-conditioning contractor.

9.1.5.6 Figures 34 and 35 are used to calculate energy consumption differences as a function of operating hours, fan volume, and static pressure for both forward and backward curved blades, respectively.

9.1.6 Install Economizer Cycle

9.1.6.1 When the outside air conditions (temperature and humidity) are similar to the conditions required for delivery from the air handling unit, it is desirable to have this air introduced into the building. If the outside air conditions do not closely match the inside requirements, it is desirable to introduce the smallest amounts required by law. An economizer cycle will allow the outside air and inside air to mix in the proper proportions so that the least amount of energy must be expended to get the air to the required conditions. The economizer cycle is provided by automatic dampers in the air ducts, controlled by sensors that monitor air temperature and humidity. This option is used for central air distribution systems and not for individual fan coil units located in the outside walls of some buildings. The economizer cycle can reduce the energy used for heating and cooling by 20%

9.1.6.1.1 *Preliminary Data Collection

Check the air intake system(s) for the building to see if any

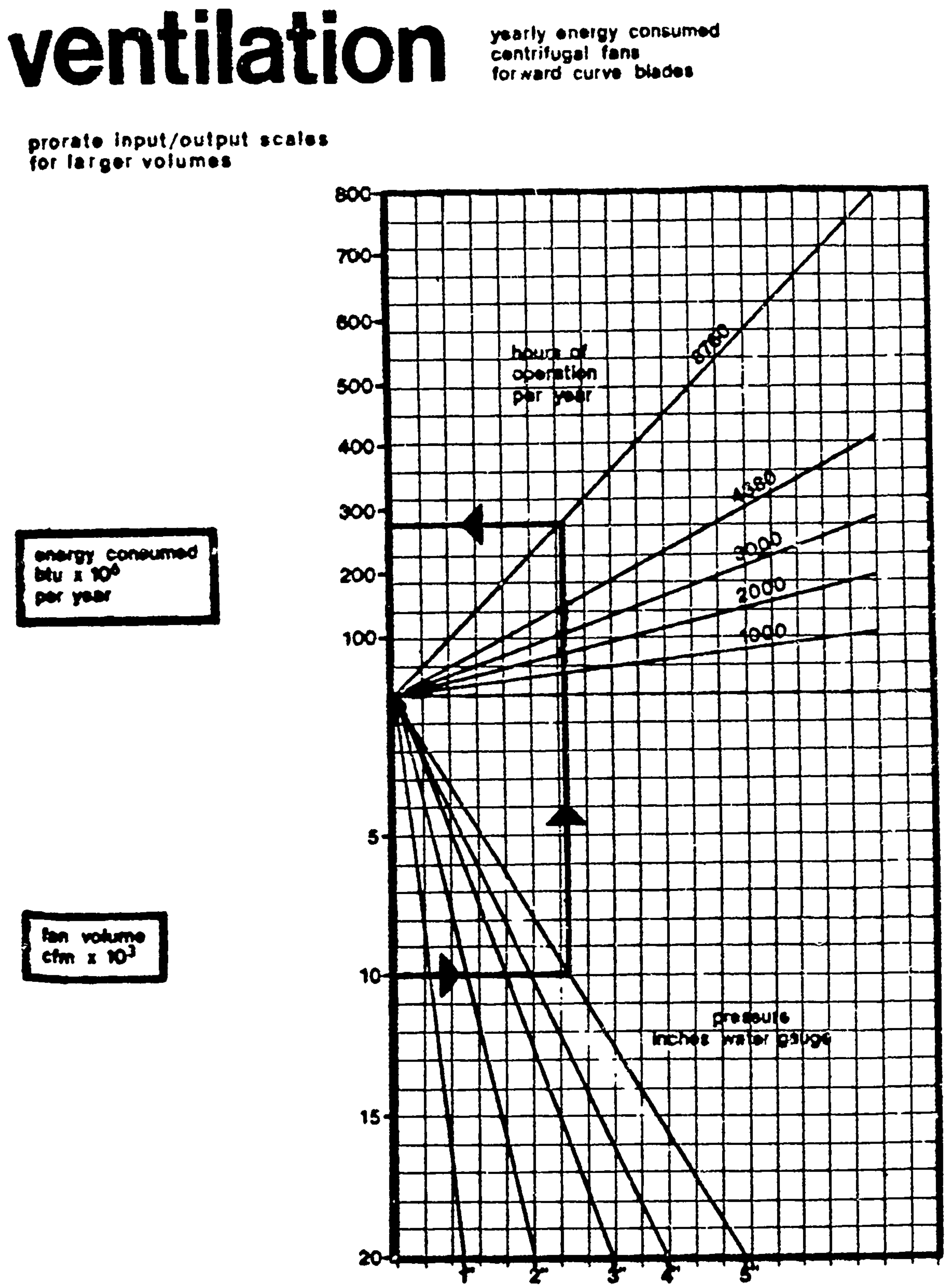


Figure 34
Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1 Federal Energy Administration 1975.

ventilation

yearly energy consumed
centrifugal fans
backward curve blades

prorate input/output scales
for larger volumes

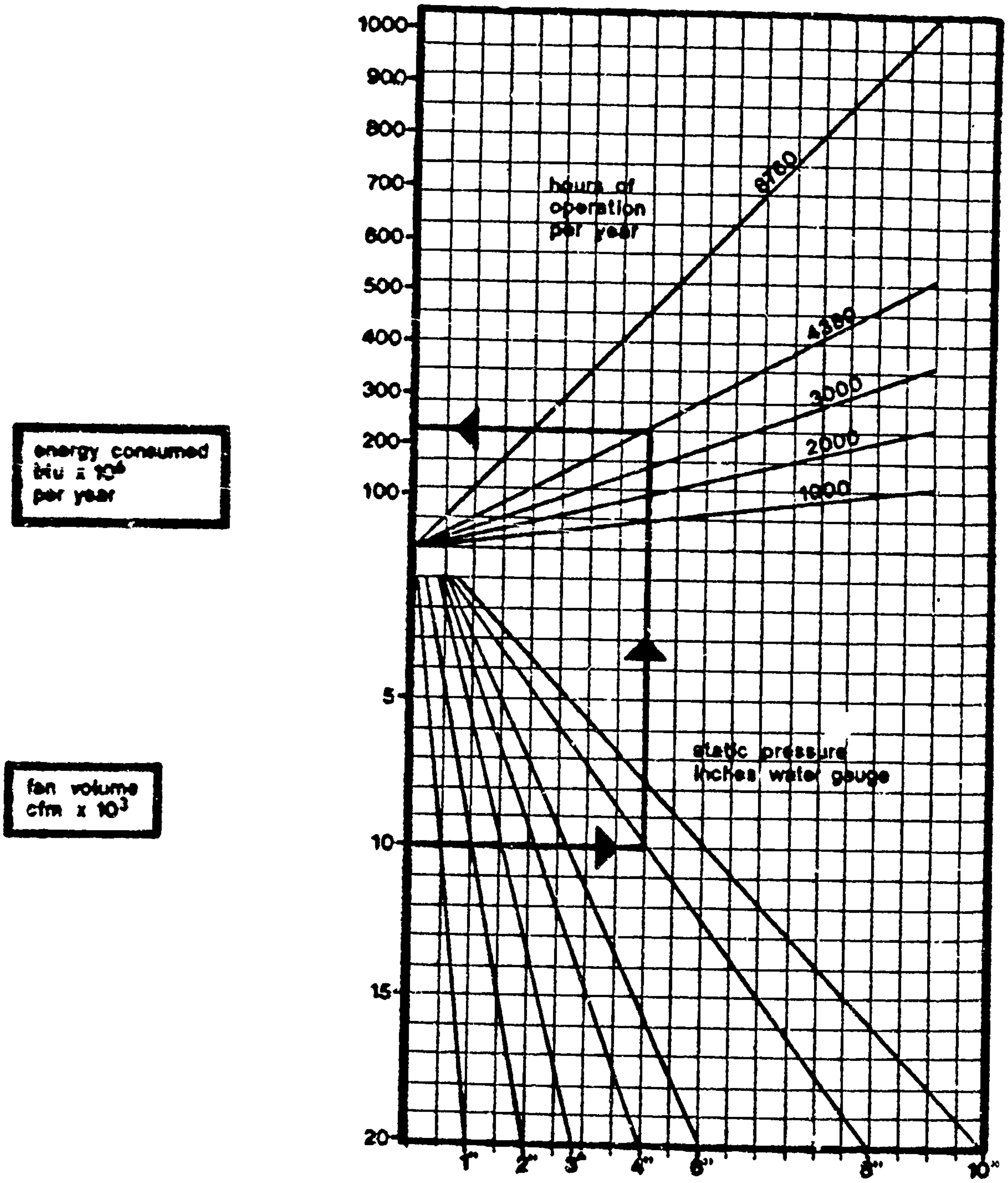


Figure 35

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1 Federal Energy Administration 1975.

dampers are installed. Also, look for return vents to see if air is returned to the heating or cooling system.

9.1.6.1.2 *Energy Savings (BTU's/year)

The approximate number of BTU's used for heating and cooling must be known to calculate an energy savings for this option. If the information is unavailable, a conservative estimate can be produced by the following computation:

0.5 x total annual BTU's for fuels used for all purposes at the total facility

$$\times \frac{\text{sq. ft. of floor area in the building being considered}}{\text{sq. ft. of floor area for facility for which fuel bills are available}}$$

= number of BTU's used for heating and cooling.

Multiply this actual or approximate number of BTU's by 0.2 (an estimation of energy savings when economizer cycles are installed).

9.1.6.1.3 *Energy Cost Savings/year

Amount of energy saved x $BTU for the fuel used

9.1.6.1.4 *Capital Cost ($)

The cost of an automatic system will vary greatly depending upon the system chosen. An HVAC (Heating, Ventilating, and Air-Conditioning) contractor or a company that supplies HVAC controls can provide cost information.

Figure 36 is a schematic of a typical economizer cycle system.

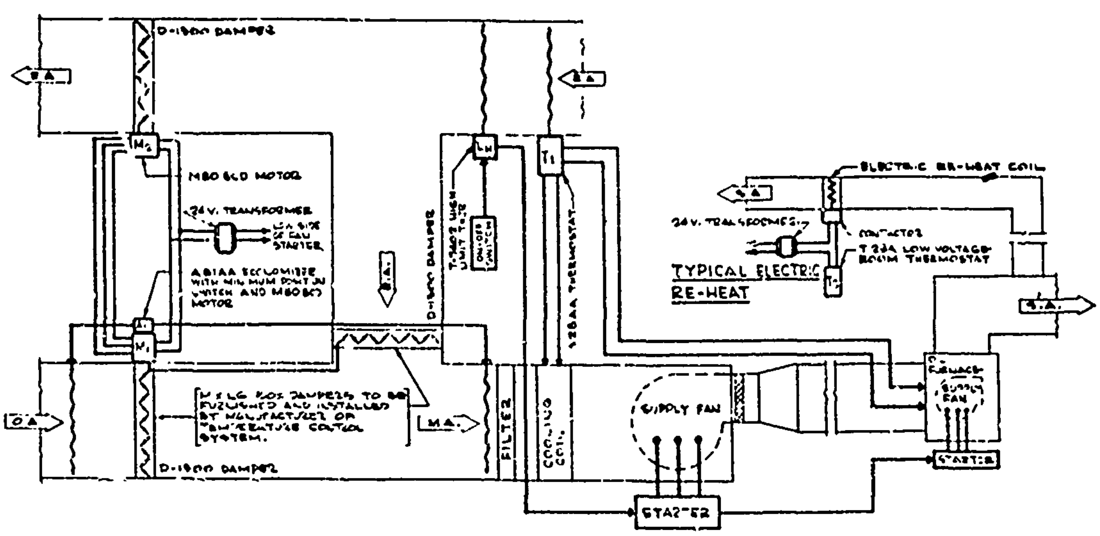
Notes:

1.) Controls indicated are as manufactured by Johnson Service Company or approved equal.

2.) Dampers shall be opposed blade, low leakage type, with leakage of less than 1/2% at 2000 FPM against 4" W.G. static.

3.) All dampers in this system to be supplied with the Temperature Control System.

4.) Provide interlocking relay which will act to energize the air conditioning unit supply fan only after the furnace supply fan has been started.



CONTROL DIAGRAM scale : none

Figure 36

9.1.7 Shut-Down Air Distribution System

There are two major types of air distribution systems; central duct systems and perimeter systems known as fan coil units. Fan coil units are found most frequently in office buildings and hospitals. If it is possible to shut down the central duct system during unoccupied times, large energy and cost reductions are possible. A control can be installed in cold climates (Zones 1 and 2) to turn the system back on should the temperature drop too greatly in the building during the winter. This would be a safety feature to prevent damage to the interior. However, most of the time the system can be shut down without adverse effects. The installation of time clocks can accomplish this with a minimum investment cost. Select time clocks with 7-day features that will allow for weekend shutdown, and with a continuous-running feature that will allow them to maintain the correct time during a power outage. If the time clocks have been installed, check whether or not they have a 7-day feature to shut down on weekends.

9.1.7.2 Fan coil units can also be controlled by a time clock. In order for these to be controlled, they must be on separate electrical circuits. If each fan coil unit requires a separate time clock, then this option is not feasible.

9.1.7.2.1 *Preliminary Data Collection

Check the building during unoccupied times to see what equipment is running. Count the number of units that could be shut down during these hours. Total the horsepower from the unit nameplate for all the motors that can be shut down. Fan coil units usually have small motors (1/8 to 1/4 hp). An electrician can find out if the fan coil units are on a separate circuits.

9.1.7.2.2 *Energy Savings (KWH's/year)

Number of hours per year that the system can be shut down x the total horsepower x 0.75 KW/hp.

9.1.7.2.3 Energy Cost Savings/year

Energy savings (KWH's/year) x $/KWH.

9.1.7.2.4 Capital Cost ($)

As an estimate, use $300 for each piece of equipment that requires the installation of a time clock. If the fan coil units are not already on separate circuits, the cost to isolate these units onto separate circuits should be estimated by a contractor and included in the capital cost of calculations.

9.1.8 Install Automatic Thermostats

9.1.8.1 The installation of 7-day thermostats can provide around-the-clock temperature control. This permits ventilating and heating air flow to be reduced or eliminated when any area of a building is unoccupied at nights or on weekends. As a rule, for heating, a reduction of each 1°F will decrease the energy use by 3%. If the option of shutting down the air distrubution system is possible, this option need not be considered. Also, if the existing thermostats are automatic, they can be identified by their multiple set-point dials.

9.1.8.1.1 *Preliminary Data Collection

Check the locations of existing thermostats and check to see if the areas they control can be set back at certain times.

9.1.8.1.2 *Energy Savings (BTU's/year)

To determine the energy saved/year, the BTU's used for heating per square foot must be estimated. Take the total number of BTU's used for heating and divide by the floor area of the building (see Figure 37). If the BTU's used for heating are unavailable use the following estimates on the particular zone location: (Figure 38)

Zone 1 - 180,000 BTU's/sq. ft./yr

Zone 2 - 140,000 BTU's/sq. ft./yr

Zone 3 - 100,000 BTU's/sq. ft./yr

Zone 4 - 60,000 BTU's/sq. ft./yr

Enter the graph at the appropriate present heating energy consumption and degree-day axis, intersect with the proper setback line, and follow the example line to determine the savings in BTU's per sq. ft. per year. Multiply this value by the gross sq. ft. floor area to give the total yearly savings in BTU's that can be expected for the entire building

The possible setbacks for most buildings will range between 5° and 15°F.

9.1.8.1.3 *Energy Cost Savings/year

Energy savings x $/BTU

9.1.8.1.4 *Capital Cost ($)

A quote for the thermostat installation should be obtained from a contractor. Normally, they will not exceed several hundred dollars per unit.

HEATING ENERGY SAVED BY NIGHT SETBACK

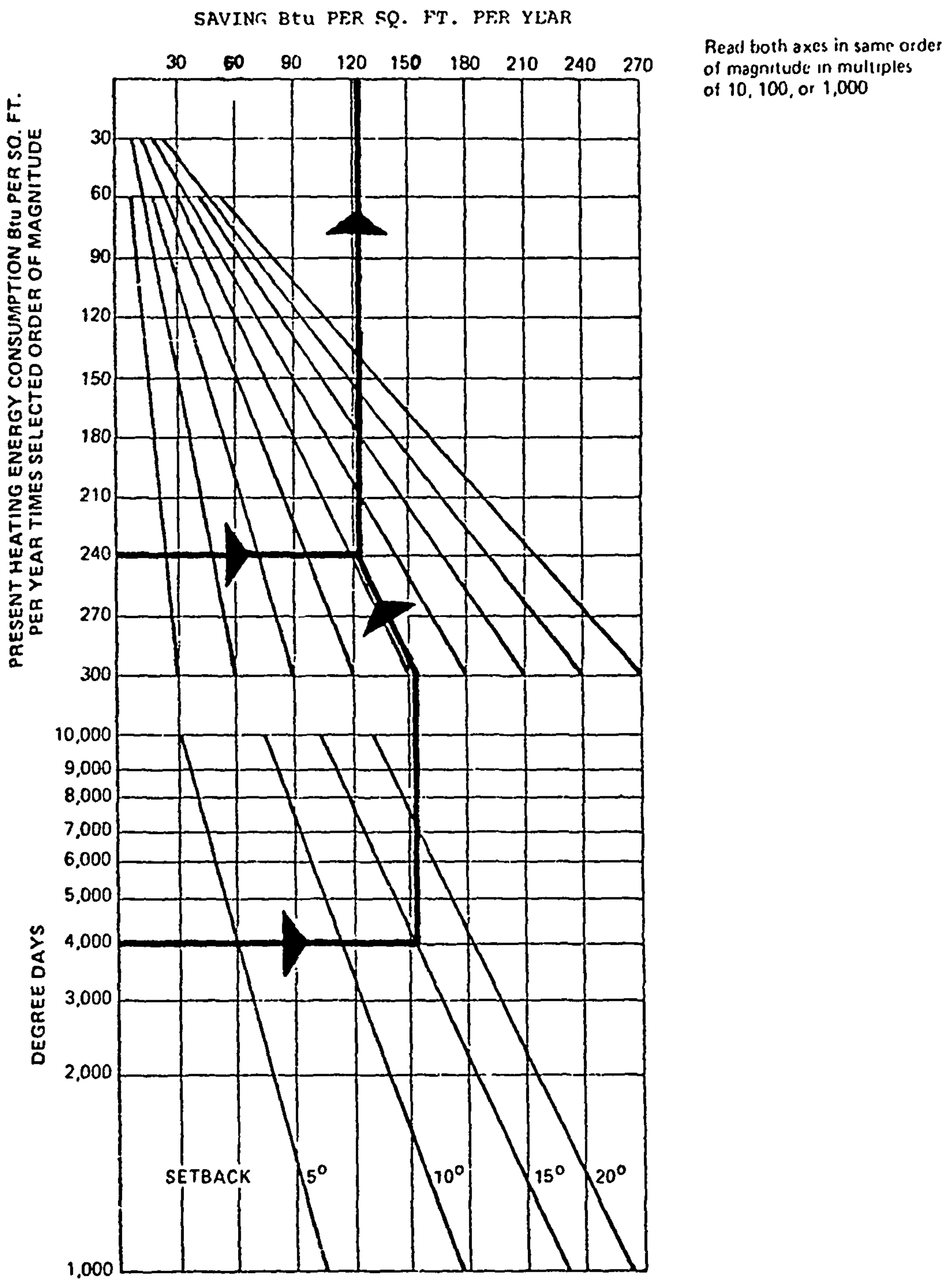


Figure 37

Guidelines for Saving Energy in Existing Buildings, ECM-1, FEA, 1975.

UNITED STATES — CLIMATE ZONES

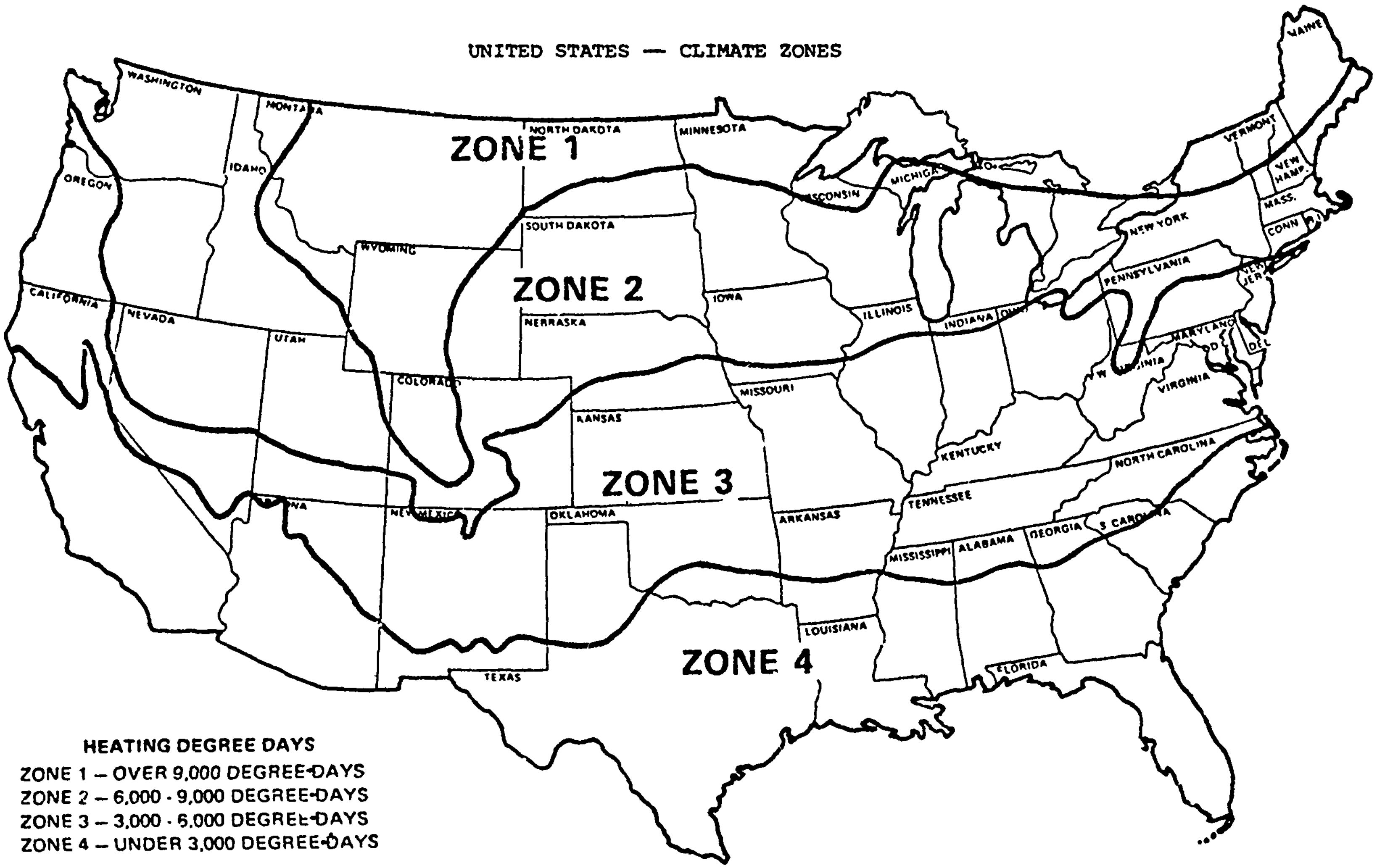


Figure 38

Identifying Retrofit Projects for Buildings, Federal Management Program, Federal Administration, Office of Energy Conservation and Environment.

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	138,700 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.

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.

Table 6

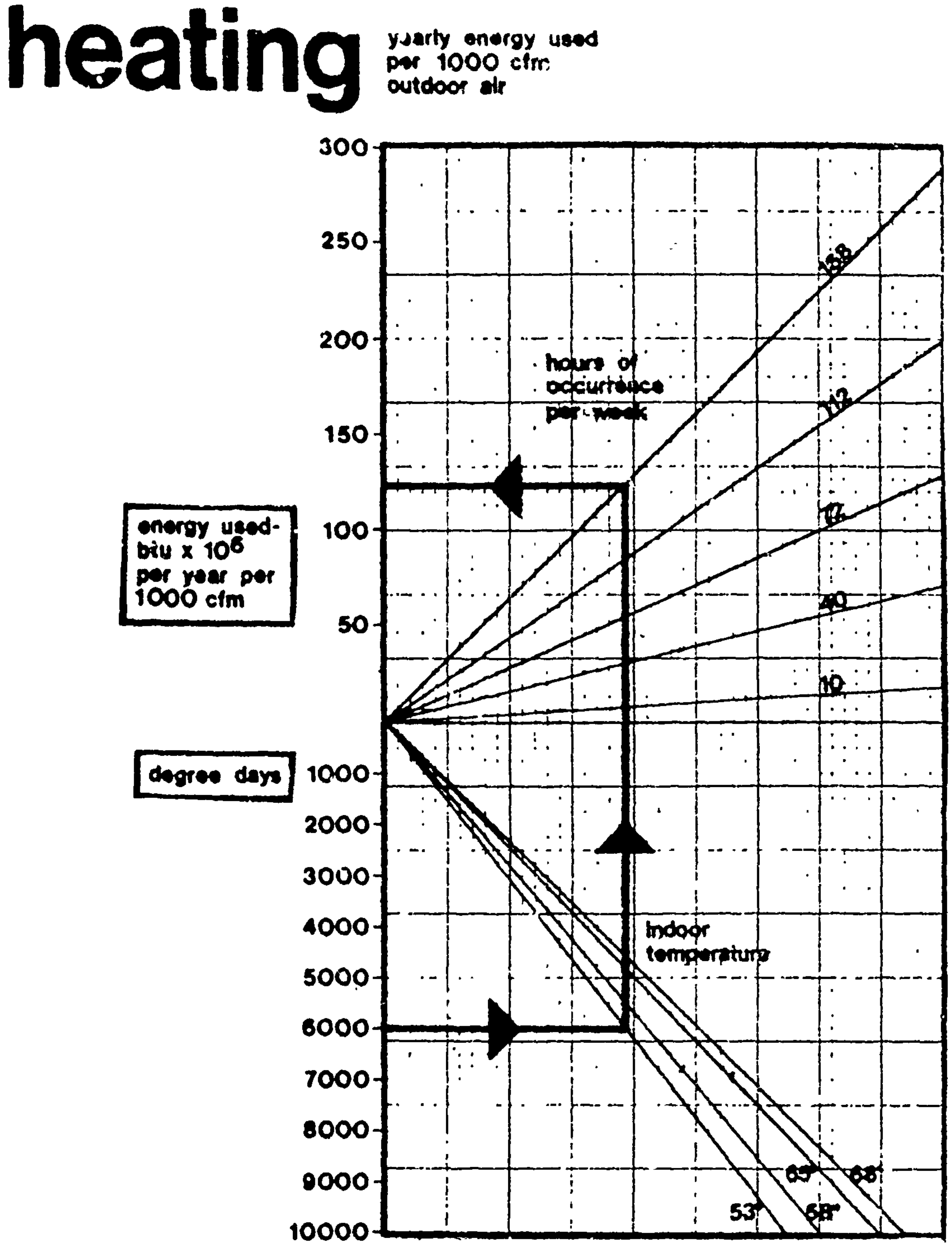


Figure 39

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975.

9.1.9 Heating - Energy Saved by Night Setback

9.1.9.1 Use Figure 39 to determine the actual savings in fuel for an average winter for any particular building. From Figure 38, the climate profile, select the degree days for the location and from Figure 31 find the number of BTU's per square foot per year now consumed for heating.

9.1.9.2 Enter the graph at the appropriate present heating energy consumption and degree day axes, intersect with the proper setback line, and follow the example line to determine the savings in BTU's per square foot per year. Multiply this value by the gross square foot floor area to give the total yearly savings in BTU's that can be expected for the entire building.

9.2 Cooling - Yearly Energy Used Per 1000 CFM to Maintain Various Humidity Conditions

Example: If the relative humidity in a building is allowed to rise from 50% to 70% the savings are calculated as follows:

-Enter Figure 40 at 8,000 WB degree hours. Follow the example line with the 50% RH line and the 40 hour line and read yearly energy used at 22.5 x 10^6 BTU/year/1,000 CFM.

-Reenter Figure 40 intersecting with the 70% RH line and read yearly energy used at 16 x 10^6 BTU's/year/1,000 CFM.

9.2.2 Savings:

The energy saved equals 22.5 - 16 or 6.5 x 10^6 BTU's/year/1,000 CFM. For 10,000 CFM, the total reductions in energy input are 7,618 KWH/year and 1,160 gallons of oil/year.

9.3 Heating - Yearly energy used per 1000 CFM Outdoor Air

9.3.1 Energy used per year is determined as follows:

-BTU/yr. = (1,000 CFM) (Degree Days/yr.) (24 Hr./day 1.08)*

Since degree days are base 65°F, the other temperatures in the lower section of the figure are directly proportioned to the 65°F line. The upper section proportions the hours of system operation with 168 hr./week being 100%. (Figure 41)

* 1.08 is a factor which incorporates specific heat, specific volume and time.

cooling

yearly energy used
per 1000 cfm to maintain
various humidity conditions

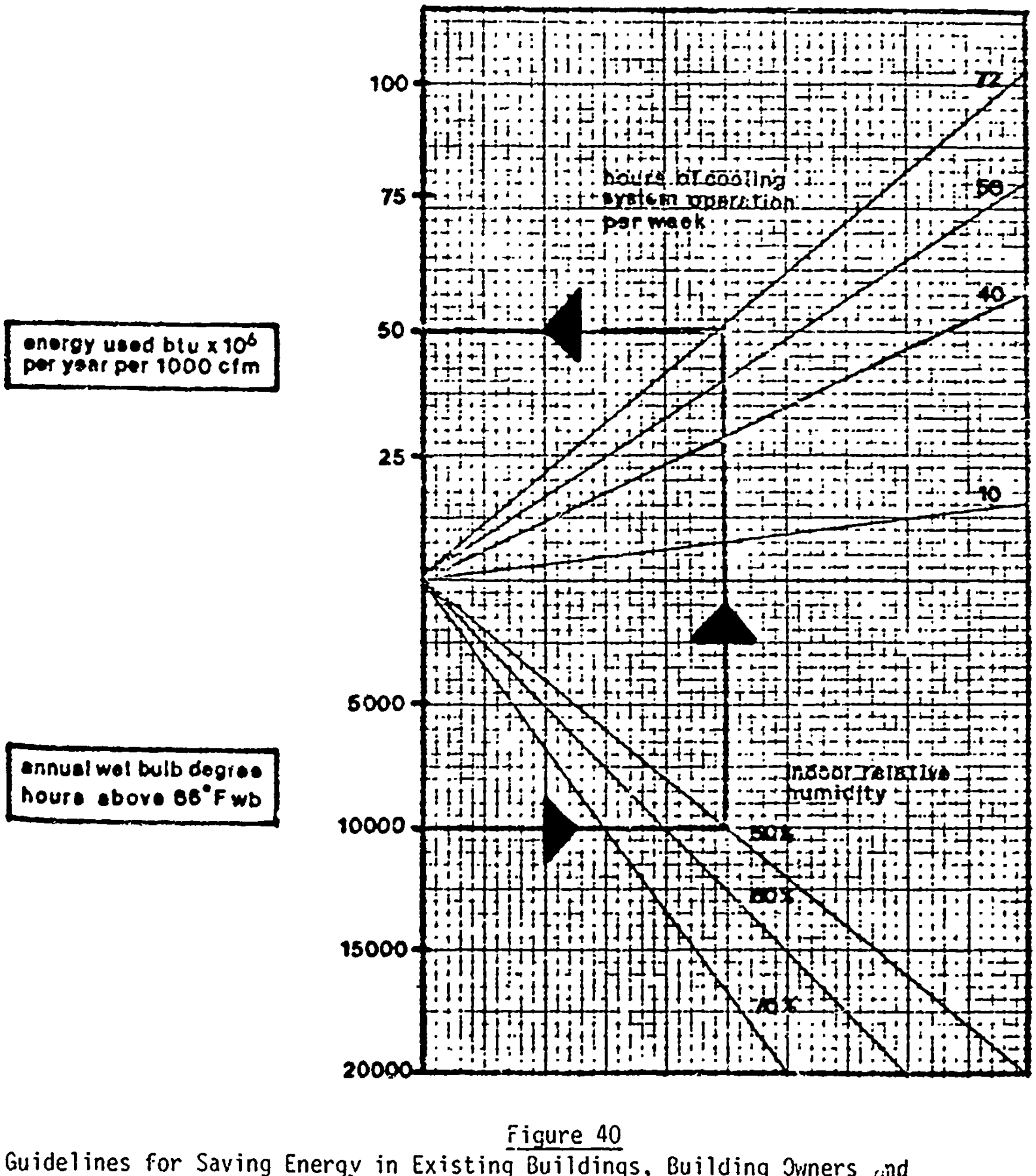


Figure 40

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

9.4 Heating - Yearly Energy Used per 1000 CFM to Maintain Various Humidity Conditions

9.4.1 Data from Figure 42

-WB degree hours based on 24 hours/day, October - April.
-Base indoor condition for figure is DB=68°F, WB =54°F, RH = 40%.
Energy used is a function of the WB degree hours below the base conditions, the RH maintained and the number of hours of controlled humidity. The figure expresses the energy used per 1,000 CFM of air conditioned or humidified.

9.4.2 An analysis of the total heat content of air in the range under consideration indicates an average total heat variation of 0.522 BTU/lb. for each degree WB change. Utilizing the specific heat of air, this can be further broken down to 0.24 BTU/lb. sensible heat and 0.282 BTU/lb. latent heat. One thousand CFM is equal to 4,286 lb./hr. and since we are concerned with latent heat only, each degree F WB hour is equal to 4,286 x 0.282 or 1,208 BTU. Further investigation of the relationship between WB temperature, DB temperature, and total heat shows that latent heat varies directly with RH at constant DB temperature. The lower section of the figure shows this proportional relationship around the base of 40% RH. The upper section proportions the hours of system operation with 168 hr./wk. being 100%.

9.5 Lighting - The Effect of Turning Off Unnecessary Lights on Power Consumption

-Example: Assume an office lighting system of 1,000 two-lamp fluorescent luminaires with f40 lamps. The full system uses 92 kilowatts. The upper graph (Figure 43) shows typical usage when lights are permitted to burn continuously from about 8:30 am to 7:30 pm. The lower graph shows efficient use of the same system leaving lights on only when used. Energy saving amounts to 262.5 kwh daily or 5,875 kwh per month.

9.6 Energy Conservation Investment Program Implementation

9.6.1 Purpose

The ECIP is a Military Construction (MILCON) funded program for retrofitting existing DoD facilities to make them more energy efficient while providing substantial savings in utility costs. It is an integral part of the DoD energy conservation goals for existing facilities as required by Executive Order 12003.

9.6.2 Criteria

(a) All projects must be cost effective, i.e. must amortize within their economic life.

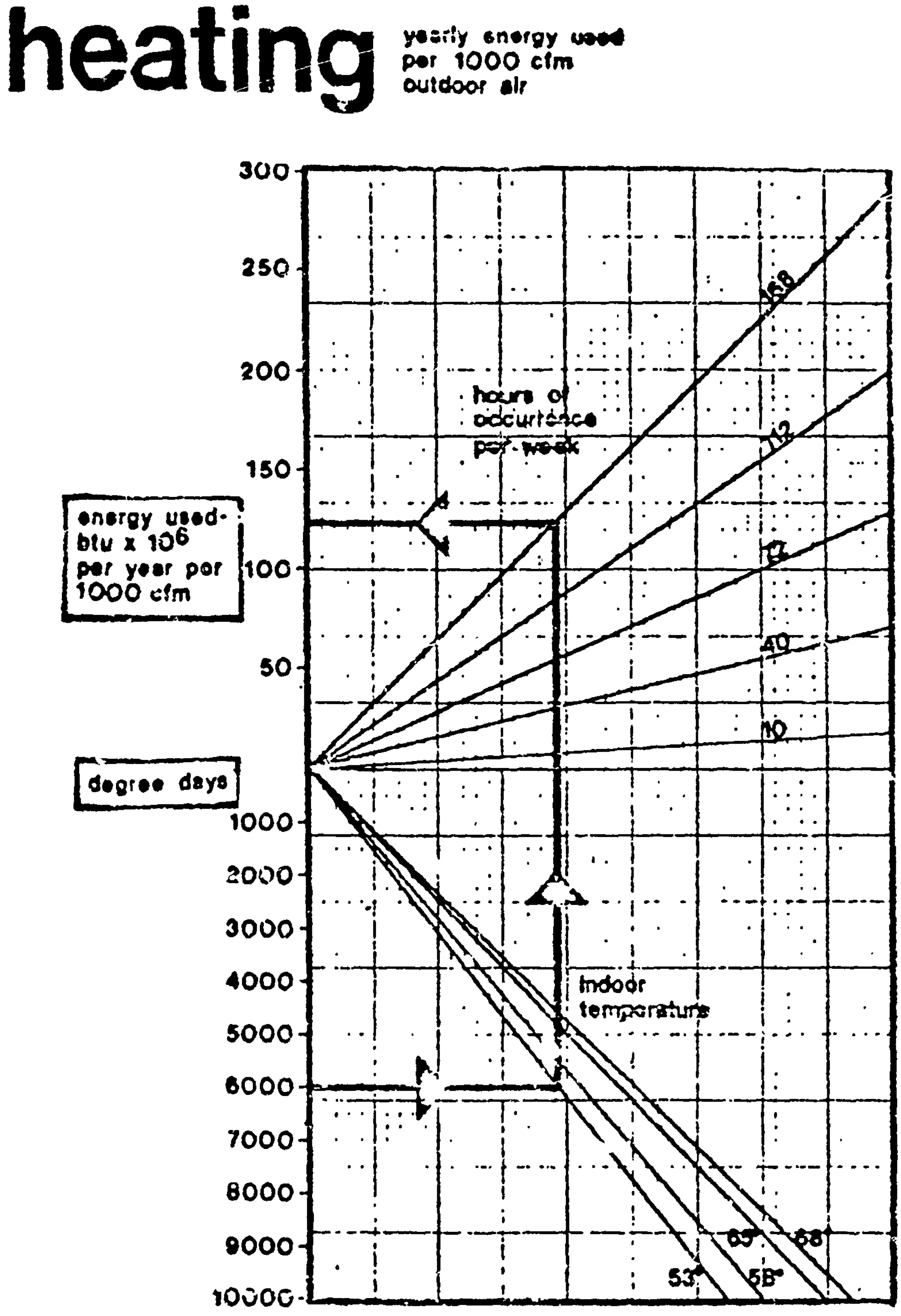


Figure 41

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, 1975

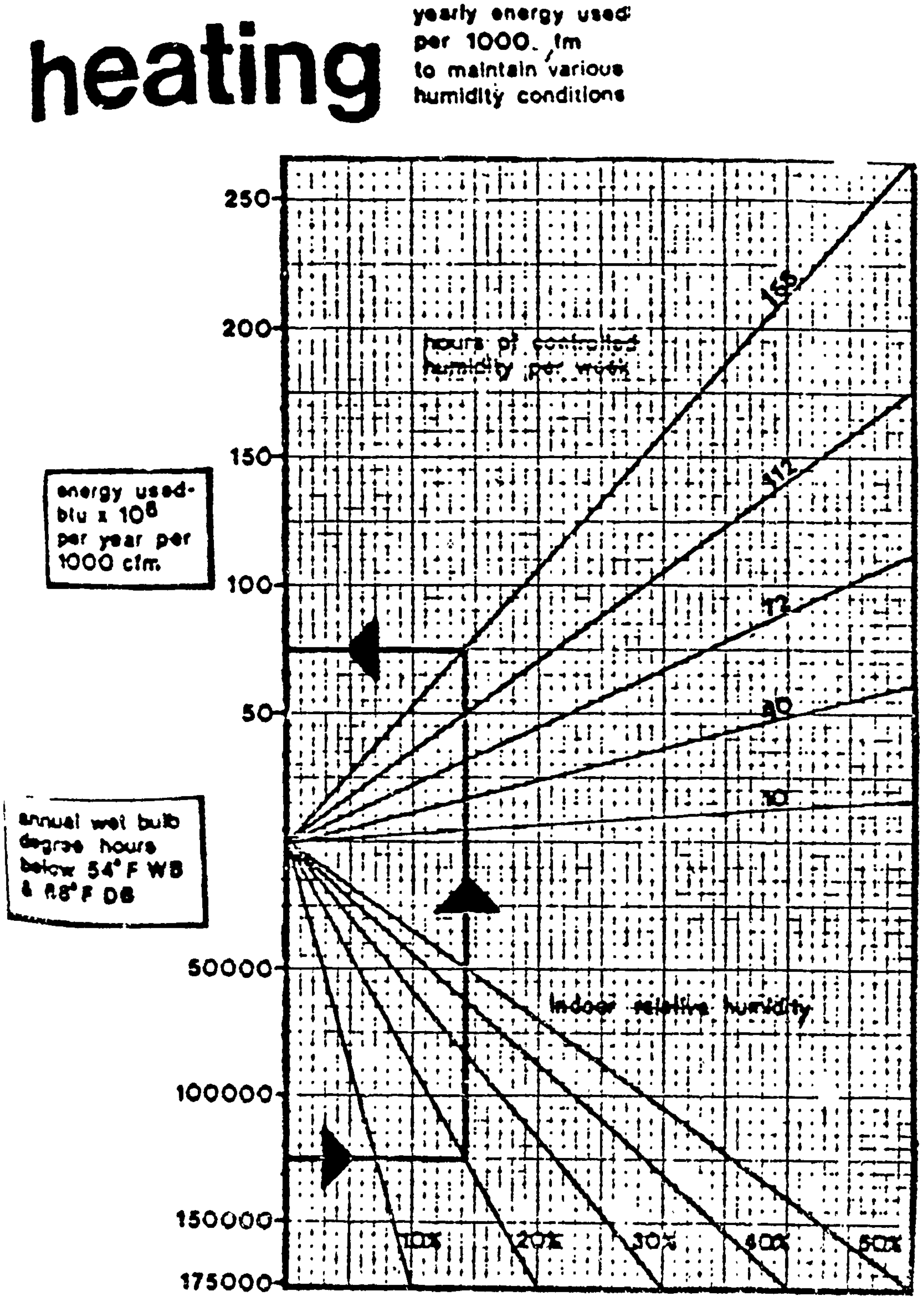
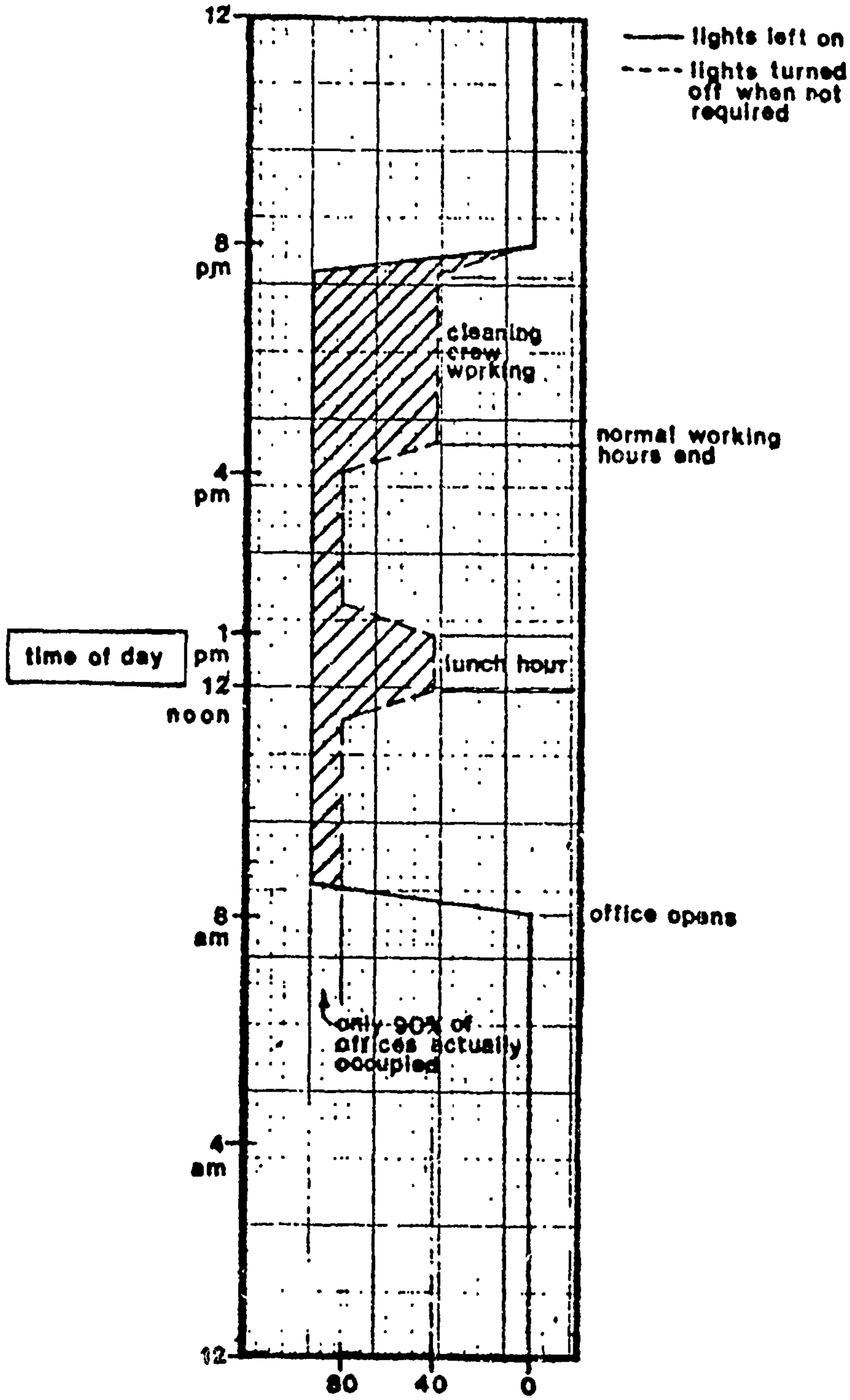


Figure 42

Guidelines for Saving Energy in Existing Buildings, Building Woners and Operators Manual, ECM-1, Federal Energy Administration, 1975



LIGHTING: the effect of turning off unnecessary lights on power consumption

Figure 43

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

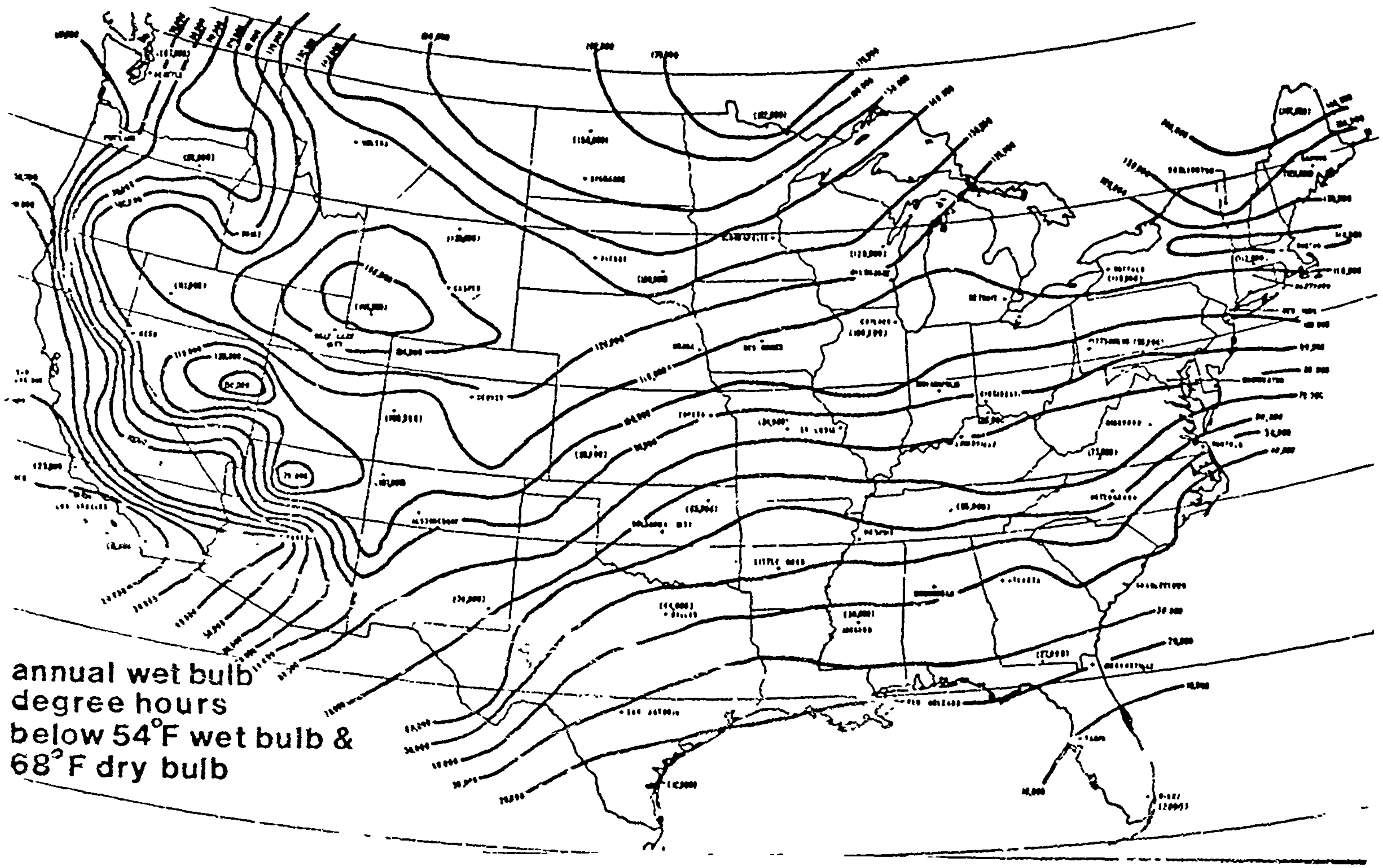


Figure 44

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

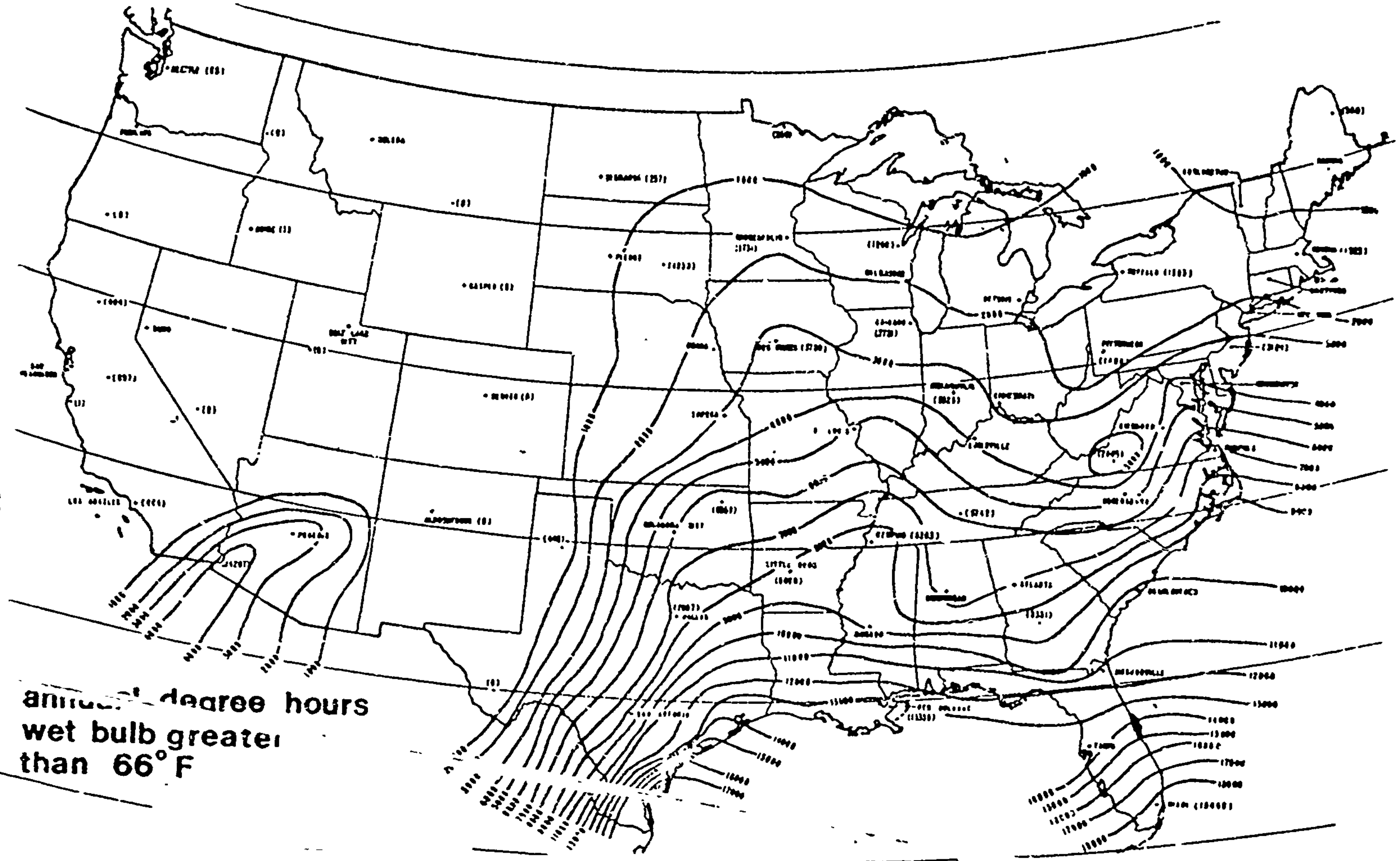


Figure 45

Guidelines for Saving Energy in Existing Buidlings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

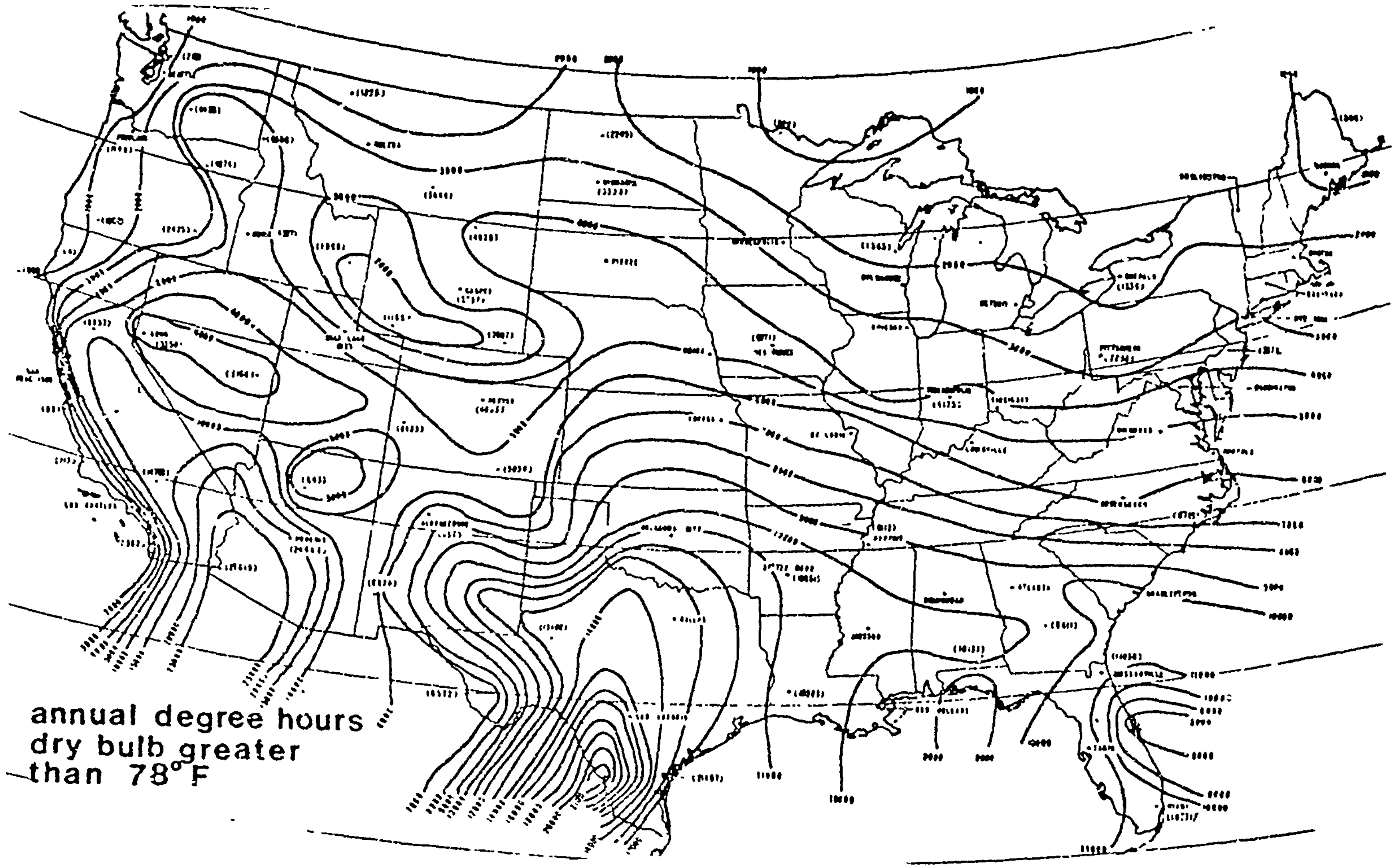


Figure 46

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

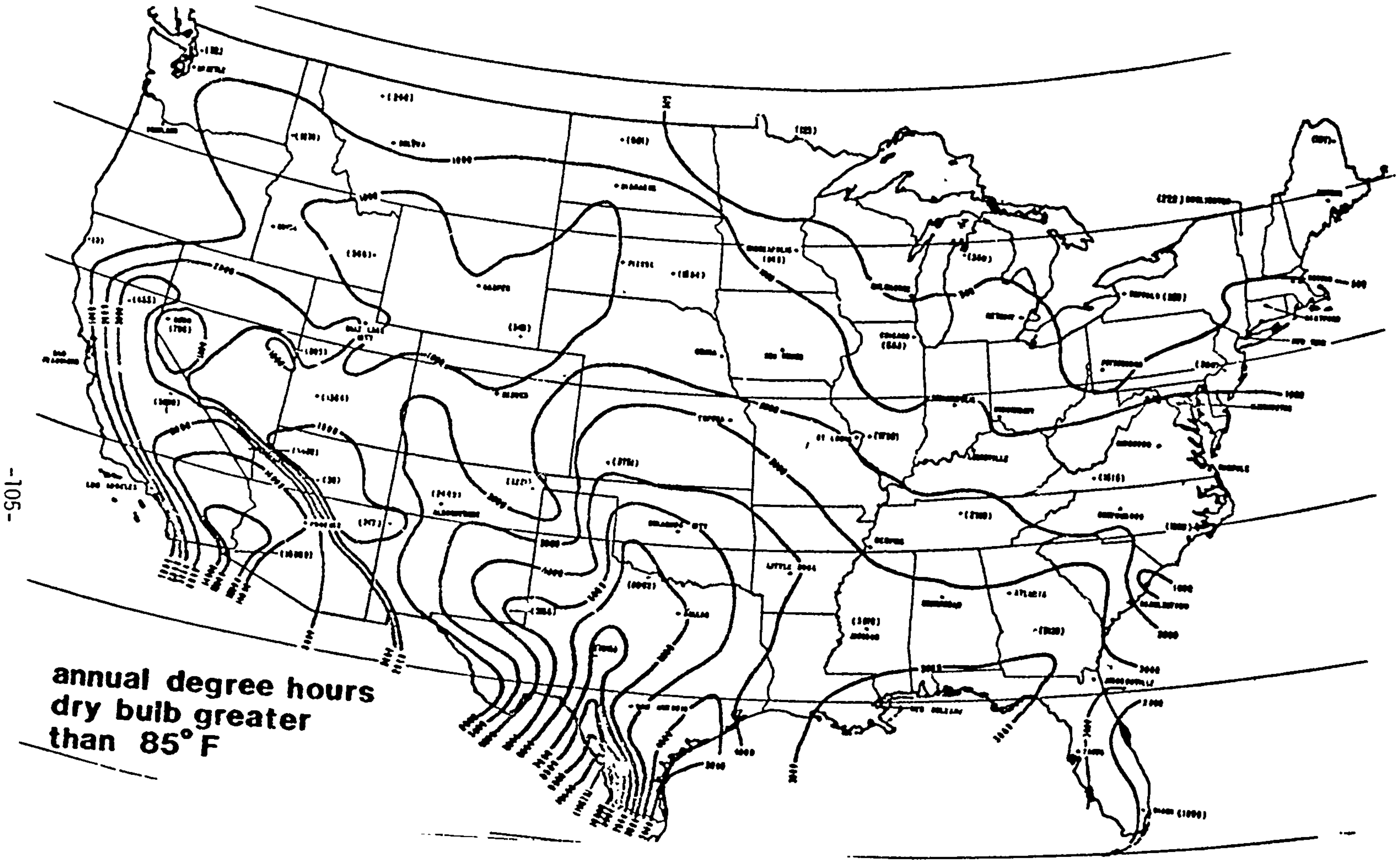


Figure 47

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1, Federal Energy Administration, 1975

SUGGESTED HEATING SEASON INDOOR TEMPERATURES

	A Dry Bulb °F. occupied hours maximum	B Dry Bulb °F unoccupied hours (set-back)
1. OFFICE BUILDINGS, RESIDENCIES, SCHOOLS		
Offices, school rooms residential spaces	65°	55°
Corridors	62°	52°
Dead Storage Closets	50°	50°
Cafeterias	65°	50°
Mechanical Equipment Rooms	55°	50°
Occupied Storage Areas, Gymnasiums	55°	50°
Auditoriums	65°	50°
Computer Rooms	65°	As required
Lobbies	65°	50°
Doctor Offices	65°	58°
Toilet Rooms	65°	55°
Garages	Do not heat	Do not heat
2. RETAIL STORES		
Department Stores	65°	55°
Supermarkets	60°	50°
Drug Stores	65°	55°
Meat Markets	60°	50°

Table 7

Guidelines for Saving Energy in Existing Buildings, Building Owners and Operators Manual, ECM-1 Federal Energy Administration 1975.

(b) All projects must produce an Energy to Cost ratio (E/C) of MBTU's of energy saved yearly per thousand dollars (K$) of current working estimate (CWE) investment equal to or greater than the minimum values for each year listed below, viz,

$$E/C = \frac{\text{MBTU saved/year}}{\text{K\$ CWE}}$$ the minimum values listed below

additionally, to meet the required reduction in facility energy use, major participants will attempt to achieve at least the average E/C ratios listed in column 3 below for each year's total program.

FY	Minimum E/C Ratio	Average E/C Ratio
79	23	58
80	22	49
81	20	41
82	19	36
83	18	32
84	17	30

Where the average amount is exceeded, a commensurate reduction in the next year's ratio may be taken, and conversely, where not achieved, the next year's ratio will be increased. Since these average goals were established by an extrapolation of the FY 76-78 ECIP program, they may not be attainable; however, they do provide a means of determining how closely the program, as executed, meets the plan in future years.

(c) To the extent that projects have been identified and analyzed in advance, projects will be prioritized in annual budget submissions based on the E/C ratio of energy saved yearly per investment cost. If two or more projects have about the same ratio, these projects will then be ranked on the basis of their benefit/cost ratios. The intent is to do those projects with the greatest energy savings per investment cost in the earlier years of the ECIP, and recognizes that not all projects will have been identified in the nearer time frame. If a project has a very high benefit/cost ratio but the E/C ratio is too low to qualify for that year's budget submission, it may be included provided it meets the minimum E/C requirements of paragraph 2b and the average of all projects will still meet the average E/C ratio.

9.6.3 <u>OCONUS Projects</u>

OCONUS projects may be included only if they effect savings of U.S. energy sources in FY 79 abd FY 80. Therefore, at least 20% of the fuel to be saved must be derived from U.S. refined products. For FY 81 and beyond, this restriction is removed, but OCONUS projects are limited to 19% of the Agency Program for each year.

9.6.4 Natural Gas Policy

DoD policy required replacing natural gas heating systems with coal or fuel oil systems where possible except for individual boilers or warm-air furnaces less than five Mega Btu per hour output. Current natural gas heating systems, except as noted above, will be evaluated for energy cost saving on the basis of equivalent fuel oil or coal prices and fuel oil or coal escalation.

9.6.5 Synergism

When two or more projects are programmed for the same structure, care must be used in computation on energy savings to insure that projected energy savings are not duplicative.

9.6.6 Economic Analysis

Executive Order 12003 and legislation require an economic analysis based on present worth techniques to determine a benefit/cost ratio for each project. The benefit/cost ratio must exceed 1.0 for each project submitted. The form on page 111 presents a method for determining that benefit/cost ratio applicable to most ECIP projects which will satisfy this requirement. Where a project requires a more detailed approach, use DoD 7041.3 Economic Analysis and program Evaluation for Resource Management, as a guide. Table 8 provides maximum allowable economic life for the various categories of investments.

Table 9 provides fuel escalation rates which may be used in determining benefits when better data derived from local conditions and experience is not available. Tables 10, 11, 12 and 13 provides single amount and cumulative uniform series discount factors for a discount rate of 10% and differential escalation rates of 0, 5, 7, and 8%. Non-energy connected monetary savings are also appropriate for inclusion in the economic analysis.

9.6.7 Energy Conversions

(a) for purposes of calculating energy savings, the following conversion factors will be used:

Purchased Electric Power	11,600 BTU/KWH
Distillate Fuel Oil	138,700 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

(b) Purchased energy is defined as being generated off-site. For special cases where electric power or steam is pruchased 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 1,200 BTU/lb.

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

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

(e) When the average fuel oil heating value is accurately known though laboratory testing for a specific military installation, that value may be used in lieu of the amount specified in paragraph 7a.

(f) 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 standby requirement.

9.6.8 Budget and POM Sumbissions

9.6.8.1 DD Forms 1391 will include information as to cost and energy savings. Budget submissions to OSI will continue to be submitted in omnibus packages for each Defense Component and Family Housing and will be identified as energy conservation investment projects at various locations. DD BQ1 will be accompanied by a line item identification, description, location, CWE, benefit/cost ratio, payback period to one decimal point, annual savings in dollars, and MBTU's saved per $1,000 of CWE as a minimum regardless of project cost. Projects will be re-evaluated prior to award and the cost variation authority under Section 603 of the current Military Construction Authorization Act applies. POM submissions need only identify total CWE by year in the following categories; Active Service, Family Housing, National Guard and Reserve.

9.6.8.1.1 Budget and POM Submissions (General)

The form on page 111 may be used for determining Benefit/Cost ratios for most projects. In using this form, the cost of construction is the escalated price of construction at the end of the year programmed for funding. Similarly the incremental maintenance and repair costs and the cost of energy/fuels are the costs escalated as above for these services and material. Design costs are escalated to the project year minus one. For a very few projects this simplified method may not be applicable.

ECIP ECONOMIC ANALYSIS SUMMARY (EXAMPLE)

Location: Fort Anywhere FY 81
Project: Install local energy control devices in 15 buildings

Economic Life: 15 Yrs. Date Prepared Oct 79 Prepared by name

COSTS

1. Non-recurring Initial Capital Costs:		
a. CWE	$ 317,080	
b. Design	$ 15,975	
c. Salvage value of existing equipment	$ -5,966	
d. Total		$327,089
BENEFITS		
2. Recurring Benefit/Cost Differential Other Than Energy:		
a. Annual Labor Decrease(+)/Increase(-)	$ -0- /Yr.	
b. Annual Material Decrease(+)/Increase(-)	$ -0- /Yr.	
c. Other Annual Decrease(+)/Increase(-)	$-12,698 /Yr.	
d. Total Costs	$-12,698 /Yr.	
e. 10% Discount Factor	$ 7.98	
f. Discounted Recurring Cost (d x e)		$-101,330
3. Recurring Energy Benefit/Costs:		
a. Type of Fuel: Electricity		
(1) Annual Energy Decrease(+)/Increase(-)	$ 3,828 MBTU	
(2) Cost per MBTU	$ 11.14/ MBTU	
(3) Annual $ Decrease/Increase ((1) x (2))	$ 42,644/ Yr.	
(4) Differential Escalation Rate (7%) Factor	$ 12,278	
(5) Discounted $ Decrease/Increase (3) x (4)	$523,583	
b. Type of Fuel: Demand Change Reduction		
(1) Annual Energy Decrease(+)/Increase(-)	Negligible MBTU	
(2) Cost per MBTU	$ --------- MBTU	
(3) Annual $ Decrease/Increase ((1) x (2))	$ 1,825 /Yr.	
(4) Differential Escalation Rate (7%) Factor	$ 12,273	
(5) Discounted $ Decrease/Increase ((3) x (4))	$ 22,398	
c. Type of Fuel: Distillate Fuel Oil		
(1) Annual Energy Decrease(+)/Increase(-)	1,408 MBTU	
(2) Cost per MBTU	$ 10.73 /MBTU	
(3) Annual $ Decrease/Increase ((1) x (2))	$ 15,108 /Yr.	
(4) Differential Escalation Rate (8%) Factor	13,112	
(5) Discounted $ Decrease/Increase ((3) x (4))	$198,096	
d. Type of Fuel: Natural Gas		
(1) Annual Energy Decrease(+)/Increase(-)	9,775 MBTU	
(2) Cost per MBTU	$ 6.87 /MBTU	
(3) Annual $ Decrease/Increase ((1) x (2))	$ 67,154 /Yr.	
(4) Differential Escalation Rate (8%) Factor	13,112	
(5) Discounted $ Decrease/Increase ((3) x (4))	$880,523	
e. Discounted Energy Benefits (3a(5)+3b(5)+3c(5)+3d(5))	$1,624,600	
4. Total Benefits (Sum 2f + 3e)	$1,523,270	
5. Discounted Benefit/Cost Ratio (Line 4÷ Line 1d)	4.6	
6. Total Annual Energy Savings (3a(1)+3b(1)+3c(1)+3d(1))	1,501 MBTU	
7. E/C Ratio (Line 6÷ Line 1a/1000)	47	
8. Annual $ Savings (2d+3a(3)+3b(3)+3c(3)+3d(3)	$114,003	
9. Pay-Back Period ((Line 1a- Salvage) ÷ Line 8)	2.7 Yr.	

9.6.8.1.2 An example of when this method is not applicable is when a one-time benefit or cost occurs in years after construction is complete, e.g. a major component replacement is required during the economic life of the RETROFIT project or when a one-time benefit is claimed during the economic life of the project such as salvage value at the end of the economic life. If this occurs, or at the option of the analyst, use DoD 7041.3 as a guide for the economic analysis. In practice this will seldom occur because the major component replacement is usually annualized as part of the recurring maintenance and repair costs and credit for salvage value at the end of economic life is usually disregarded because of an unknown market at 12 to 25 years in the future. An example benefit/cost computation for a typical ECIP project is as follows:

9.6.8.2 (a) Title Block

Economic life is the period of time over which the benefits to be gained from a project may reasonably be expected to accrue. As such, the economic life may differ from its physical and technological life. It may further be limited by military or political considerations. The analyst determined economic life based on his knowledge of the factors above; this often times is a difficult task. Therefore, the economic lives in Table 8 may be used in the absence of better data. Ordinarily, these values will not be exceeded.

9.6.8.3 (b) Line 1

Non-recurring capital costs include Construction, and Supervision, Inspection, and Overhead (SIOH) which together make up initial one-time costs such as the negative cost for the residual value of existing equipment removed during construction. They do not include energy audit costs, preliminary design, nor analysis costs since those efforts are required by Executive Order, legislation or DoD requirements whether or not the project is approved and thus become sunk costs. This is the basis for initial justification of a project.

After final design is complete, the benefit/cost ratio is usually recomputed based on final design figures. At that time frame design is also considered a sunk cost since funds are expended which cannot be retrieved whether or not the project is advertised. Non-recurring capital costs are escalated at the rates indicated in Table 9, Annual Escalation Rates.

9.6.8.4 (c) Line 2

The recurring Benefit/Cost differentials other than energy are primarily incremental maintenance and repair costs. Savings are a positive value and costs are a negative value. Attach a work sheet showing computation of this incremental cost if applicable. Escalate only to end of program year of construction.

The discount present worth factor automatically provides for general inflation during the economic life. Ordinarily no differential escalation factor is applicable to these costs. Thus, use the discount from Table 10 for a 10% discount rate with a zero differential escalation rate for line 2e.

(d) By definition ECIP projects must save energy, thus there will always be an overall energy cost decrement. However, the overall decrement may include increases in use of one fuel and decreases in the use of another. Benefits (decreases) are positive and additional costs (increases) are negative. Attach computations to show calculations of energy savings. Use conversion factors discussed in paragraph 7 (Energy Conversions) of this section and on page 95 to convert to MBTU's.

Cost per MBTU is the present unit cost of the energy form escalated to the end of the program year by the short term rates in Table 9. The differential escalation rate is defined as the expected annual escalation resulting from factors unique to the fuel market over and above those experienced by the economy as a whole. The long term differential escalation rates in Table 9 may be used or, where local conditions and experience indicate more valid differential escalation rates, these should be used with the project file indicating the basis for the projection. Differential escalation rate discount factors are taken from Table 9.

9.6.8.5 (e) Line 5

To be eligible as an ECIP project, the project must have a Benefit/Cost ratio of greater than one.

9.6.9 Economic Analysis Computations

9.6.9.1.1 Non-recurring Initial Capital Costs

Construction	$250,000
SIOH @ 5%	12,500
Unescalated CWE	$262,500

CWE (Escalated to end FY 81) = $262,500 x 1.07 x 1.065 x 1.06
= $317,080
(Enter $317,080 on Line 1a.)

Unescalated Design @ 6% of Construction = .06 x 250,000
= 15,000

Design (Escalated to end FY 80) = 15,000 x 1.065 = 15,975
(Enter $15,975 on line 1b.)

Salvage value of removed equipment (Controls, etc.) = $5,000

Salvage value (Escalated to end (FY 81) = -5,000 x 1.064 x 1.062 x 1.056 = $5,966
(Enter -$5,966 on Line 1c.)

9.6.9.2 Recurring Benefit (+)/Cost(-) Differential Other Than Energy

Labor (Unescalated) = 0
(Enter 0 on Line 2a.)

Materials (Unescalated) = 0
(Enter 0 on Line 2b.)

On the Annual decrease or increase (Training & Maintenance) = 1,000 + $317,080 x 1.03 = $10,512.

Other (Escalated to end FY 81) = $10,512 x 1,07 x 1.065 x 1.06 = -$12,698
(Enter -$12,698 on Line w.c.)

9.6.9.3 Recurring Energy Benefits (+)/Cost(-)

9.6.9.3.1 Electric

$$\text{MBTU Saved} = \frac{\text{KWH Saved} \times \text{BTU/KWH}}{\text{BTU/MBTU}} = \frac{330,000 \times 11,600}{10^6} =$$

= 3,828 MBTU/yr
(Enter 3,828 MBTU/yr on Line 3a. (1)).

$$\text{\$Cost/MBTU} = \frac{\text{KWH Saved} \times \text{\$KWH}}{\text{MBTU saved}} = \frac{330,000 \times .08}{3,828} = \$7.33/\text{MBTU}$$

$Cost/MBTU (Escalated to end FY 81) = $7.33 x 1.16 x 1.16 x 1.13 = 11.14/MBTU
(Enter $11.14 on Line 3a. (2)).

9.6.9.3.2 Demand Charge Reduction

MBTU Saved: Negligible

Annual Dollar Saving = $1,200/yr

Annual Dollar Saving (Escalated to end FY 81) = 1,200 x 1.16 x 1.16 x 1.13 = $1,825
(Enter $1,825/yr on Line 3b. (3)).

9.6.9.3.3 Distillate Fuel Oil

$$\text{MBTU Saved} = \frac{\text{Gal. Oil Saved} \times \text{BTU/Gal.}}{\text{MBTU Saved}} = \frac{10,150 \times 138,700}{1,408} =$$

=$7.06/MBTU

$Cost/MBTU (Escalated to end FY 31) = $7.06 x 1.16 x 1.16 x 1.13 = $10.73
(Enter $10.73/MBTU on Line 3c. (2)).

9.6.9.3.4 Natural Gas

$$\text{MBTU Saved} = \frac{\text{Cu. Ft. Saved x BTU/Cu. Ft.}}{\text{BTU/MBTU}} = \frac{9{,}480 \times 1031}{10^6}$$

= 9,775 MBTU/yr
(Enter 9,775 MBTU/yr on Line 3d. (1)).

$$\text{\$Cost/MBTU} = \frac{\text{Cu. Ft. Saved x \$/Cu. Ft.}}{\text{MBTU Saved}} = \frac{9{,}480{,}900 \times .0047}{9775}$$

= $4.56/MBTU

$Cost/MBTU (Escalated to end FY 81) = $4.56 x 1.15 x 1.15 x 1.14 = $6.87/MBTU
(Enter $6,87/MBTU on Line 3d. (2)).

9.6.9.4 Computation of Energy/Cost Ratio

9.6.9.4.1 CWE (Line 1s., ECIP Econ. Analysis Summary $317,080

MBTU Saved/Year (Line 6, ECIP Econ. Analysis Summary) $15,011 MBTU/yr

$$\text{Then E/C Ratio is: } \frac{\text{MBTU Saved/yr.}}{\text{CWE/1000}} = \frac{15{,}011}{317} = 47.35$$

Since the Benefit/Cost Ratio in Line 5 is greater than 1.0 and since the E/C ratio computed above is greater than 20.0, the project is an eligible candidate for ECIP funding.

9.7 Project Categories

9.7.1 Project Categories are the major elements of a building system or facility in which energy conservation of energy efficiency actions can be classified.

9.7.1.1. -Heating, Ventilating and Air Conditioning (HVAC) - building systems and equipment which create and maintain specified interior temperature and air change conditions.

9.7.1.2. -Lighting Systems
building or facility systems that provide artificial light and use more efficient lighting sources, selective controls, timers, and photo-electric cells.

MAXIMUM ECONOMIC LIFE

Maximum economic lives are established for the categories of investments listed below even though the equipment or facilities involved may have a physical or technological life of a greater number of years. In the absence of better data, these figures may be used in computing benefit/cost ratios.

Buildings (Insulation, Solar Screens, Heat Recovery Systems, Solar Installations, etc.)	25 years
Utilities, Plants, and Utility Distribution Systems	25 years
Energy Monitoring and Control Systems	15 years
Controls (Thermostats, Limit Switches, Automatic Ignition Devices, Clocks, Photo Cells, Flow Controls, Temperature Sensors, etc., when these constitute the major end item at the project.)	
Refrigeration Compressors	15 years

Table 8

ANNUAL ESCALATION RATES

1. Use the escalation rates given below for extending costs and benefits to the program year in paragraphs 1 and 2 of ECIP Economic Analysis Summary, i.e. to the end of the fiscal year in which construction is programmed if better local data are not available.

	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83
Design, Construction, SIOH	8.0%	7.0%	6.5%	6.0%	6,0%	6.0%
Main., & Rpr. O&M, Salvage	7.1%	6.4%	6.2%	5.6%	5.6%	5.6%
Coal	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Fuel Oil	16.0%	16.0%	16.0%	14.0%	14.0%	14.0%
Natural Gas & LPG	15.0%	15.0%	15.0%	14.0%	14.0%	14.0%
Electricity and Demand Charge Reduction	16.0%	16.0%	16.0%	13.0%	13.0%	13.0%

2. Long Term Differential Escalation Rates

Use the differential escalation rates given below for computing the present worth of recurring annual costs/benefits in paragraphs 4 and 5 of ECIP Economic Analysis Summary, if better local data are not available.

Maint. & Rpr., O & M	0.0%
Coal	5.0%
Fuel Oil	8.0%
Natural Gas & LPG	8.0%
Electricity and Demand Charges Reduction	7.0%

Table 9

Differential Inflation Rte = 0%*

Discount Rate = 10%

Economic Life Years	One Time Cost Factors	Recurring Benefits/Costs Factors
1	0.954	0.954
2	0.867	1.821
3	0.788	2.609
4	0.717	3.326
5	0.652	3.977
6	0.592	4.570
7	0.538	5.108
8	0.489	5.597
9	0.445	6.042
10	0.405	6.447
11	0.368	6.815
12	0.334	7.149
13	0.304	7.453
14	0.27[illegible]	7.729
15	0.25[illegible]	7.980
16	0.2[illegible]8	8.209
17	0.208	8.416
18	0.[illegible]89	8.605
19	0.172	8.777
20	0.156	8.933
21	0.142	9.074
22	0.129	9.203
23	0.117	9.320
24	0.107	9.427
25	0.097	9.524

*These factors are to be applied to cost elements which are anticipated to escalate at the same rate as the general price level.

Table 10

Differential Inflation Rate = 5%*

Discount Rate = 10%

Economic Life Years	One Time Cost Factors	Recurring Benefits/Costs Factors
1	0.977	0.977
2	0.933	1.910
3	0.890	2.800
4	0.850	3.650
5	0.811	4.461
6	0.774	5.235
7	0.739	5.974
8	0.706	6.680
9	0.673	7.353
10	0.643	7.996
11	0.614	8.610
12	0.586	9.196
13	0.559	9.755
14	0.534	10.288
15	0.509	10.798
16	0.486	11.284
17	0.464	11.748
18	0.443	12.191
19	0.423	12.614
20	0.404	13.018
21	0.385	13.403
22	0.368	13.771
23	0.351	14.122
24	0.335	14.458
25	0.320	14.777

*These factors are to be applied to cost elements which are anticipated to escalate at the same rate as the general price level.

Table 11

Differential Inflation Rte = 7%*

Discount Rate = 10%

Economic Life Years	One Time Cost Factors	Recurring Benefits/Costs Factors
1	0.986	0.986
2	0.959	1.946
3	0.933	2.879
4	0.908	3.780
5	0.883	4.670
6	0.859	5.529
7	0.836	6.364
8	0.813	7.177
9	0.791	7.968
10	0.769	8.737
11	0.748	9.485
12	0.728	10.212
13	0.708	10.920
14	0.688	11.608
15	0.670	12.278
16	0.651	12.930
17	0.634	13.563
18	0.616	14.180
19	0.600	14.779
20	0.583	15.363
21	0.567	15.930
22	0.522	16.482
23	0.537	17.019
24	0.522	17.541
25	0.508	18.049

*These factors are to be applied to cost elements which are anticipated to escalate at the same rate as the general price level.

Table 12

Differential Inflation Rte = 8%*

Discount Rate = 10%

Economic Life Years	One Time Cost Factors	Recurring Benefits/Costs Factors
1	0.991	0.991
2	0.973	1.964
3	0.955	2.919
4	0.938	3.857
5	0.921	4.777
6	0.904	5.681
7	0.888	6.569
8	0.871	7.440
9	0.856	8.296
10	0.840	9.136
11	0.825	9.961
12	0.810	10.770
13	0.795	11.565
14	0.781	12.346
15	0.766	13.112
16	0.752	13.865
17	0.739	14.603
18	0.725	15.329
19	0.712	16.041
20	0.699	16.740
21	0.687	17.427
22	0.674	18.101
23	0.662	18.762
24	0.650	19.412
25	0.638	20.050

*These factors are to be applied to cost elements which are anticipated to escalate at the same rate as the general price level.

Table 13

9.7.1.3. -<u>Electrical Energy Systems</u>
equipment such as solid state rectifiers to replace inefficient motor-generator set, and capacitors for power factor correction to reduce the consumption of electrical energy.

9.7.1.4. -<u>Energy Monitoring and Control Systems (EMCS)</u>
specialized equipment designed to monitor interior and exterior environmental conditions and automatically control building operations or alert personnel to the need for such adjustments. to achieve specified objectives. Known by several other terms, such as utility control systems, such equipment may also provide safety and security monitoring.

9.7.1.5. -<u>Weatherization</u>
building design features aimed at achieving maximum energy efficiency for given climatic conditions, including insulation storm windows and doors, caulking, weather-stripping, etc.

9.7.1.6. -<u>Solar</u>
building systems or equipment using the energy of sunlight at the building site to provide part or all of the services necessary, e.g., domestic hot water, space heating and/or cooling.

9.7.1.7. -<u>Steam and Condensate Systems</u>
facility central steam distribution system modifications such as installation of condensate return lines, installation of cross connect lines and looped systems to permit plant shutdown and sectionalized line shutdown during low load summer months as well as modernization and rehabilitation of existing lines including improved insulation and steam flow metering and controls.

9.7.1.8 -<u>Boiler Plant Modifications</u>
facility central steam plant modifications such as improved boiler controls, economizers, and the installation of small boilers to facilitate the closing of long deteriorated sections of the central distribution system.

9.7.1.9 -<u>Energy Recovery System</u>
systems to recover heat or primary energy from processes to be reused to satisfy additional energy requirements.

9.7.2 -<u>Miscellaneous</u>
any system or equipment not classifiable in one of the other categories.

GLOSSARY

Absorption Chiller	A refrigeration machine using heat as the power input to generate chilled water.
Absorption Coefficient	The fraction of the total radiant energy incident on a surface that is absorbed by the surface.
Absorptivity	The physical characteristic of a substance describing its ability to absorb radiation.
Accumulator	A register and associated circuitry in the arithmetic logic units of a CPU in which logic arithmetic functions are performed.
Activated Carbon	A form of carbon capable of absorbing odors and vapors.
Address	A coded representation of the origin or destination of a data message.
Air Changes	Expression of ventilation rate in terms of room or building volume. Usually air changes/hour.
Alarm	A warning signal indicating that a condition is not normal and not within operating limits.
Algorithm	A rule of procedure for solving a recurrent mathematical problem.
Alphanumeric	Alphabetic characters, numeral or specific symbols.
Analog	A continuously varying signal value (temperature, current, pressure, etc.)
Architecture	The general organization and structure of hardware and/or software.

ASCII

American Standard for Coded Information Interchange - Coded character set to be used for the general interchange of information among information processing systems, communication systems, and associated equipment.

Assembler

Utility program which translates assembly language into the machine-executable object code.

Assembly Language

A low level language used to program and manage the operations of a computer.

Asynchronous

Each event or the performance of each operation starts as a result of a signal generated by the completion of the previous event or operation, or by the availability of the parts of the computer required for the next event or operation.

Back Plane

A device for connecting individual cards or printed circuit boards used in a microcomputer.

Ballast

A device used in starting circuit for fluorescent and other types of lamps.

BASIC

A programming language noted for its ease of learning.

Baud

Modulation rate used to describe the speed of serial data transfers of information bits (bits/sec).

BCD

Binary Coded Decimal - A method for representing non-integer numbers in a computer.

BIT

A data element which is either a "zero" or a "one". A contraction for the words "Binary Digit".

Blow Down

The discharge of water from a boiler or cooling tower pump that contains a high proporation of total dissolved solids.

BTU — British Thermal Unit - A heat unit equal to the amount of heat required to raise one pound of water one degree Farenheit.

Building Envelope — All external surfaces which are subject to climatic impact; e.g. walls, windows, roof, floor, etc.

Building Load — Heating load is the rate of heat loss from the building at steady state conditions when the indoor and outdoor temperatures are at their selected design levels (design criteria). The heating load always includes infiltration and may include ventilation loss and heat gain credits for lights and people.

Cooling load is the rate of heat gain to the building at a steady state condition when indoor and outdoor temperatures are at their selected design levels, solar gain is at its maximum for the building configuration and orientation, and heat gains due to infiltration, ventilation, lights, and people are present.

Cable — Insulated electrical conductor (s) covered with a protective sheath.

Card — A hardware component of an electronic system, generally consisting of a single printed circuit, designed for ease of removal and replacement.

Cavity Ratio — Number indicating room cavity proportions which is calculated using length, width, and height.

CCU — Central Control Unit - A process control digital computer that includes a CPU, central memory and an I/O bus.

Central Memory — Core or semiconductor memory communicating directly with a central processing unit.

Centrifugal Fan — Device for propelling air by centrifugal action. Forward curved fans have blades which are sloped forward relative to direction of rotation. Backward curved fans have blades which are sloped backward relative to direction of rotation. Backward curved fans are generally more efficient at high pressures than forward curved fans.

CLM/CLMI — Command Line Mnemonic/Interpreter- A set of fixed, simplified English commands designed to assist operators unfamiliar with computer technology in operating the EMCS.

Coax — Coaxial Cable - Specially constructed cable having specific electrical characteristics for transmission of data information, generally consisting of a central insulated wire and a surrounding conductive sheath which is protected by an insulative cover.

COBOL — A programming language noted for its application to business and data handling problems.

Coefficient of Utilization — Ratio of lumens on work plane to lumens emitted by the lamps.

Cold Deck — A cold air chamber forming part of a ventilating unit.

Compiler/Interpreter — System software used for converting high level language instructions into the machine language of the computer.

Computer — A device capable of solving problems by accepting data, performing prescribed operations with the data and producing results of such operations.

Condensate — Water obtained by changing the state of water vapor (i.e. steam or moisture in air) from a gas to a liquid, usually by cooling.

Condenser — A heat exchanger which removes latent heat from a vapor changing it to its liquid state. (In refrigeration chillers, the component which rejects heat.)

Conductance, Thermal — A measure of the thermal conducting properties of a single material expressed in units of BTU inch thickness per (sq. ft.) (hour) (degree F temperature difference).

Controller — A device that measures changes in controlled variables and sends an appropriate signal to adjust such system functions.

Controls — Devices which govern the performance of a system.

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

Cooling Tower — Device that cools water directly by evaporation.

CPU — Central Processing Unit - The portion of a computer (CCU) that performs the interpretation and execution of instructions.

CRT — Cathode Ray Tube - An electron beam tube in which the beam is focused to a small cross section on a luminescent screen and varied in position and intensity to produce a visible pattern.

Cycle Time — In microseconds/word for central memory is the minimum time interval that must elapse between the starts of two successive accesses to any one storage location.

Data — A collection of facts, numeric and/or alphabetical characters which are processed for or generated by a computer.

Damper — A device used to vary the volume of air passing through an air outlet, inlet, or duct.

Degree Day — The difference between the median temperature of any day and 65^{o}F when the median temperature is less than 65^{o}F.

Degree Hour — The difference between the median temperature for any hour and selected datum.

Demand Factor — The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or part of the system under consideration.

Dessicant — A substance possessing the ability to absorb moisture.

Digital — A non-continuous signal. In radix 2 the signal is either on or off (zero or one).

Direct Expansion — Generic term used to describe refrigeration systems where the cooling effect is obtained directly from the refrigerant (e.g. refrigerant is evaporated directly in a cooling coil in the air stream).

Disability Glare — Spurious light from any source, which impairs a viewer's ability to discern a given object.

Disk Memory — A bulk storage, random access device for storing digitally coded information, usually constructed of a thin rotating circular plate containing a magnetizable coating, a read/write head, and associated control equipment.

Distributed Processing System — A system of multiple, programmable processors each performing its own task, yet working together as a complete system to solve still other tasks.

Discrete — Data describing the status of a two-position control point, either "zero" or "one".

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

Double Bundle Condenser — Condenser (usually in refrigeration machine) that contains two separate tube bundles allowing the option of either rejecting heat to the cooling tower or to another building system requiring heat input.

Dry Bulb Temperature — The measure of the sensible temperature of air.

Duplex — Simultaneous two-way independent transmission.

Economizer Cycle — A method of operating a ventilation system to reduce refrigeration load. Whenever the outdoor air conditions are more favorable (lower heat content) than return air conditions, outdoor air quantity is increased.

Efficacy of Fixtures — Ratio of usable light to energy input for a lighting fixture or system (lumens/watt).

EIA — A component or coupling device that conforms to Electronic Industries Association standards, which specializes in the electrical and functional characteristics of interface equipment.

EMCS — Energy Monitoring and Control System - A system designed and operated to control the energy-consuming equipment of an institution or installation of buildings. The system includes control points, signal transmission, computer components, and attendant software.

<u>Energy Requirement</u>

The total yearly energy used by a building to maintain the selected inside design conditions under the dynamic impact of a typical year's climate. It includes raw fossil fuel consumed in the building and all electricity used for lighting and power.

<u>Enthalpy</u>

For the purpose of air conditioning enthalpy is the total heat content of air above a datum usually in units of BTU/lb. It is the sum of sensible and latent heat and ignores internal energy changes due to pressure change.

<u>Equivalent Sphere Illumination</u>

That illumination which would fall upon a task covered by an imaginary transparent hemisphere which passes light of the same intensity through each unit area.

<u>Evaporator</u>

A heat exchanger which adds latent heat to a liquid changing it to a gaseous state (in a refrigeration system it is the component which absorbs heat).

<u>Executive Program</u>

The main system program designed to establish priorities and to process and control other programs. Sometimes called the Operating System.

<u>FID</u>

Field Interface Device - A small, intelligent hardware device containing software which implements the distributed processing aspects of operation with the central computer as well as maintaining effective control of field control loops in the absence of higher level influence. Operating constants are changed by downline loading from the CCC as well as from within the FID.

Foot-candle	Energy of light at a distance of one foot from a standard (sperm oil) candle.
FORTRAN	FORmula TRANslator - A high-level, English like programming language used for technical applications.
Function Keys	Keys which when depressed, are interpreted by the computer as a specific command.
Hardware	The EMCS equipment such as CPU, peripherals, etc. as opposed to software.
Hardware Vectored Interrupts	Hardware feature which allows the CPU to directly determine the identity of an interruptive device and to automatically transfer control to a program which will service the interrupt.
Heat, Latent	The quantity of heat required to effect a change in state.
Heat, Sensible	Heat that results in a temperature change but no change in state.
Heat, Specific	Ratio of the amount of heat required to raise a unit mass of material one degree to that required to raise a unit mass of water one degree.
Heat Gain	As applied to HVAC calculations, it is that amount of heat gained by a space from all sources, including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that must be removed from a space to maintain indoor comfort conditions.
Heat Loss	The sum cooling effect of the building structure when the outdoor temperature is lower than the desired indoor temperature. It represents the amount of heat that must be provided to a space to maintain indoor comfort conditions.

Heat Pump — A refrigeration machine possessing the capability of reversing the flow so that its output can be either heating or cooling. When used for heating, it extracts heat from a low temperature source to the point where it can be used.

Heat Transmission Coefficient — Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures.

Hot Deck — A hot air chamber forming part of a ventilating unit.

Humidity, Relative — A measurement indicating moisture content of air.

Indication — A visual display of status.

Infiltration — The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows, etc. (Usually undesirable).

Insolation — The amount of solar radiation on a given plane. Expressed in Langleys or BTU/ft.^{2}.

Integer — A number having no fractional part.

Interface — A common boundary between computer systems or parts of a single system.

Interrupt — An externally generated signal requesting that current operations be suspended to perform more important tasks.

I/O — Input/Output.

I/O Bus — The connection through which data is transmitted and received from peripheral devices wishing to interact with the processor.

K — (as in 64K words) 1K = 1024.

Life Cycle Cost	The cost of the equipment over its entire life including operating and maintenance costs.
Line Printer	A printer device that can simultaneously print several character graphics as a permanent record.
Load Leveling	Deferment of certain loads to limit electrical power demand to a predetermined level.
Load Profile	Time distribution of building heating, cooling, and electrical load.
LSI	Large Scale Integration - Manufacturing technology in micro-miniaturization in which many thousands of components are packaged into a small "chip".
Lumen	Unit of luminous flux.
Luminaire	Light fixture designed to produce a specific effect.
Machine Language	A programming language which allows computer control and management at the "zero" and "one" (digital) level
Macro	A single programming symbolic instruction that generates multiple absolute language instructions.
Make-up	Water supplied to a system to replace that lost by blow down, leakage, evaporation, etc.
Manchester, N.H. Project	A demonstration building commissioned by GSA (Isaak and Isaak, Architects) and developed by Dubin-Mindell-Bloome Associates to incorporate energy conserving architectural features and mechanical and electrical systems.
MCR	Master Control Room - The central facility containing the operator console, CCU, CCC, and related equipment for control and supervision of the complete EMCS.

Memory	A device or media used to store information.
Memory Modules	Increments of memory, usually 4K, 8K, or 16K words in length.
Micro-Computer	A small computer consisting of a micro-processor together with memory, I/O interfaces and peripheral devices. Micro-computers typically provide an 8-bit word length.
Micro-Processor	A large scale integration processing unit containing a single integrated circuit (IC) chip or a set of IC chips with limited memory.
Mini-Computer	A small computer with word length, storage, and processing capabilities generally exceeding that available in a micro-computer. The mini-computer typically provides a 16-bit word length and used peripheral equipment originally designed for full size business and scientific computers.
Mnemonic	A symbolic representation or abbreviation designed to help operators remember.
Modem	Modulator-Demodulator - A hardware device for converting digital information to and from a form suitable for transmission over a telephone system.
Modular	System arrangement whereby the demand for energy (heating, cooling) is met by a series of units sized to meet a portion of the load.
MSI	Medium Scale Integration - As in LSI to a lesser degree.
MUX	Multiplex - A device which combines multiple signals on one transmission media.
Object Code	A term used to describe machine language code.

Operating System	A complex software system which manages the computer and its components and allows for human interaction.
Oriface Plate	Device inserted in a pipe or duct which causes a pressure drop across it. Depending on oriface size it can be used to restrict flow or form part of a measuring device.
Orsat Apparatus	A device for measuring the combustion components of boiler or furnace flue gases.
Parity	A checking code within a binary word used to help identify errors.
Peripheral Equipment	Equipment used for man-machine communications and further support of a processor.
Piggyback Operation	Arrangement of chilled water generation equipment whereby exhaust steam from a steam turbine driven centrifugal chiller is used as the heat source for an absorption chiller.
Point	Actual input to or output from the EMCS from or to the systems being monitored and controlled.
Power Factor	Relationship between KVA and KW. When the power factor is unity, KVA equals KW.
Program	A series of instructions which define in detail the computer steps necessary to perform a function.
R-Value	The resistance to heat flow expressed in units of Sq. Ft. hour Degree F/BTU.
RAM	Random Access Memory.
Raw Source Energy	The quantity of energy input at a generating station required to produce electrical energy including all thermal and power conversion losses.

Real-Time — A situation in which a computer monitors, evaluates, reaches decisions and effects controls within the relaxation time of the fastest loop or specified response time.

Relay — A device for converting an electrical or pneumatic signal into an electromagnetic switching device having electrical contactors energized by electrical current through its coil.

ROM, PROM, EPROM — Read-Only-Memory, Programmable-Read-Only-Memory, Erasable-Programmable-Read-Only-Memory.

Roof Spray — A system that reduces heat gain through the roof by cooling the outside surface with a water spray.

RS-232C — A standard developed by the Electronic Industries Association applicable to the interfacing of data terminal equipment.

Scan — To examine stored information for a specific purpose as for content ar' arrangement; to examine the status of input/output channels to determine whether data is being received or transmitted.

Scheme — Energy control method.

Seasonal Efficiency — Ratio of useful output to energy input for a piece of equipment over an entire heating and cooling season. It can be derived by integrating part load efficiencies against time.

Sensors — Devices used to detect or measure physical phenomena.

Software — Term used in relation to computers normally describing computer programs and other intangibles.

Sol-air Temperature — The theoretical air temperature that would give a heat flow rate through a building surface equal in magnitude to that obtained by the addition of conduction and radiation effects.

Source Code — A term used to describe assembler and high level programmer developed code.

Stand-Alone — A term used to designate a device or system which can perform its function totally independent of any other device or system.

System Status — The condition of a particular point of a system such as Normal, Abnormal, On, Off, Up, Alarm, and Overload.

Ton of Refrigeration — A means of expressing cooling capacity: 1 ton = 12,000 BTU/hour cooling.

Trunk Wiring — The transmission circuit used to send signals between the central control console and the remote sites.

TTL — An interface compatible with total transistor logic components suitable for discrete data transmission.

TTY — An interface compatible with teletype equipment suitable for serial data transmission.

'U' Value — A coefficient expressing the thermal conductance of a composite structure in BTU per square foot hour degree F temperature difference.

Unit — Description of equipment (chillers, boiler, etc.) which may contain any combination of points.

Veiling Reflection — Reflection of light from a task, or work surface, into the viewer's eyes.

Vapor Barrier — A moisture impervious layer designed to prevent moisture migration.

<u>Wet Bulb Temperature</u>	The lowest temperature attainable by evaporating water in the air without the addition or subtraction of energy.
<u>Word</u>	A set of binary bits handled by the computer as the primary unit of information.
<u>Zone</u>	An area composed of a portion of a building, a building, or a group of buildings affected by a single device or equipment.

ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BTU	British Thermal Unit
BTU's x 10^6	Millions of BTU's
BTU's x 10^3	Thousands of BTU's
CFM	Cubic Feet per minute
COP	Coefficient of performance
CU	Coefficient of utilization
DB	Dry bulb temperature
DX	Direct Expansion
ESI	Equivalent Sphere Illumination
IES	Illuminating Engineers Society
HID	High intensity discharge (lamps)
HZ	Hertz
HVAC	Heating, Ventilation and Air-Conditioning
KVA	Kilovoltampere
KWH	Kilowatt hour
O.A.	Outside air
P.F.	Power Factor
PSI	Pounds per square inch
SQ. FT.	Square foot
TD	Temperature difference
TE	Total Energy (system)
WB	West bulb temperature

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650 Capitol Mall
Sacramento, CA 95814

USA Engr Dist, Far East
ATTN: Chief, Engr Div
APO San Francisco, CA 96301

USA Engr Dist, Japan
APO San Francisco, CA 96343

USA Engr Div, Europe
European Div, Corps of Engineers
APO New York, NY 09757

USA Engr Div, North Atlantic
ATTN: Chief, NADEN-T
90 Church St
New York, NY 10007

USA Engr Div, South Atlantic
ATTN: Chief, SAEN-TE
510 Title Bldg
30 Pryor St, SW
Atlanta, GA 30303

USA Engr Dist, Mobile
ATTN: Chief, SAMEN-C
P.O. Box 2288
Mobile, Al 36601

USA Engr Dist, Louisville
ATTN: Chief, Engr Div
P.O. Box 59
Louisville, KY 40201

USA Engr Div, Norfolk
ATTN: Chief, NAOEN-D
803 Front Street
Norfolk, VA 23510

USA Engr Div, Missouri River
ATTN: Chief, Engr Div
P.O. Box 103 Downtown Station
Omaha, NE 68101

USA Engr Div, South Pacific
ATTN: Chief, SPDED-TG
630 Sansome St, Rm 1216
San Francisco, CA 94111

USA Engr Div, Huntsville
ATTN: Chief, HNDED-ME
P.O. Box 1600 West Station
Huntsville, AL 35807

USA Engr Div, Ohio River
ATTN: Chief, Engr Div
P.O. Box 1159
Cincinnati, Ohio 45201

USA Engr Div, North Central
ATTN: Chief, Engr Div
536 S. Clark St.
Chicago, IL 60605

USA Engr Div, Southwestern
ATTN: Chief, SWDED-TM
Main Tower Bldg, 1200 Main St
Dallas, TX 75202

USA Engr Dist, Savannah
ATTN: Chief, SASAS-L
P.O. Box 889
Savannah, GA 31402

Commander
US Army Facilities Engineering
Support Agency
Support Detachment II
Fort Gillem, GA 30050

Commander
US Army Facilities Engr Spt Agency
ATTN: MAJ Brisbine
Support Detachment III
P.O. Box 6550
Fort Bliss, Texas 70015

NCOIC
US Army Facilities Engr Spt Agency
Support Detachment III
ATTN: FESA-III-SI
P.O. Box 3031
Fort Sill, Oklahoma 73503

NCOIC
US Army Facilities Engr Spt Agency
Support Detachment III
ATTN: FESA-III-PR
P.O. Box 29704
Presidio of San Francisco, CA 94129

NCOIC
US Army Facilities Engr Spt Agency
ATTN: FESA-III-CA
Post Locator
Fort Carson, Colorado 80913

Commander/CPT Ryan
US Army Facilities Engr Spt Agency
Support Detachment IV
P.O. Box 300
Fort Monmouth, New Jersey 07703

NCOIC
US Army Facilities Engr Spt Agency
ATTN: FESA-IV-MU
P.O. Box 300
Fort Monmouth, New Jersey 07703

NCOIC
US Army Facilities Engr Spt Agency
Support Detachment IV
ATTN: FESA-IV-ST
Stewart Army Subpost
Newburgh, New York 12250

NCOIC
US Army Facilities Engineering
Support Agency
Support Detachment II
ATTN: FESA-II-JA
Fort Jackson, South Carolina 29207

NCOIC
US Army Facilities Engr Spt Agency
Support Detachment II
P.O. Box 2207
Fort Benning, Georgia 31905

NCOIC
US Army Facilities Engr Spt Agency
Support Detachment II
ATTN: FESA-II-KN
Fort Knox, Kentucky 40121

Naval Facilities Engineering Cmd
Energy Programs Branch, Code 1023
Hoffmann Bldg. 2, (Mr. John Hughes)
Stovall Street
Alexandria, VA 22332

US Army Facilities Engineering
Support Agency
FE Support Detachment I
APO New York, NY 09081

Navy Energy Office
ATTN: W.R. Mitchum
Washington DC 20350

David C. Hall
Energy Projects Officer
Dept. of the Air Force
Sacramento Air Logistics Center (AFLC)
2852 ABG/DEE
McClellan, CA 95652

USA Engineer District, Chicago
219 S. Dearborn Street
ATTN: District Engineer
Chicago, IL 60604

rectorate of Facilities Engineer
Energy Environmental & Self Help Center
Fort Campbell, KY 42223

Commander and Director
Construction Engineering Research Laboratory
ATTN: COL Circeo
P.O. Box 4005
Champaign, IL 61820

Mr. Ray Heller
Engineering Services Branch
DFAE, Bldg. 1950
Fort Sill, OK 73503

HQ, US Military Community Activity, Heilbronn
Director of Engineering & Housing
ATTN: Rodger D. Romans
APO New York 09176

Commanding General
HQ USATC and Fort Leonard Wood
ATTN: Facility Engineer
Fort Leonard Wood, MO 65473

NCOIC
535th Engineer Detachment, Team A
ATTN: SFC Prenger
P.O. Box 224
Fort Knox, KY 401212

NCOIC
535th Engineer Detachment, Team B
ATTN: SP6 Cathers
P.O. Box 300
Fort Monmouth, NJ 07703

NCOIC
535th Engineer Detachment, Team C
ATTN: SFC Jackson
P.O. Box 4301
Fort Eustis, VA 23604

NCOIC
535th Engineer Detachment, Team D
ATTN: SFC Hughes
Stewart Army Subpost
Newburg, New York 12550

Commander-in-Chief
HQ, USAEUR
ATTN: AEAEN-EH-U
APO New York 09403

HQ AFESC/RDVA
Mr. Hathaway
Tyndall AFB, FL 32403

Commander and Director
Construction Engineering Research Laboratory
ATTN: Library
P.O. Box 4005
Champaign, IL 61820

HQ, 5th Signal Command
Office of the Engineer
APO New York 09056

SSG Ruiz Burgos Andres
D.F.E., HHC HQ Cmd 193d Inf BDE
Ft. Clayton, C/Z

Energy/Environmental Office
ATTN: David R. Nichols
USMCA-NBG (DEH)
APO New York 09696

Commander
535th Engineer Detachment
P.O. Box 300
Fort Monmouth, New Jersey

Commander
Presidio of San Francisco, California
ATTN: AFZM-DI/Mr. Prugh
San Francisco, CA 94129

Facilities Engineer
Corpus Christi Army Depot
ATTN: Mr. Joseph Canpu/Stop 24
Corpus Christi, TX 78419

Walter Reed Army Medical Center
ATTN: HSWS-E/James Prince
6825 16th St., NW
Washington, DC 20012

Commanding Officer
Installations and Services Activity
ATTN: DRCIS-RI-IB
Rock Island Arsenal
Rock Island, IL 61299

Commanding Officer
Northern Division Naval
Facilities Engineering Command
Code 102 (Mr. E.F. HUMM)
Naval Base
Philadelphia, PA 19112

Commander US Army Facilities Engineering
Support Agency
Support Detachment I
APO New York 09081

HQ, USA Health Services Cmd
Bldg 2792
ATTN: HSLO-F
Fort Sam Houston, TX 78234

HQDA
(DAEN-MPE-E)
WASH DC 20314

Commanding Officer
Northern Division Naval
Facilities Engineering COmmand
Code 10
Naval Base, Building 77
Philadelphis, PA 19112

Facilities Engineer
Fort Leavenworth
Fort Leavenworth, KS 66027

Facilities Engineer
Fort Benjamin Harrison
Fort Benjamin Harrison, IN 46216

Office of the A&E
ATTN: MAJ Johnson
Camp Ripley
Little Falls, MN 56345

Commander
US Army Garrison
ATTN: HSD-FE
Fort Detrick, MD 21701

AFESC/DEB
ATTN: Mr. Fred Beason
Tyndall AFB, FL 32403

Mr. David White
Defense Audit Service
888 North Sepulveda Blvd.
Suite 610
El Sequndo, CA 90245

Facilities Engineer
Bldg. 308
Fort Myer, VA 22211

NAVFAC
ATTN: John Zekan
Code 0833
Hoffmann Building
200 Stovall Street
Alexandria, VA 22332

1 3 ·96,927· AG--Ft Belvoir