CR 83.021

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

Sponsored by
CHIEF OF NAVAL MATERIAL
NAVAL FACILITIES ENGINEERING COMMAND

EMCS OPERATOR TRAINING MANUAL

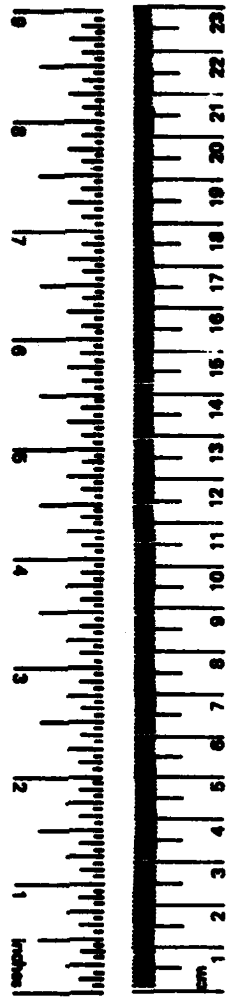
April 1983

An Investigation Conducted by
NEWCOMB & BOYD, Consulting Engineers
One Northside 75
Atlanta, Georgia

N62474-81-C-9405

Approved for public release; distribution unlimited

METRIC CONVERSION FACTORS



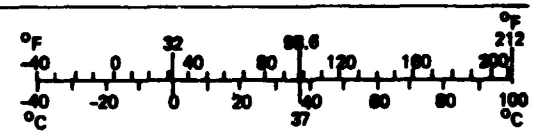
Approximate Conversions to Metric Measures

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

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

Approximate Conversions from Metric Measures

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



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CR 83.021	2. GOVT ACCESSION NO. AD-A128	3. RECIPIENT'S CATALOG NUMBER C87
4. TITLE (and Subtitle) EMCS Operator Training Manual		5. TYPE OF REPORT & PERIOD COVERED Final Sep 81 - Dec 1982
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Catherine Cornelius; Billy Wise; and Steven Bruning		8. CONTRACT OR GRANT NUMBER(s) N62474-81-C-9405
9. PERFORMING ORGANIZATION NAME AND ADDRESS NEWCOMB & BOYD, Consulting Engineers One Northside 75 Atlanta, GA 30318		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6.3; Z0829-01-221D
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Civil Engineering Laboratory Port Hueneme, CA 93043		12. REPORT DATE April 1983
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Chief of Naval Material, Washington, DC Naval Facilities Engineering Command Alexandria, VA		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer; controls; HVAC; energy; EMCS; operator; training

ENERGY MONITORING AND CONTROL SYSTEM

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

This manual is a training aide to accompany the EMCS Operator Training Course. It is also intended as a working reference for the EMCS operator. The manual discusses the basics of HVAC system operation convering most systems which would be connected to an EMCS. It includes a generic description of EMCS hardware, explanations of the energy savings strategies of the EMCS

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) applications software and discussions of EMCS alarm analysis and system operation.

EMCS Operator Training Manual

Table of Contents

INTRODUCTION

This manual was written as a training aid to supplement the EMCS Operator Training Course classroom lectures. The manual and classroom notes may also be used as a working reference for the trainee while on duty as an EMCS operator. The objectives of the EMCS Operator Training Course are to provide EMCS operators with an understanding of the effective use of an EMCS as an energy conservation and facility management tool; and to train them to perform as operators in three functional modes:

1. Normal HVAC operation, including entering parameters for the various energy conservation routines performed by an EMCS.

2. Recognition and response to alarm conditions occurring in HVAC systems that are connected to an EMCS on a typical installation.

3. Understanding the concept of fine tuning or "tweaking" the system to maintain or to maximize energy conservation.

The course is primarily aimed at potential EMCS operators who have a high school education and field experience or technical schooling in HVAC or a related field. For those students who have no HVAC or related experience or training, an overview of the principles of heating and air conditioning and the operation of typical HVAC equipment is included in the first chapter. This will also provide a review for other students.

This course is only the first step in a four phase training program for EMCS operators. The four phases include:

- EMCS Operating Training Course
- Vendor Training
- Maintenance Shop Rotation
- On-the-Job Training

The objectives of the EMCS operator training course as described above include a generic introduction to the EMCS concept as based on the Tri-Service EMCS Guide Specifications and Technical Manual. The second phase is Vendor Training, which will provide equipment familiarization and operating procedures for the computers and energy conservation programs actually being installed at the site. The third phase is Maintenance Shop Rotation, which will provide an opportunity for EMCS operator trainees to see the actual HVAC equipment and controls at the site in operation. The final phase is on-the-job training, where the trainee will work with an experienced operator on the EMCS operator console at the site. This four-phase trianing cycle could be completed in about six months.

An Energy Monitoring and Control System (EMCS) is an energy management system which employs computer technology to monitor and control equipment scattered throughout a facility. A central computer supervises operation and provides the EMCS operator access for entering and retrieving information from remote control points. Sensors and control devices are wired into electronic field panels which combine signals (multiplex) for transmission to the central computer. The central computer automatically analyzes information received from sensors and initiates control actions through control devices in the field. In addition to automatic operation, the central computer provides reports and displays information for the use of a human operator. Based on this information, the operator can manually override automatic operations or can adjust parameters used by the automatic control programs to achieve greater energy conservation or better quality control. The EMCS may be used to affect energy and manpower savings, for heating, ventilating, and air conditioning, process equipment, lighting, chillers and boilers. The EMCS may also be used to assist in maintenance management. Some EMCS are also used for fire and security alarm purposes. Fire and security functions have not been generally implemented on EMCS at military bases, therefore, those capabilities are not concentrated on in this manual and course.

The systems which have evolved to become modern EMCS were originally developed during the 1960's, primarily as maintenance and alarm recording tools. With the Arab oil embargo of 1973, the importance of energy conservation was brought to the forefront. Spiralling fuel costs since that time have brought ever increasing pressure on all segments of society to conserve energy. As this occurred, the capabilities of an EMCS type system to conserve energy became the primary focus of their ongoing development process. Within the government sector, President Carter's Executive Order 12003 mandated a 20% reduction in energy consumption by 1985 compared to 1975 consumption. Within the military services, this resulted in a concentrated program of capital investments to improve the energy efficiency of military facilities. This program was titled The Energy Conservation Investment Program (ECIP). The ECIP program has been used to fund a wide variety of capital energy improvement projects ranging from modernized boiler plants, addition of wall insulation, family housing units, heat recovery projects, etc. One of the most common ECIP projects is the installation of a central computerized control system for each military base. Although the systems have been installed under a wide variety of names, (Utility Control Systems, Utility Monitoring and Control Systems, Energy Management Systems, Central Energy Management Systems, etc.) the common terminology used today for these systems is "Energy Monitoring and Control Systems (EMCS)".

The primary use of EMCS on military facilities has been the monitoring and control of heating, ventilating, and air conditioning (HVAC) systems. While there has been some applications of EMCS for lighting control, electrical distribution control, water and sewer system control, etc., these vary from site to site, depending on the operating philosophy and funding availability of a particular military base. Since the majority of EMCS are used for control of HVAC systems, the EMCS Operator Training Course will concentrate on the principles and application of typical HVAC systems to provide the EMCS operator with a baseline background in the types of systems he will be dealing with on an everyday basis. The course will not deal with specific details on individual pieces of equipment used in HVAC systems (fans, pumps, etc.), but will primarily concentrate on those components as they fit into an overall HVAC system, the control of those systems, and how an EMCS is applied to each of those systems.

The second area of concentration for the EMCS operator course is a general familiarization with EMCS technology, terminology, and basic operation principles. The course provides basic definitions of terms the operator will encounter in dealing with the many different disciplines involved with an EMCS. These include computer technology, sensor and control technology, utilities system operation, HVAC system operation and facilities maintenance operations. In addition to HVAC system concepts and EMC system concepts, the course will provide training in the application of the EMCS to HVAC systems to accomplish energy conservation and equipment trouble diagnosis. It is not possible to obtain an in depth education in such a wide variety of fields within the course of any training program. This course only attempts to familiarize operator personnel with some of the basic concepts and provide him with an overview of the technologies with which he will deal on a daily basis.

CHAPTER 1

HVAC SYSTEMS

Section 1. BASICS OF HVAC SYSTEMS

The primary purpose of heating, ventilating, and air conditioning (HVAC) systems is to provide a healthy, comfortable environment for people, and in some cases equipment. Human comfort is dependent on a number of factors, including:

1. Air temperatures

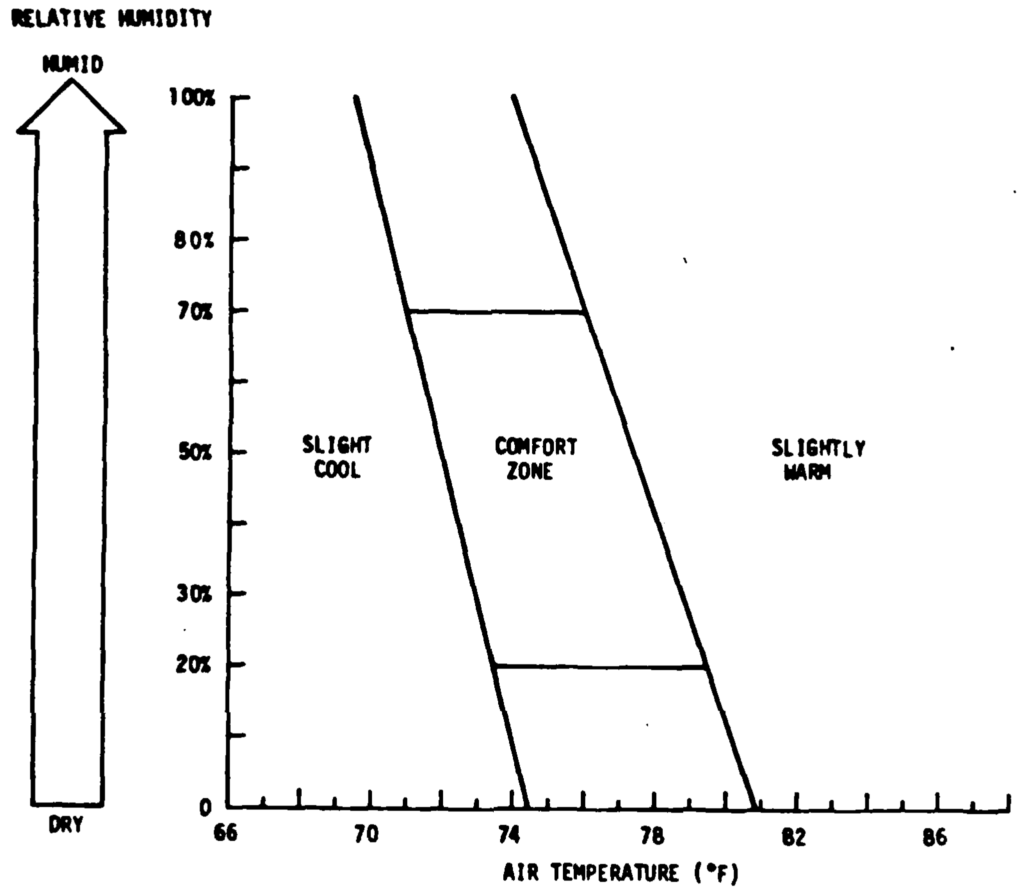
2. Temperatures of surrounding surfaces.

3. Air humidity

4. Air motion, and

5. Air freshness

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has performed extensive research into human "comfort conditions". Figure 1-1 provides an illustration of a "comfort zone" based on the combination of air temperature and humidity. As can be seen from the figure, as humidity decreases, comfortable air temperature increases.



EXPERIMENTALLY DETERMINED COMFORT ZONE

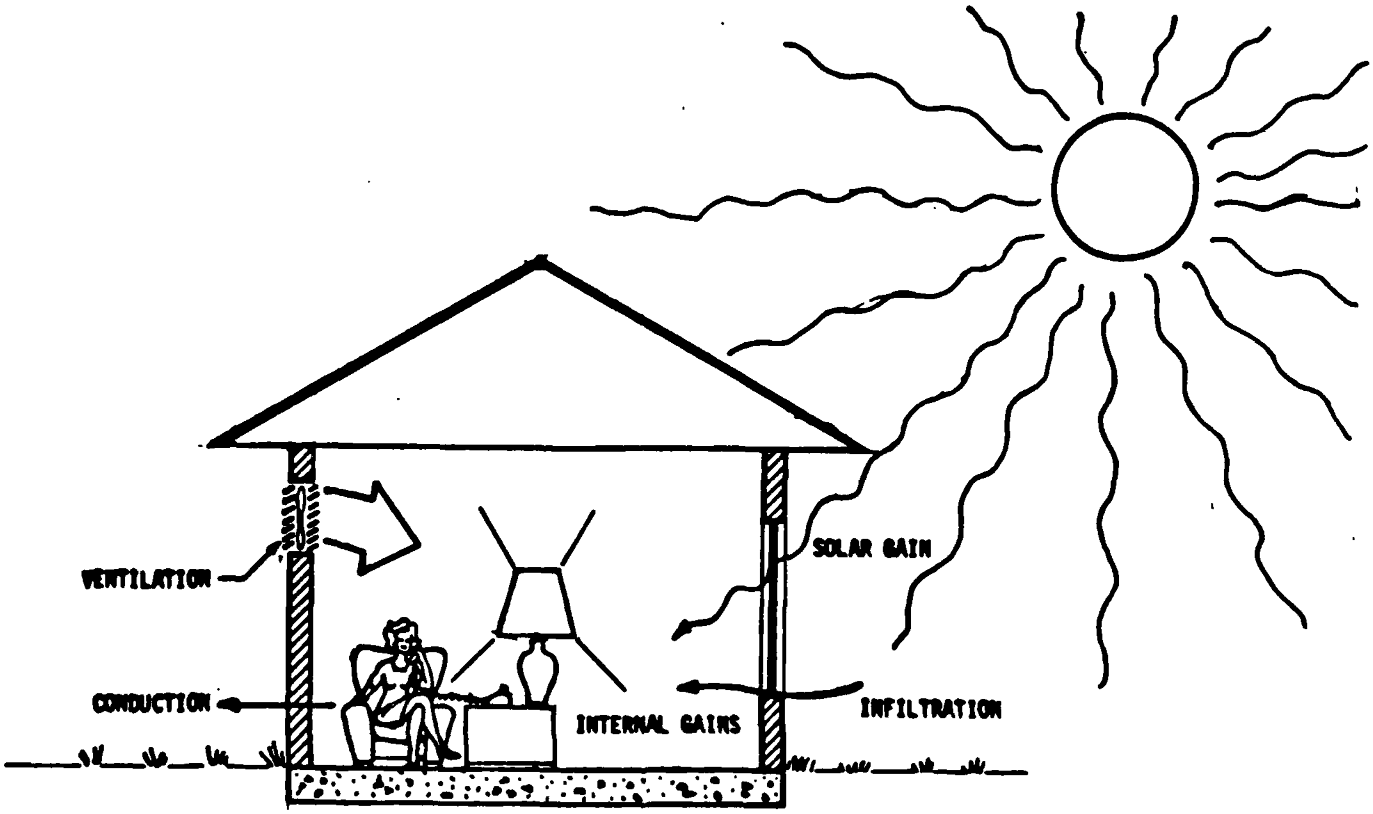
Figure 1-1

Thus, 78° air temperature with 25% relative humidity "feels" comfortable to a building occupant while 78° with a relative humidity of 70% will be uncomfortable. Therefore, HVAC systems must address both air temperature and humidity to maintain comfort conditions. The comfort of a space can be affected by heating or cooling the space, humidifying or dehumidifying air within the space, ventilating (introduction of fresh outside air) and filtering of the air in that space. These are the basic processes accomplished by an HVAC system. Note that governing criteria (DOD, local or service wide) may dictate design or operation outside the Figure 1-1 zone for energy conservation purposes.

In order to maintain a space at any given temperature, there must be no net gain or loss of energy in that space. When energy is transferred out of a space, it is called a heat loss. When energy is transferred into a space, it is called a heat gain. HVAC systems are designed to exactly offset heat gains or heat losses resulting from external or internal factors. Thus the amount of heating to be provided by an HVAC system (the heating load) must equal the net heat loss from the spaces served by that HVAC system. If the spaces served by an HVAC system have a net heat gain, then that equivalent amount of energy must be removed by the HVAC system by cooling the space (the cooling load).

Heat gains and losses are a result of heat transfer through the building exterior envelope (walls, roofs, doors, windows, etc.), internal heat gains, and transfer of outside air into the conditioned space. Building envelope loads result from conduction heat transfer and solar heat gain. Conduction heat transfer is caused by a temperature difference between the space inside and the air outside. The greater the difference between the inside and outside temperatures, the more heat is transferred. If the outside temperature is greater than the inside temperature, heat energy is transferred into the space. If the inside temperature is warmer than the outside temperature, heat is lost from the space. In addition to the amount of temperature differential, the construction of the wall, roof or window through which heat is being conducted, also effects the amount of energy transferred between the inside and outside. A measure of the tendency for a wall or other structure to resist the flow of heat is it's thermal resistance. Insulated walls conduct less heat than uninsulated walls, because the addition of the insulation material increases the thermal resistance of that wall.

In addition to conduction, heat may be transferred into a space as a result of solar heat gain. This can be due to the sun striking an opaque surface of a room, such as a wall and heating that wall to a temperature that is higher than the room temperature. Solar heat gain can also result directly



SOURCES OF HEAT GAINS AND LOSSES

Figure 1-2

from sunlight passing through a translucent or transparent surface such as a window, striking objects within the room, and warming them to a temperature warmer than the space temperature.

In addition to the building envelope loads, internal heat gains can also contribute to cooling loads. Any time an object within a space has a higher temperature than the space itself, it results in a transfer of heat from that object into the space. That heat must be removed by the air conditioning system in order to maintain the space temperature. People, lights, office equipment and other appliances in rooms have higher temperatures than the space itself. Thus, all of these objects provide an internal heat gain to a space. The heat gain as a result of this temperature difference is called "sensible" heat gain. "Dry bulb temperature" is a measure of the sensible heat content of a substance as measured by a conventional thermometer.

In addition to sensible heat gains, a second type of heat gain must be considered in air conditioning applications. As illustrated on the comfort condition chart, human comfort is related to the humidity within a space. Any increase of space humidity due to addition of moisture to the air in the space contributes to the "latent" heat gain and must be removed by the air conditioning system in order to maintain the space's humidity. Moisture evaporating from the surface of people's skin is one source of latent heat gain in a space. Appliances such as kitchen equipment which result in evaporation of water or moisture into the air also add a latent heat gain to space.

In addition to building envelope and internal heat gains, heating or cooling loads may result from the introduction of outside air into a space. Outside air may enter a space through cracks around windows or doors or from opening and closing of doors or other openings in the exterior building skin. This addition of outside air is called "infiltration". If the outside air introduced by infiltration is at a different temperature than the space temperature, it adds a sensible heating or cooling load to the space. If the outside air contains more moisture than the room air, it adds a latent cooling load to the space. In addition to infiltration, outside air must be added to the space by the HVAC system for ventilation purposes. Ventilation air also can add heating or cooling loads on the HVAC system if it is not the same temperature and humidity as that being maintained in the space.

The actual heating or cooling load within a space is equal to the sum of all individual heat gains and heat losses to that space. During most of the time, spaces have both heat gains and heat losses. For example, when the outside temperature is cold, heat losses occur through walls and windows while at the same time, people and lights within that space provide heat gains. If heat losses are exactly equal to heat gains, then no net heating or cooling load occurs in the space. If the total of heat losses is greater than the total of heat gains, then the difference between the two is equal to a heating load (i.e. HVAC must add heat to the space). They may have a net heating or cooling load depending on a wide variety of factors, including outside air temperature, solar heat gain and internal loads.

Groups of spaces along the exterior of the building are normally referred to as perimeter zones, and are the most influenced by exterior conditions. Spaces within the building, which are not adjacent to any exterior surface of the building, are called interior zones. Interior zones generally require cooling even during the winter because internal gains from lights, people and equipment are not offset by losses through exterior surfaces. This requirement for cooling in interior zones while perimeter zones may require heating adds complexity to HVAC systems. The HVAC system of a building must be able to provide cooling to interior spaces at the same time it provides heating to perimeter zones. The wide variety of HVAC systems which will be discussed later in the course is in large part due to this requirement.

Every building that is heated, requires some means for converting raw energy into heat (thermal energy). The source of energy may include fossil fuels, wood, sunlight, purchased steam, electricity or waste heat recovered from refrigeration machinery or other processes. The function of the HVAC equipment is to effectively convert the specific form of energy to heat and <u>transfer</u> this heat from the source to the conditioned space. The amount of heat transferred is usually designated as a rate of flow in BTU per hour.

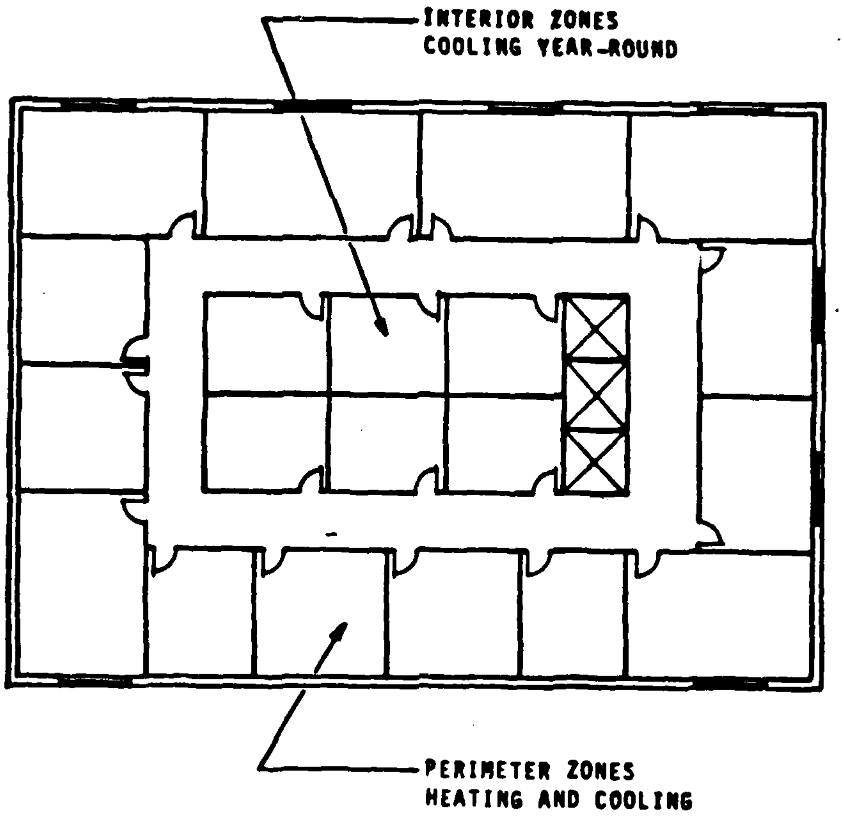


Figure 1-3

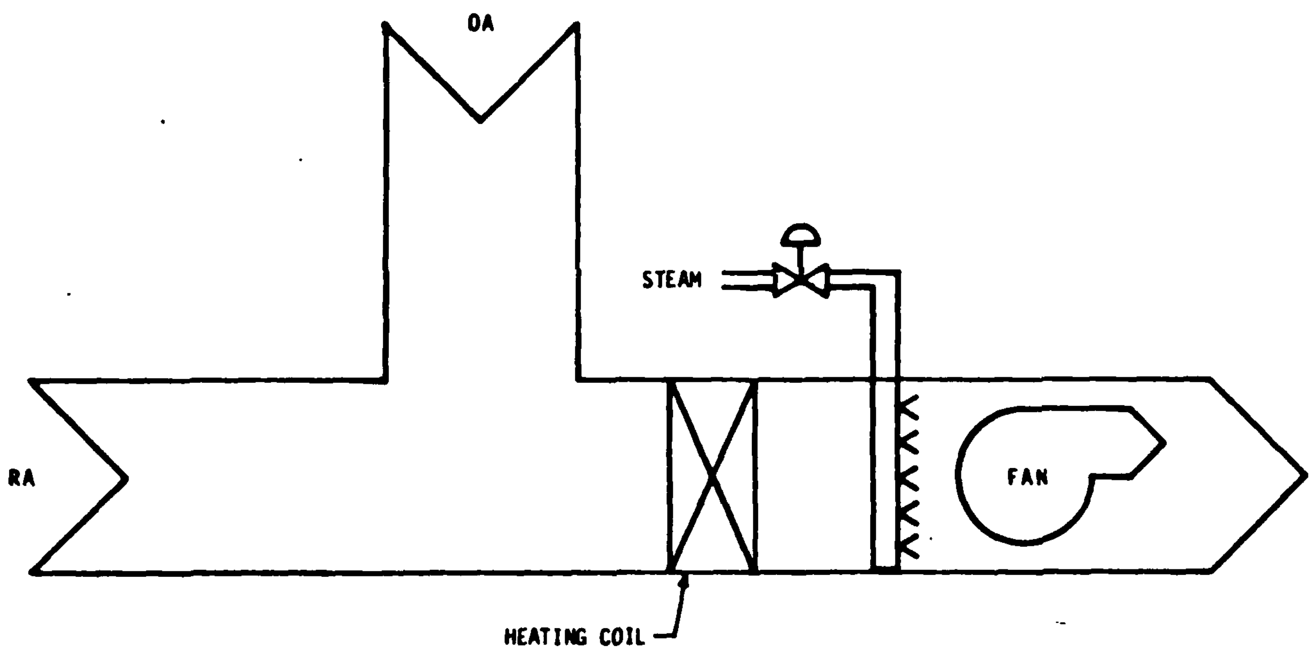
A BTU or British Thermal Unit is the amount of heat that must be added to one pound of water to raise its temperature one degree Fahrenheit.

Some equipment is designed to radiate heat into a space: wood-burning stoves, electric heat strips, and radiators. Other equipment is designed to transfer heat to a moving stream of air which is circulated through the space to be heated: direct-fired furnaces, unit heaters, fan coils, and central air distribution systems. The heat from combustion of fuel or other heat source may be transferred directly to the air stream as in a direct-fired furnace or air solar collector. In other systems water is heated at a central boiler, heat recovery unit, or solar collector panels and distributed to the fan units. The fan blows or draws air across either a steam or hot water heating coil installed inside a duct. A coil is made of many feet of twisted finned tubing through which the hot water or steam flows. The heat transfer capacity of the coil is varied by varying the flow rate of water or steam through it with a control valve.

If the energy source being used is electricity, then the energy conversion process is accomplished by means of some type of electrical resistance coil. The wires or elements of a coil have a resistance to the electricity flowing through them. The electrical current flowing through this resistance results in heating of the coil surfaces. That heat is then transferred to the medium which is to be heated. Electric heat may be used directly to heat room air as is the case with electric baseboard heat or it may be used in an electric duct heater to control supply air temperature which is then transferred to the room to be heated. Electric heat may also be used to heat hot water which may then be transferred to heating coils or radiators to provide heat for the building.

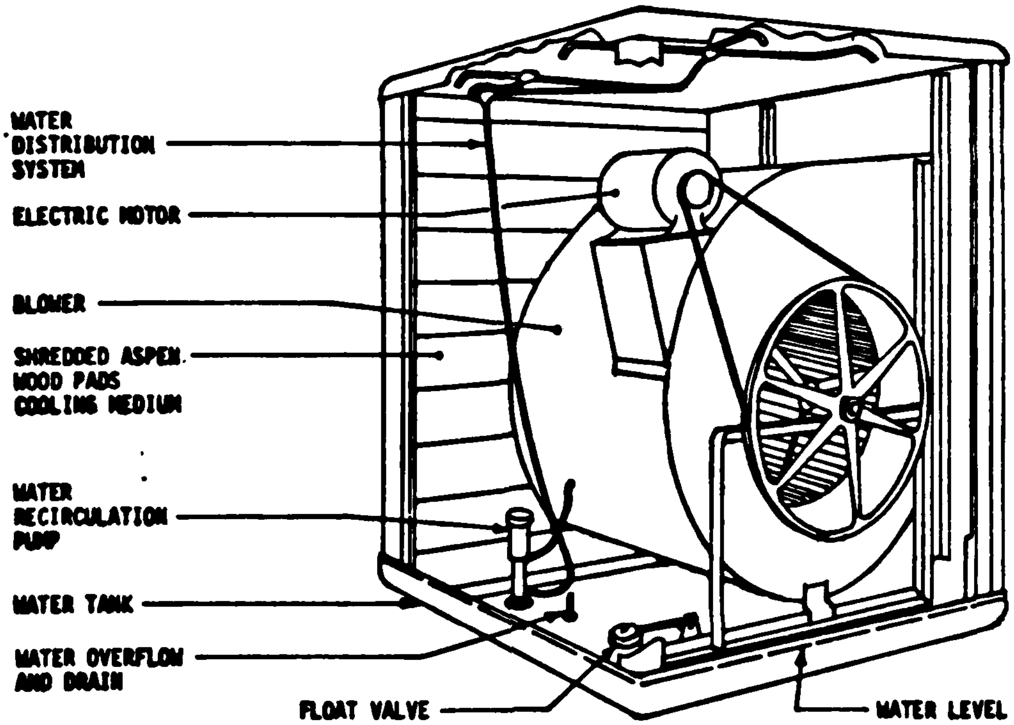
A variety of combustible fuels are used in building heating applications. These include coal, natural gas, propane gas, light oil (#2), heavy oil (#6) or combinations of these fuels. In all of these cases, the process used to obtain heat is that of combustion. The fuels are burned at a high temperature adn the heat given off in the combustion process is then transferred to the building or space to be heated.

During the heating season humidification of heated air may be desirable. In spite of the addition of moisture to the inside environment by the presence of people, the relative humidity can decrease to an uncomfortable level due to infiltration and ventilation with outside air. By definition, relative humidity is the ratio of the amount of water vapor in a sample of air under study to the maximum amount of water vapor which could be in that air at the same temperature without condensing. Warm air can hold a larger amount of water vapor than cool air. Therefore, when air is heated without the addition of moisture, the relative humidity decreases. For example, outside air at 35°F and 40% relative humidity heated to 68°F will have a resultant humidity of 11%. The most common method for humidifying supply air is by steam injection as shown in Figure 1-4.



STEAM INJECTION HUMIDICATION

Figure 1-4



TYPICAL EVAPORATIVE COOLER

Figure 1-5

Heat gains must be compensated by removal of heat from the conditioned space. This is accomplished by passing an air stream through a cooling coil or evaporative cooler. A typical evaporative cooler is shown in Figure 1-5. Three sides of the metal housing is covered with a porous material that is kept saturated with water. A small pump circulates water from the basin up and over the porous material. A float valve in the basin regulates the flow of make-up water that replaces water which evaporates and is carried off by the air stream. Heat is required for the vaporization of the water and is supplied by the sensible heat of the air resulting in a lower dry bulb temperature. As a result of the process, however, the humidity and thus the latent heat of the air increases. This method of cooling is only feasible in arid climates such as the Southwest states.

Cooling coils are capable of removing latent heat as well as sensible heat from an air stream, thus performing the dehumidification function. The temperature of the coil must be below the dewpoint of the air stream, the temperature at which water will condense out of a sample of air. This temperature varies depending on the amount of moisture in the air. Thus, as the air passes over the coil moisture will condense on the cold tubes.

Cooling coils may be either chilled water coils or direct expansion (DX) coils. As with hot water heating coils chilled water is pumped throughout a building to the chilled water coils from a central chilled water plant. The chilled water is generated by a vapor compression refrigeration cycle or absorption refrigeration process in the central plant chillers. Refrigerant is the cooling medium flowing through a DX coil, which is an integral part of a vapor compression cycle.

The vapor compression refrigeration process is based on the fact that the temperature at which a liquid boils varies proportionally with the pressure. For example, water at atmospheric pressure boils at 212°F. The same water in a closed container, such as a pressure cooker, at 15 psig (15 pounds per square inch above atmospheric pressure) boils at 250°F. Thus, by changing the pressure in a closed system it is possible to condense a gas at one temperature and vaporize the same substance at a lower temperature. Cooling, that is heat removal, from the surroundings is achieved when a liquid boils or vaporizes at a temperature lower than the surroundings. Thus, certain substances are used in refrigerating systems which under controlled pressures will boil at the desired temperatures.

Many substances have been used as refrigerants, but the most common used today in air conditioning systems are fluorinated hydrocarbons. They are composed of carbon, hydrogen, chlorine, and fluorine in different proportions, and are non-corrosive, non-flammable, non-toxic, non-explosive, clear water-white, and have a slightly sweet odor. Refrigerant-12 and Refrigerant-22 are good refrigerants for air conditioning. The boiling temperatures corresponding to various pressures are listed in Table 1 for Refrigerant-12 and Refrigerant-22.

Table 1

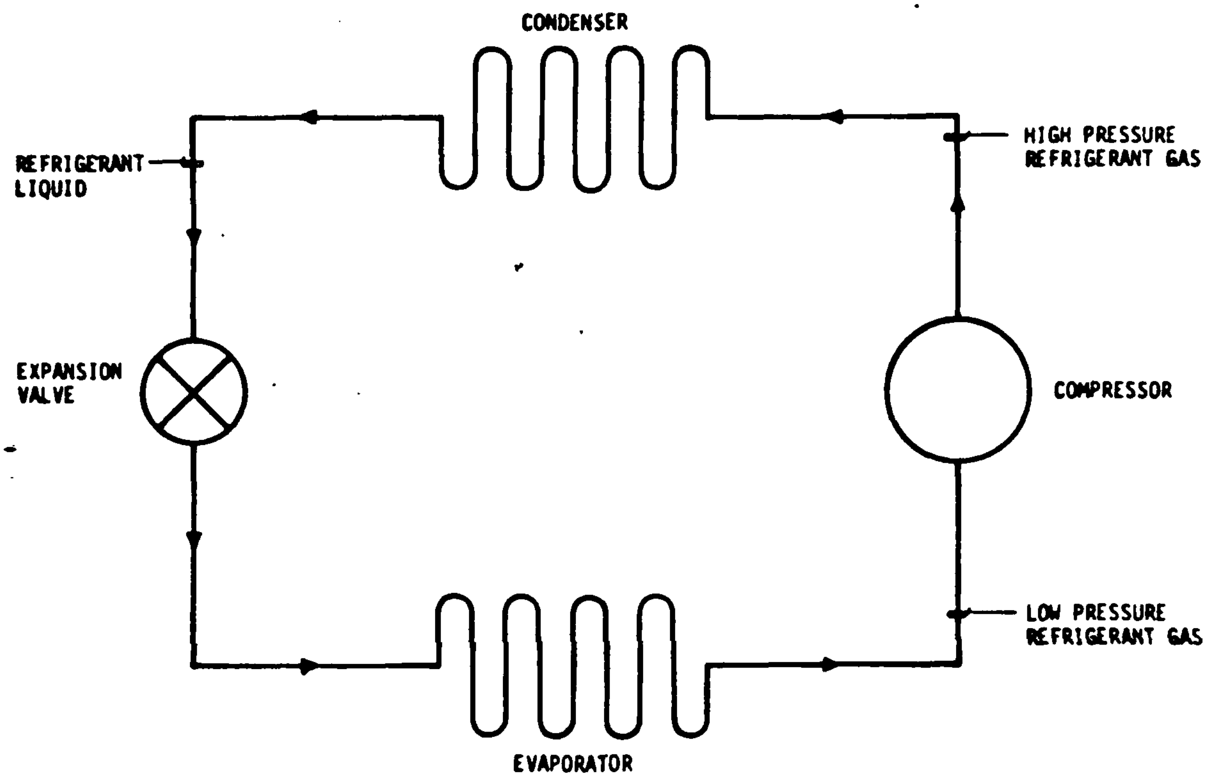
Properties of Saturated Refrigerants

Temp. °F	R-12 Press. psia	R-12 Ht. of Vap. BTU/lb	R-22 Press. psia	R-22 Ht. of Vap. BTU/lb
-40	9.3076	72.913	15.222	100.257
-30	11.999	71.903	19.573	98.801
-20	15.267	70.874	24.845	97.285
-10	19.189	69.824	31.162	95.704
0	23.849	68.750	38.657	94.056
10	29.335	67.651	47.464	92.338
20	35.736	66.522	57.727	90.545
30	43.148	65.361	69.591	88.674
40	51.667	64.163	83.206	86.720
50	61.394	62.926	98.727	84.678
60	72.433	61.643	116.31	82.540
70	84.888	60.309	136.12	80.298
80	98.870	58.917	158.33	77.943
90	114.49	57.461	183.09	75.461
100	131.86	55.929	210.60	72.838
110	151.11	54.313	241.04	70.052
120	172.35	52.597	274.60	67.077
130	195.71	50.768	311.50	63.877
140	221.32	48.805	351.94	60.403
150	249.31	46.684	396.19	56.585

Also listed is the heat of vaporization per pound of refrigerant corresponding to the temperature/pressure states shown. The heat of vaporization is the amount of heat which a substance absorbs when it vaporizes. Pressure is listed in units of pounds per square inch absolute. Note that Refrigerant-12 boils at -21.6°F and Refrigerant-22 boils at -41.4°F at atmospheric pressure (14.7 psia); therefore, they are both gases at atmospheric conditions. Refrigerant-22 was originally developed for low temperature applications. It also provides a greater cooling capacity for the same size equipment, as indicated by the larger heats of vaporization at given pressures. It is not recommended, however, that refrigerant in a system be changed without approval of the compressor manufacturer.

A schematic of the vapor compression refrigerant cycle is shown in Figure 1-6. The cycle consists of four basic processes. In one process the pressure and temperature of gaseous refrigerant is increased by the action of the compressor. The compressor can be thought of as a pump for gases, and serves the function of pushing the refrigerant through the balance of the cycle. In the next process heat is rejected from the refrigerant and it condenses to a liquid in a heat exchanger aptly called the condenser. Next, the liquid refrigerant is allowed to expand through an automatic throttling device (expansion valve) which is actuated by temperature and pressure. At the lower pressure resulting from the expansion process the liquid vaporizes in a heat exchanger called the evaporator, absorbing heat as it does so. The higher pressure in the system is referred to as either the condenser pressure or head pressure. The lower pressure is referred to as the evaporator pressure or suction pressure.

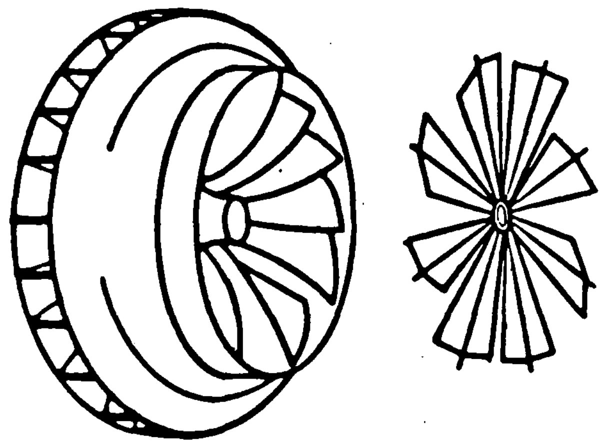
The capability of refrigeration equipment to cool is usually expressed in tons. The term dates from the era before mechanical refrigeration, when ice was used for refrigeration. A ton of ice melting in 24 hours will absorb heat at the rate of 12,000 BTU per hour. Thus, in the field of mechanical refrigeration, a heat removal capacity of 12,000 BTU/hr is referred to as one ton of refrigeration.



REFRIGERATION CYCLE

Figure 1-6

Vapor compression refrigeration machines generally use one of two types of compressors: reciprocating or centrifugal. The reciprocating compressor is comparable to an internal combustion engine in some respects, made up of pistons, all attached to the same rotating shaft and moving up and down in cylinders. On the intake stroke of the piston, a quantity of refrigerant gas fills the cylinder. On the compression stroke, the refrigerant is compressed and discharged from the cylinder. Refrigeration applications up

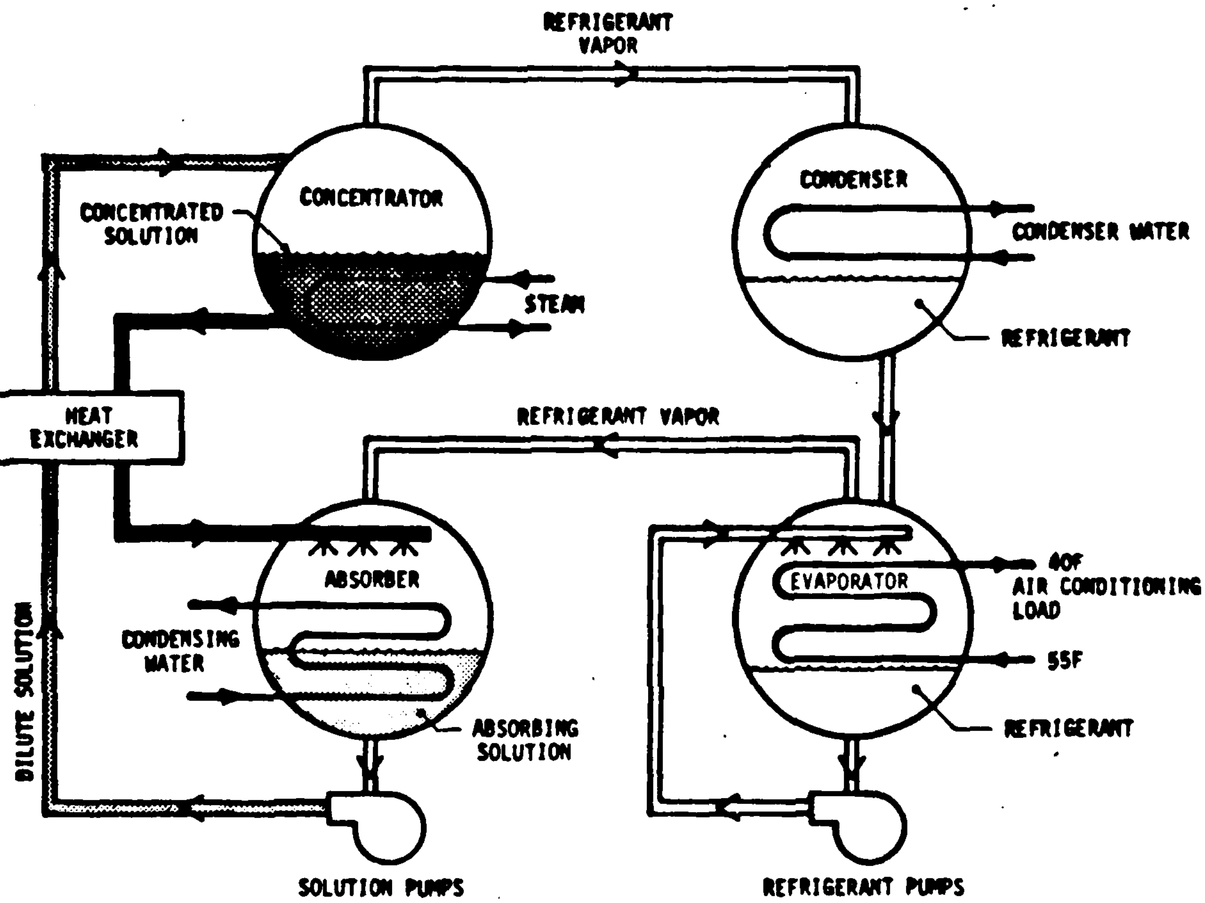


ADJUSTABLE INLET GUIDE VANE FOR CAPACITY CONTROL OF CENTRIFUGAL COMPRESSOR

Figure 1-7

to 60 tons generally use reciprocating compressors. From 60 to 200 tons, either reciprocating or centrifugal compressors may be found in use. Above 200 tons normally centrifugal compressors are used.

Centrifugal refrigeration machines were developed to fill the need for single refrigeration units of large capacity. The operating member of a centrifugal compressor is the impeller. The center of the impeller is fitted with vanes that draw gas into the rotating impeller body. Impeller rotation accelerates the refrigerant gas. As the gas flows through the compressor passages the kinetic energy, or energy of motion, is converted to static energy or pressure. A centrifugal compressor is suited for a wide range of cooling loads. The cooling capacity is varied by adjusting the position of inlet vanes located ahead of the impeller. Vane position affects the entering gas quantity as well as the angle at which gas enters the impeller.



FLOW DIAGRAM OF ABSORPTION REFRIGERATION SYSTEM

Figure 1-8

Absorption refrigeration machines are based on the two facts: that water has a low boiling point in a vacuum, and that salt has a high affinity for water. Figure 1-8 is a flow diagram of an absorption refrigeration system. Usually the refrigerant in the absorption cooling process is distilled water and the absorbing solution is lithuim bromide salt dissolved in water. The four chambers are generally located within one shell which is purged of air. The heat exchanger and pumps are external to the shell. The evaporator and absorber are at a pressure 1/100 that of atmospheric pressure. The concentrator and condenser are at a higher pressure, which is still about 1/10 that of atmospheric pressure.

In the concentrator refrigerant is boiled from the dilute solution at about 210°F. Heat is supplied from a steam or hot water coil immersed in the solution. The refrigerant vapor migrates to the condenser leaving behind a concentrated solution which returns to the absorber. In the condenser the vapor is condensed at about 112° on the surfaces of the condenser tube bundle which carries cooler condensing water. The liquid refrigerant is expanded through an orifice to the lower pressure evaporator. The instant evaporation or flashing of some of the liquid cools the remainder to a boiling temperature of about 40°F. The refrigerant is circulated from the bottom of the evaporator chamber and sprayed over the evaporator tube bundle. As the liquid evaporates it cools the water which flows through the tubes and back out to air conditioning cooling coils. The evaporated refrigerant vapor migrates to the absorber section where it is absorbed by the concentrated absorbing solution. The heat released in this process is rejected to condensing water. The diluted solution is then pumped back to the concentrator.

Absorption machines were developed for large capacity use before the advent of the centrifugal chillers. Absorption equipment is highly inefficient having efficiencies of only 20 to 30 percent. As a result, their use has declined except in buildings that have waste steam or excess steam available. Absorption refrigeration can be useful as a back up to centrifugal equipment in situations where it is crucial to hold down the electrical power use.

Besides heating, cooling, humidifying, and dehumidifying, HVAC equipment provides good interior air quality. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) has established standards for air quality. City codes also frequently specify the amount of outside air that must be brought into a space. The process of supplying and removing air by natural or mechanical means to or from a space is termed ventilation. The purpose of ventilation is to replenish oxygen in a building and remove air that has been contaminated. Most fan systems are designed to bring in a certain amount of outside air. The amount of fresh air required is dependent on the function of the interior space. For example, a chemical laboratory may require that 100% of the air supplied to the lab be brought in from outside to replace the interior air contaminated by chemical fumes. An office building may require as little as 10% of the supply air be brought in from outside, the remainder being recirculated air. Table 2 lists a sampling of ventilation requirements as recommended by ASHRAE. Note that Department of Defense or local codes may vary considerably from the requirements listed in Table 2 and that the applicable code or guidance for a particular facility should be used for that facility.

Table 2

Outdoor Air Requirements for Ventilation

	Smoking	Non-smoking
Cafeterias	35	7 cfm/person
Hotel bedrooms	30	15 cfm/room
Hotel lobbies	15	5 cfm/person
Office space	20	5 cfm/person
Pet shops	1	1 cfm/ft^2
Hospital operating rooms	-	40 cfm/person
Auditorium	35	7 cfm/person

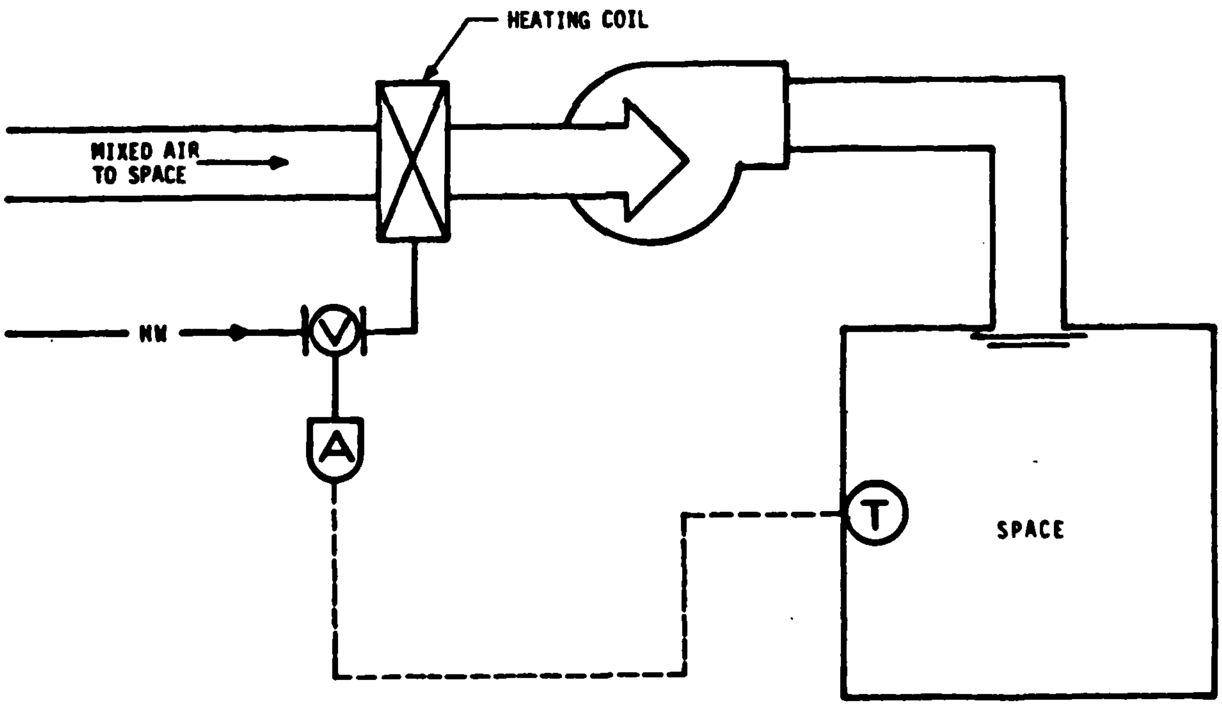
HVAC fan systems also control air purity by reducing or eliminating unwanted particulate or gaseous matter from the air supplied to a space.

This is accomplished by placement of filters in the air streams. There are many types of filters which vary in the degree of efficiency. Normal applications are generally concerned with removal of only particulate matter. Laboratory "clean rooms" require very high efficiency filters which will remove a major percentage of very small particles. Other applications require filters capable of eliminating odors, viruses, and bacteria.

Ventilation and filtering affect the energy consumption of HVAC equipment. Outside air which is introduced to a building needs to be heated and cooled contributing to the heating and air conditioning load. Therefore, it should be kept at a minimum, within recommended limits, most of the time. Filters are an obstacle to the flow of air in an air handler adding to the horsepower requirements of the system fans. More efficient filters result in greater pressure loss and the need for larger fans. So high efficiency filters should only be installed where the function of the conditioned space requires it. Dirty filters result in greater load on existing fans and cut down on the actual volume of air delivered to a space. To maintain greater system energy efficiency as well as filtering efficiency filters should be cleaned or replaced regularly.

SECTION 2. CONTROL CONCEPTS

Most HVAC systems have some kind of automatic control system, often referred to as a local control loop, which at least controls the operation based on a room thermostat if not much more. The primary components for the automatic control systems are sensors, controllers, and actuators. The sensor senses changes in a variable, and sends a signal to a controller indicating a change has taken place. The controller receives that signal, interprets it, and takes an action based on the sensed input and the



HEATING COIL CONTROL

Figure 1-9

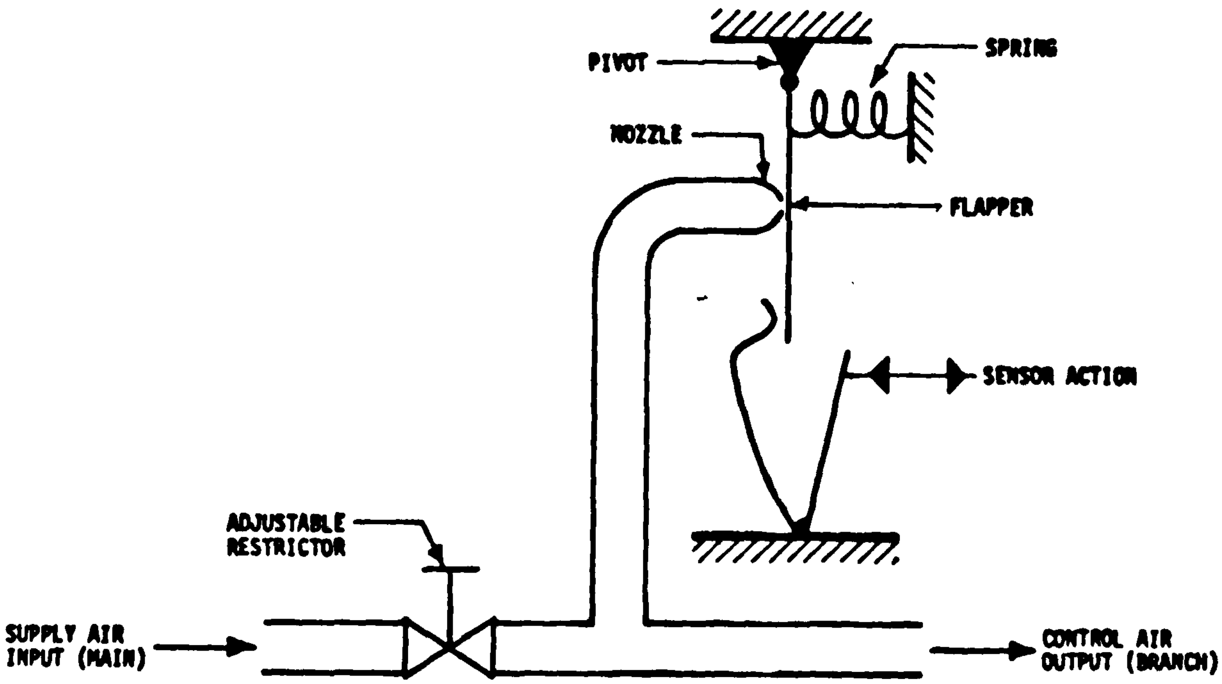
controller settings. The output of the controller signals an actuator which effects some change on a component of the HVAC system.

As an example of a control system consider a person driving an automobile. The sensor is the eyes which note the changes in the curve of the road. The brain is the controller which interprets what the eyes see and decides what corrective action needs to be taken to keep the car on the road. The hands are the actuator which respond to the brain's signals and adjust the steering wheel to maneuver the car which is the controlled system.
The typical control situation in an HVAC system is a thermostatically controlled hot water valve on a heating coil, illustrated in Figure 1-9. The room thermostat is the controller which also houses the sensor that senses air temperature. The valve actuator positions the valve to limit the amount of hot water flow through the coil.

There are two primary types of measurement and control used in HVAC applications: two position and modulating (proportional). Two position control devices designate one of two operational modes, such as on/off or open/closed. Two position measurement sensors detect if the equipment is on or off, open or closed. Two position type measurement also can be used to sense whether a measured variable is above or below a set value. For example, a freezestat can detect whether or not a temperature is above 40°F, and as a result opens or closes electrical contacts in a circuit. Likewise a differential pressure switch interrupts or completes an electric circuit if the difference in pressure between two pressure sensors is above or below a set value. A flow switch responds the same to flow of a liquid.

Modulating or proportional control devices set an actuator or motor at any position between on or off (open or closed). For example, a modulating control device may be used to position a valve to regulate the flow of water. As the valve position varies from open to closed the flow rate of water varies from full flow to no flow. Proportional measurement produces a signal whose value is related to the value of a real physical parameter.

For example, a temperature sensor produces a output signal which is proportional to the temperature it is measuring. Such devices generally have a limited range over which they operate. For example, a temperature sensor designed to measure room temperature would be reasonably accurate over the range of 50° to 100°F, but would not be accurate for measuring boiler stack gas temperatures on the order of 1000°F.



SIMPLE PNEUMATIC CONTROLLER

Figure 1-10

Another element which is necessary for automatic control is a source of power to supply energy to the actuator and for the transmission of signals. This power supply can be either pneumatic or electric/electronic. Both two position and modulating control systems can be constructed using either pneumatic or electrical control devices.

Pneumatic controls are powered by compressed air, usually 15 to 20 psig pressure, although higher pressures are occasionally used for operating very large valves or dampers. Pneumatic devices are inherently modulating, since air pressure may easily be provided with infinite variation over the control range. Because of their simplicity and low cost, pneumatic controls are frequently found on commercial and industrial installations using more than eight or ten devices.

Pneumatic devices available include sensors, controllers, actuators, relays, and transducers. A relay is a two position switch. Transducers are devices which can convert a variable output electrical voltage to a varying air pressure or vice versa. Relays and transducers may be used to interface pneumatic and electric devices or control systems. For example, a pneumatic/electric (PE) relay is an electric switch which opens or closes in response to a pressure signal. An electric/pneumatic (EP) relay is a solenoid air valve which is opened or closed based on the status of the electrical circuit to which it is connected.

Electric controls are available in a wide variety of configurations for every conceivable purpose in HVAC application. All of these are based on one of four operating principles: The switch, the electromagnetic coil and solenoid, the two position motor, and the modulating motor.

Any electrical circuit includes three elements: a power source, a switch, and a load. The load represents resistance and consumes the power. The switch serves to turn the power on and off. In an HVAC system, the load will be an actuator or relay, the switch will be sensor-controller. The power source is usually the building's electrical power which may be used at a normal 120 volts or transformed to some lower voltage, typically 24 volts. Some electrical devices use direct current (DC). This may be supplied by a battery or an alternating current (AC) source by means of a transformer and rectifier.

In addition to classifying controls as two position or modulating and pneumatic or electric, a new classification is evolving with the integration of computer technology into control systems. This classification is analog versus digital type control systems. In the past, most control systems have been analog systems where signals within the control system varied continuously in some physical manner related to the control system activity and control logic was implemented by means of relays, controllers, actuators, and other physical devices. Digital control systems, which are becoming more common, use micro computers to perform control logic functions and computations. Sensor and control signals are transmitted in the form of digitally encoded data rather than continuous varying signals.

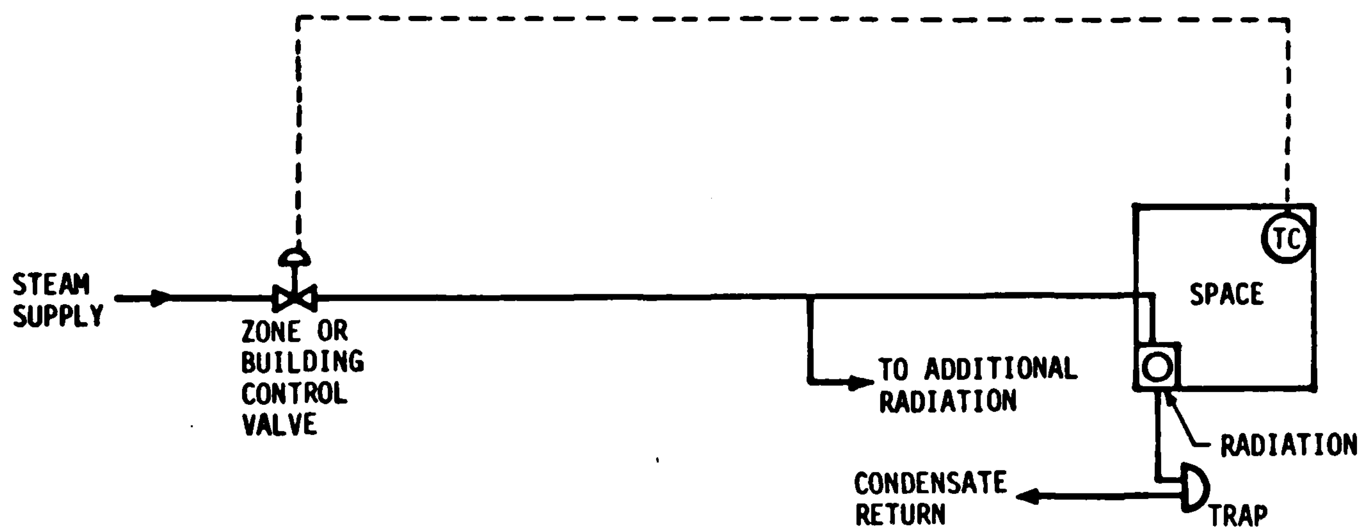
SECTION 3. CONFIGURATION AND OPERATION OF TYPICAL HVAC SYSTEMS

There are a wide variety of HVAC systems used to provide heating and cooling to buildings, in fact almost every building/HVAC system combination is unique in its implementation and operation. In this section, a general description of the most commonly used HVAC systems will be provided, however, it should be understood that at a particular installation the actual implementation and operation of HVAC systems may vary considerably from what is described herein. However, the basic concepts and terminology should give the EMCS operator a overview of HVAC systems and their functions.

Radiator

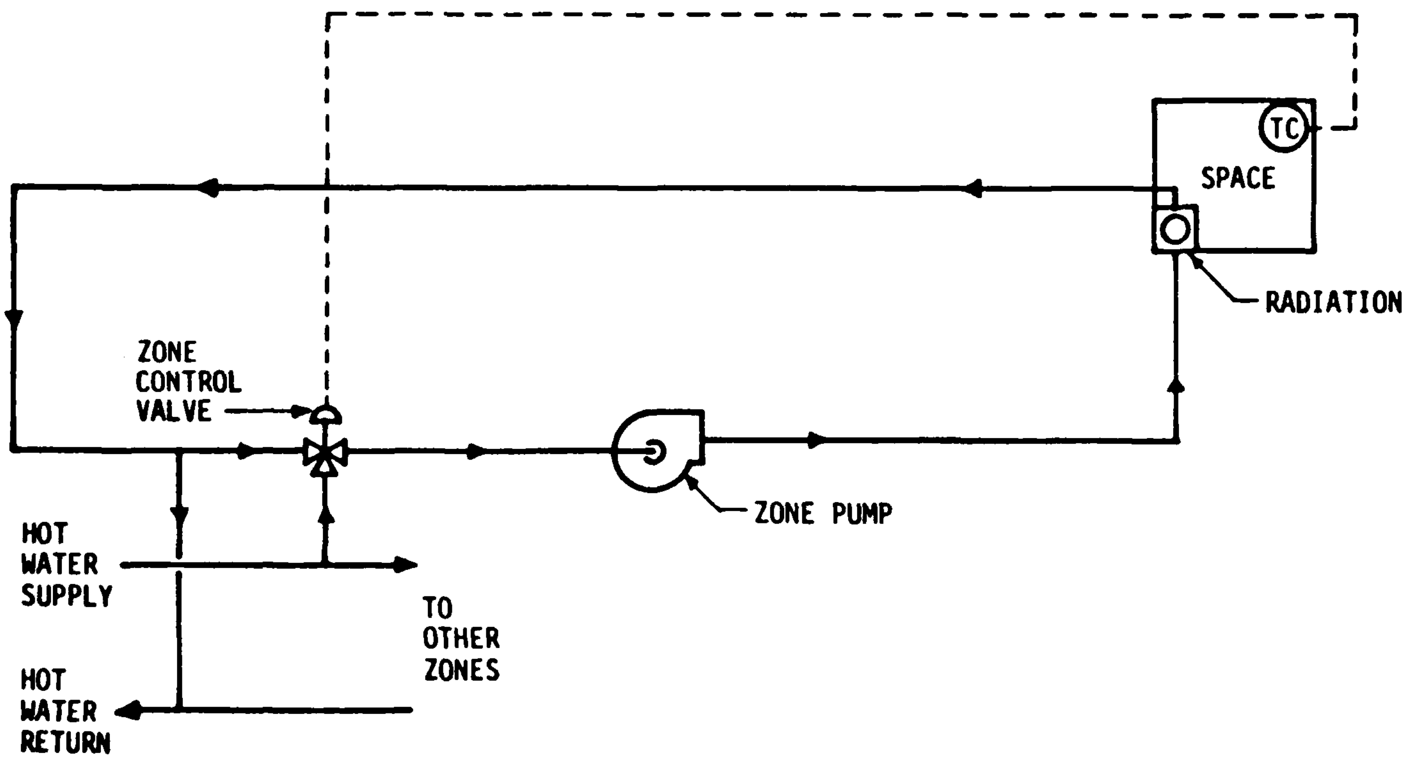
The simplest type of HVAC equipment is the radiator. It only provides heating. Heat is transferred to the air, people and objects in the room by radiation and natural convection from the hot surfaces of the radiator. Natural convection is the process by which heat is transferred between a solid surface and a fluid (liquid or gas) which moves across it as a result of the temperature difference. The heating medium in radiators is steam, hot water, or electricity.

A radiator may be automatically or manually controlled. Automatic control is achieved by thermostatic control of a steam valve at each radiator. Usually a self contained thermostat/valve combination is used for that purpose. In addition to individual room control, entire radiator systems may be controlled based on the outside air temperature. If the outside air temperature is above a certain setpoint, the pump (for hot water systems) or main steam valve (for steam systems) may be turned off or closed. In addition, for hot water systems the temperature of the water supplied to the radiators may be varied depending on outside air temperature. For example, if the outside air temperature is 60° the water supplied to the radiators may be set at 100°, while if the outside air temperature is 0°, the hot water temperature may be set at 200°.



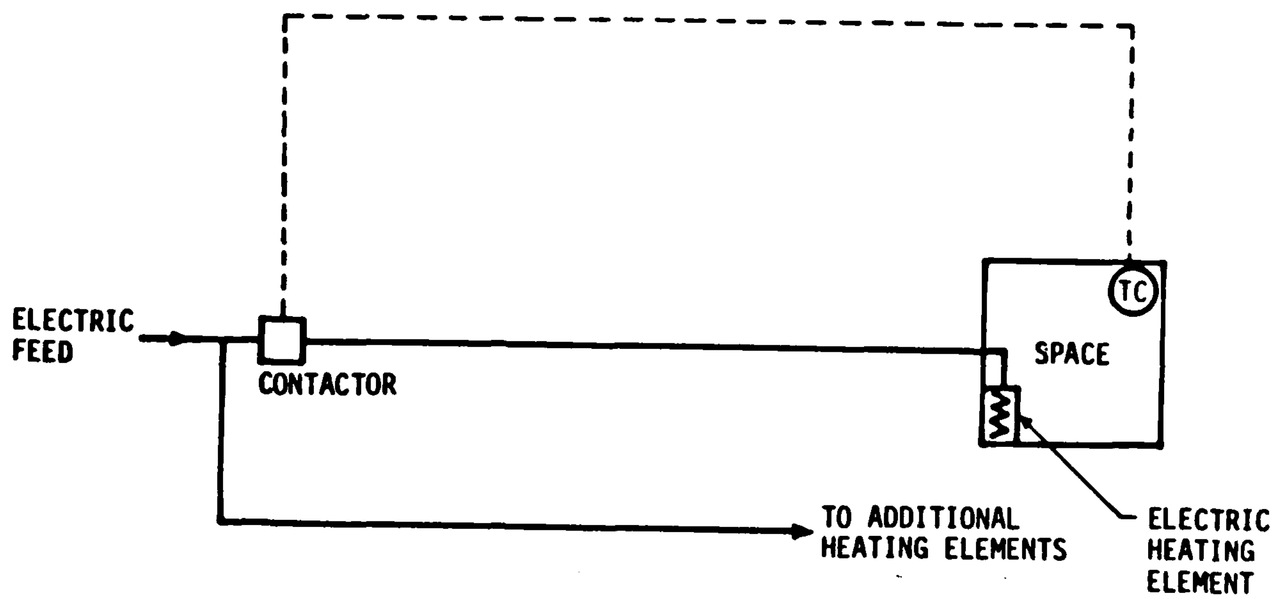
STEAM RADIATION

Figure 1-11.



HOT WATER RADIATION

Figure 1-12.



ELECTRIC RADIATION

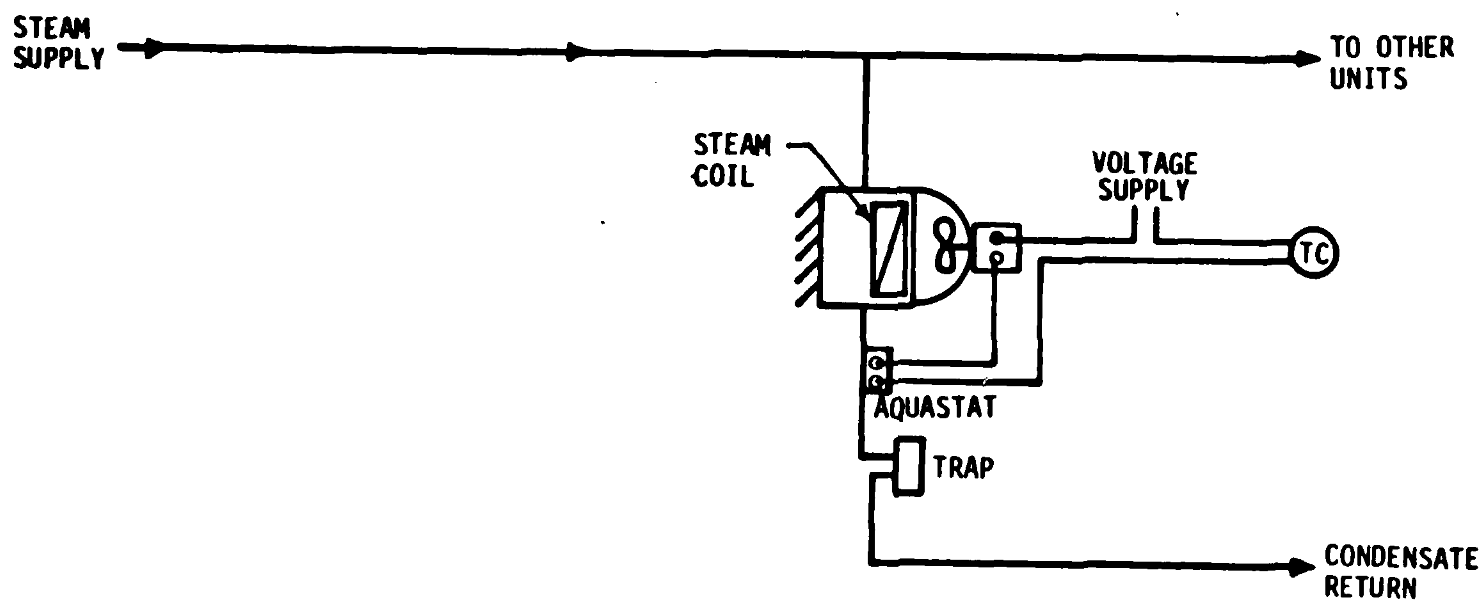
Figure 1-13.

Most radiation systems are not properly controlled. As a result, they can waste energy and easily overheat a space. If the occupants of the space have no other means of control, they usually open the windows to maintain the space at a reasonable temperature. This obviously is an extreme waste of energy, a result of the inability of the control system to do its job.

A convector is a variation of the radiator, designed to transfer heat to the space primarily through convection. Convectors have specially designed enclosures to promote free air flow through a coil or other heat transfer surface. The same types of control used for radiators are used for convectors.

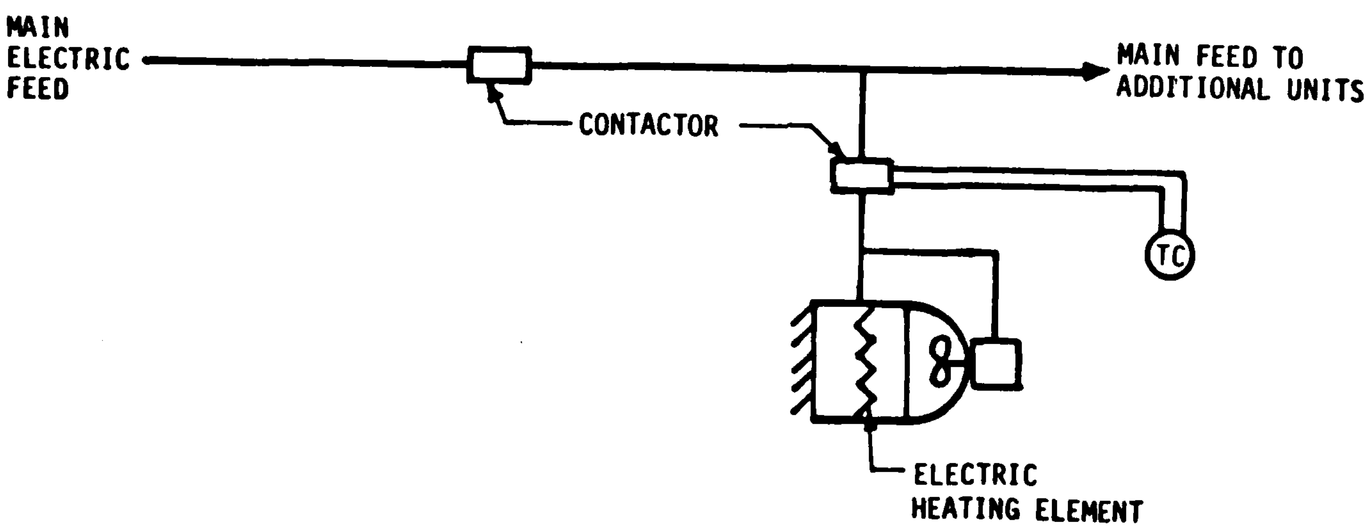
Unit Heater

Another type of heating only device is called a unit heater. A unit heater is basically a radiator or convector with a fan added to the system. A unit heater may be steam, electric, or hot water type and may be controlled using the methods described for radiation systems. In addition, control may be accomplished by cycling the unit heater fan in response to a room thermostat. However, an additional control mechanism must be provided to prevent the unit heater fan from operating when a heat source is not available (i.e. when the steam supply to the building has been turned off). This may be accomplished through wiring interlocks or by an aquastat attached to the piping supplying the unit heater coil. The aquastat senses the temperature of the piping and if it is below a set temperature (indicating the heat source has been turned off) it will not allow the unit heater fan to run, even though the thermostat in the room calls for heating. This prevents the fan from circulating cold air, which would cause further discomfort to the room occupants. While the unit heater is still a heating only system, it has greater flexibility than radiators and convectors in that it can more widely distribute the heat within the space it serves.



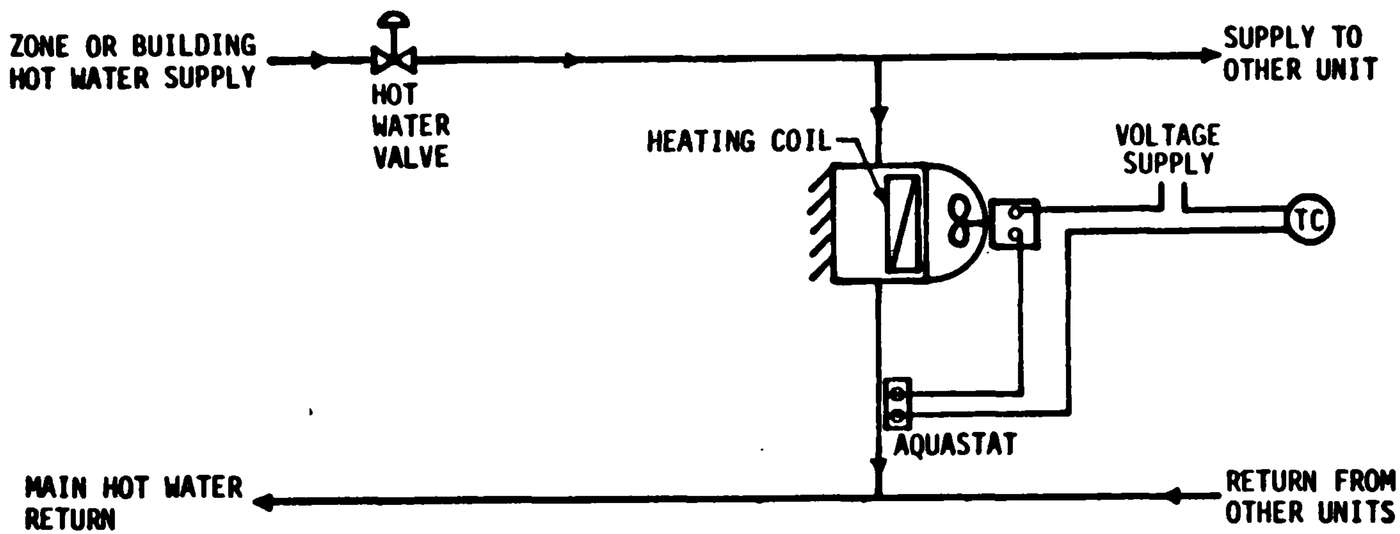
STEAM UNIT HEATER

Figure 1-14.



ELECTRIC UNIT HEATER

Figure 1-15.



HOT WATER UNIT HEATER

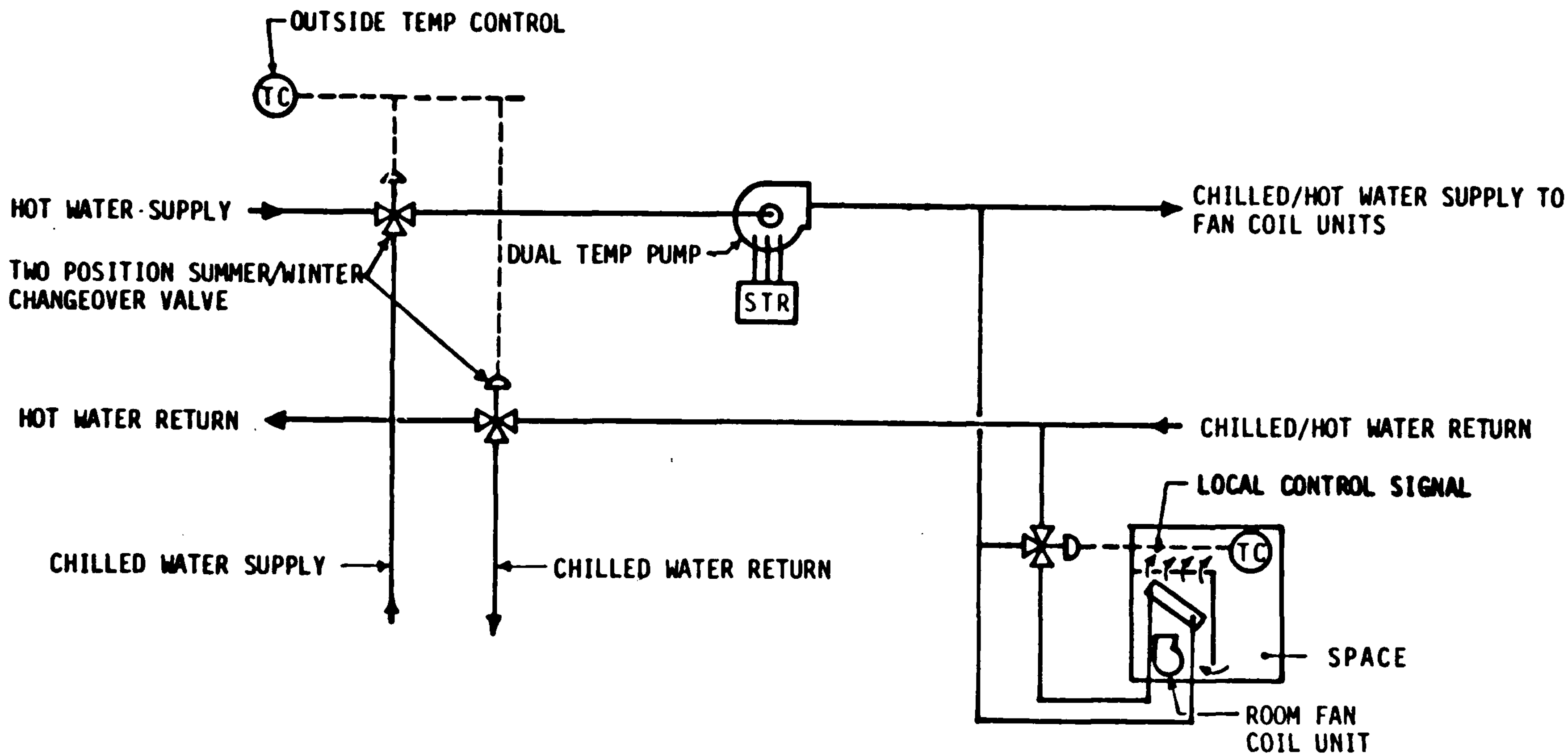
Figure 1-16.

Fan Coil

Another type of HVAC system similar to the unit heater is called a fan coil system. Fan coil systems generally provide heating and cooling. A fan coil unit consists of a small fan and coils mounted within an enclosure. An individual fan coil unit normally serves a single room and may be mounted above the ceiling with a diffuser or register supplying air or on the floor at an exterior wall. Normally, many fan coil units are connected together by the piping network which carries hot or chilled water from some central heating or cooling equipment location.

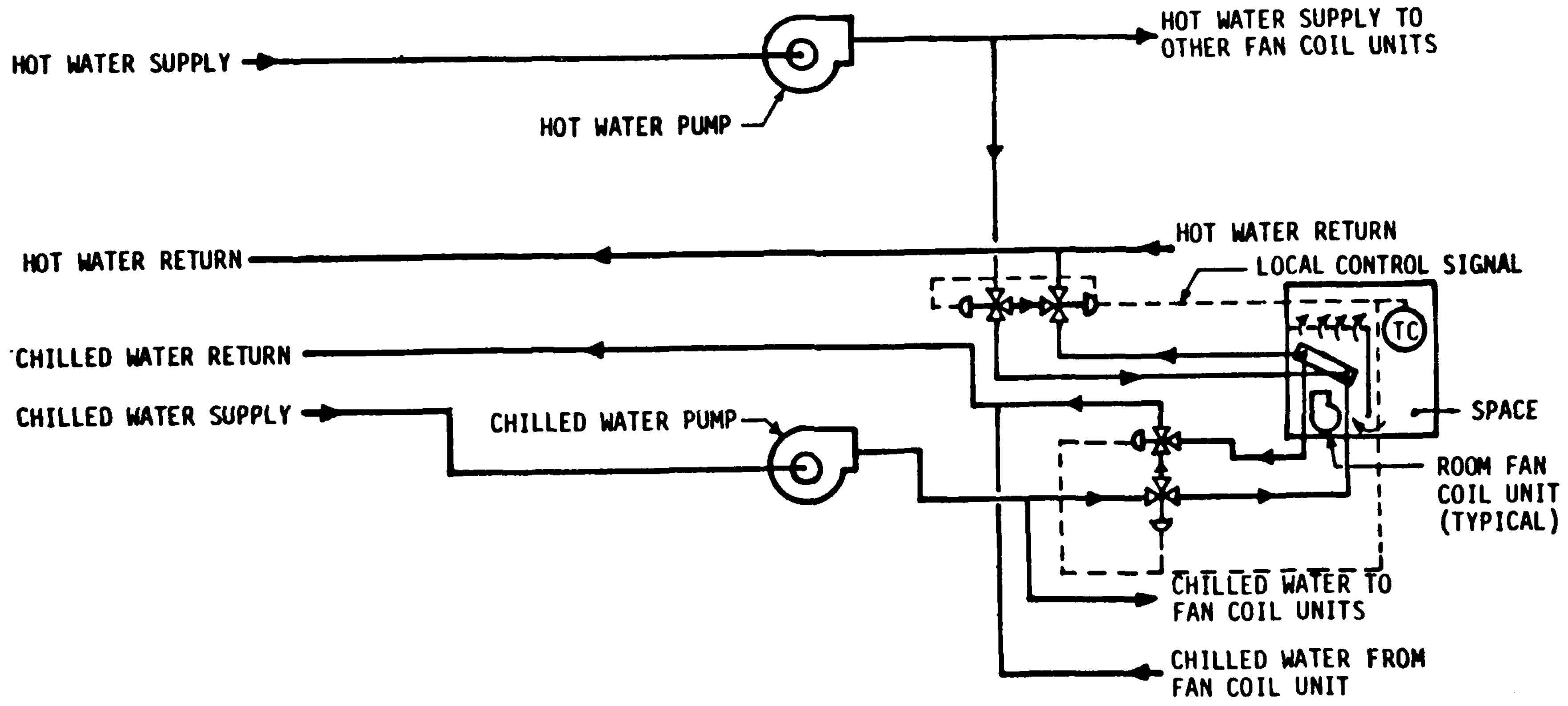
Fan coil systems classified as "two pipe" systems house a single coil which is used for heating in the wintertime and cooling in the summertime. It is connected to a single supply pipe and single return pipe. In the summer, chilled water is circulated in the piping system and in the winter hot water is circulated in the piping system. A "four pipe" fan coil system has two separate coils connected to separate chilled water and hot water circulating systems. Thus, in a four pipe system, heating or cooling may be chosen by the room thermostat based on the room temperature.

Fan coil system controls generally consist of a thermostat which controls the action of the fan coil unit. The thermostat may be mounted within the fan coil unit enclosure or mounted separately on a wall. Some fan coil control systems allow the fan to run continuously and modulate temperature by opening or closing chilled or hot water valves serving the fan coil unit. Other control systems cycle the fan coil unit fan on and off based on the temperature requirements. In addition to the local controls at each fan coil unit, a two pipe fan coil system must contain controls which perform the changeover from circulation of hot water to chilled water when operation of the system is changed from heating to cooling and vice versa. This changeover control may be accomplished automatically based on outside air temperature or other parameters, or may be manually accomplished based on the season of the year.



TWO PIPE FAN COIL

Figure 1-17.



FOUR PIPE FAN COIL

Figure 1-18.

Some fan coils have an outside air vent with a manually controlled damper for bringing in a small amount of fresh air. Individual room units with more sophisticated automatic damper control of outside air also exist. These are usually termed unit ventilators.

Central Fan Systems.

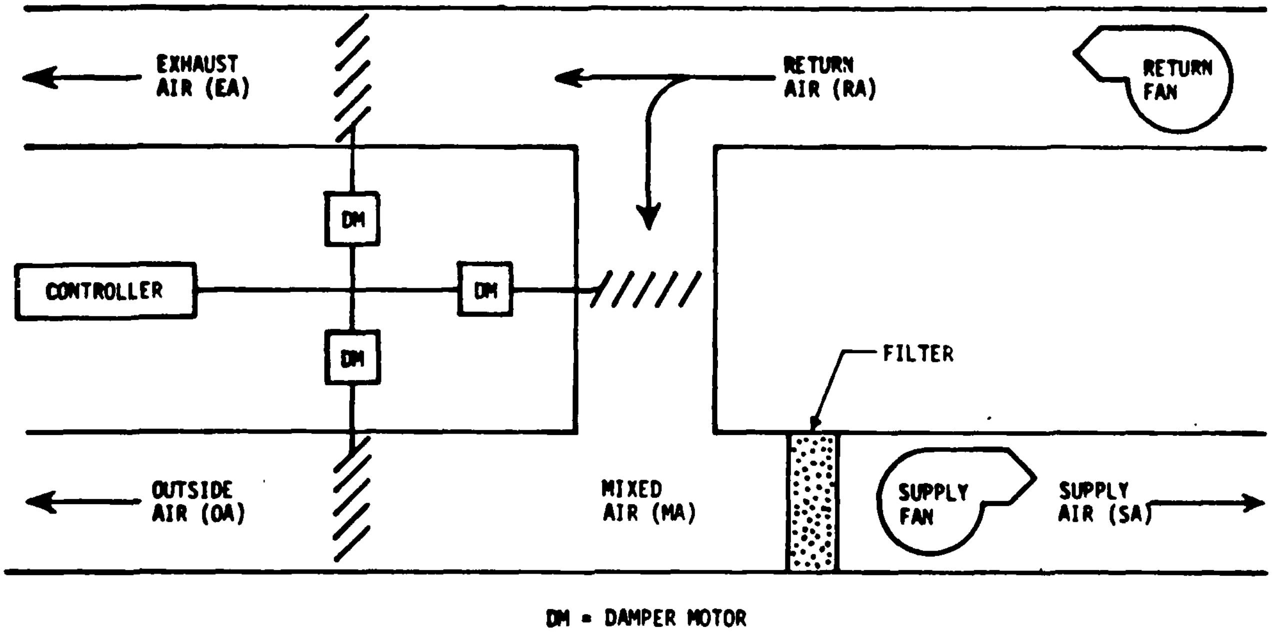
Radiators were the most common heating system used in the past. Now fan coil units are used heavily for specific types of applications (hotels, motels, dormitories, etc.), but most buildings which would be connected to an EMCS are provided with heating and cooling through various types of central fan systems. These systems provide for the distribution and control of heating and cooling energy to individual spaces within a building. They may or may not include the primary energy conversion mechanism for heating or cooling. In general, central fan systems use a system of ductwork to distribute heated or cooled air from the fan system location to the spaces it serves. Air is returned from those spaces through separate ducts or plenum system for recirculation or exhaust. A central fan system generally serves several areas of a building instead of only one room. The different types of central fan systems which will be discussed are:

1. Single zone air handling unit.
2. Terminal reheat air handling unit.
3. Multizone air handling unit.
4. Double duct air handling unit.
5. Variable air volume air handling unit.

In addition to the temperature controls, central air systems normally have safety controls to prevent damage to the equipment or to provide occupant safety. Common devices for these purpose are freezestats, firestats, and smoke detectors. A freezestat is normally located on the inlet of heating or cooling coils which are susceptible to freezing. If the entering air temperature to the coils drops below the 35° to 40° temperature range, the freezestat will automatically shutdown the fan system to prevent freezing of the coils. In a similar manner, firestats are located within the fan system such that if they detect a temperature above 125°F they shutdown the air handling system. Most modern systems also include smoke detectors within the air handling system and in the occupied spaces which sense the presence of smoke and shut down the air system, if smoke is detected. Smoke detectors may also be used to operate central air systems in special smoke control modes, when the air system is actually used to evacuate smoke or to pressurize areas adjacent to smoke filled spaces to prevent migration of smoke into the uncontaminated areas. These smoke control systems can be extremely complicated and sophisticated.

Most central fan systems have the capability of providing varied amounts of outside air for ventilation. Air pulled from conditioned spaces through a return air duct or plenum is mixed with outside air drawn in through an outside air louver or other intake means. In order to maintain a balance of air pressure inside and outside the building, the same amount of air must be exhausted as is brought in through the outside air inlet. In most commercial buildings, a slightly greater pressure inside the building is desirable. This reduces, if not eliminates, the occurrence of infiltration through walls, doors, and windows. Therefore, fan systems are usually designed to bring in a slight excess of outside air.

Air is exhausted from a building in a variety of ways: through toilet exhaust fans, kitchen exhaust fans, fume hoods, and gravity relief dampers. Air may also be exhausted through exhaust air ducts and dampers at a central fan system. Where automatic control of the amount of outside air or condition of the mixed air (mixture of return air and outside air) is desired, variable position dampers are placed in the three air streams: return, exhaust, and outside air. These control the quantity and direction of flow of the three air streams.



VENTILATION CONTROL

Figure 1-19

The dampers are positioned by a damper motor or three separate damper motors controlled simultaneously. The outside air and return air dampers work in opposition to each other. For example, if the outside air damper is 100% open, the return air damper is 100% closed. As the outside air damper begins to close, the return air damper opens an equal amount. The exhaust air damper works in unison with the outside air damper, so if 100% outside air is brought in, then all of the return air brought back by the return fan is exhausted. A controller will position the dampers based on a variety of different control schemes which can take into account mixed air temperature, return air temperature, outside air temperature, minimum outside air percentage, and other safety factors. See Figure 1-19 for an illustration of the position of ventilation dampers.

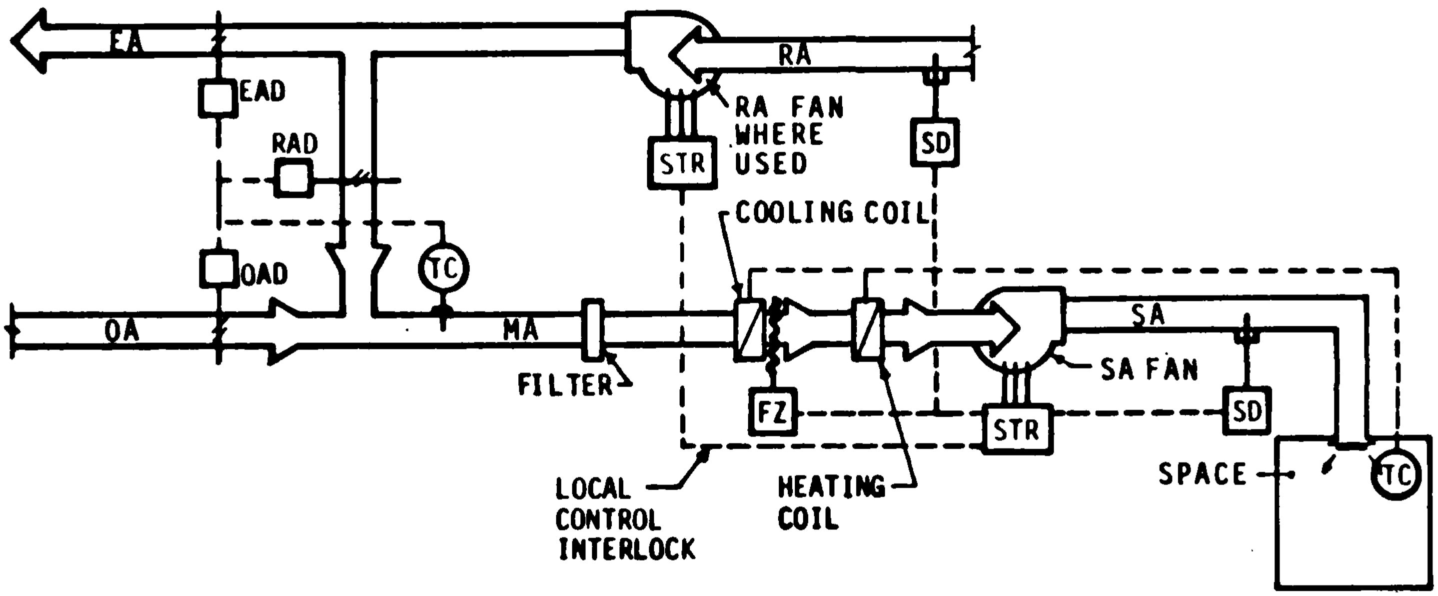
Single Zone Air Handling Unit

A single zone air handling unit serves several areas with a single supply duct system. Air is heated or cooled in the unit and supplied at a fixed flow rate (constant volume) to the spaces served. The unit may have both heating and cooling coils in series and in some cases a humidifier may be provided. The heating energy may be supplied by steam, hot water, or electricity, and the cooling coil may be supplied with chilled water or may be a direct expansion type coil.

The operating control of the single zone air handling system is accomplished by varying the supply air temperature in response to the temperature of the space served. If the space requires heating, the supply air temperature is increased by the control system, and if the space requires cooling, the supply air temperature is decreased by the control system. Supply air temperature control may be accomplished by modulating or cycling valves on the supply lines to the heating and cooling coils.

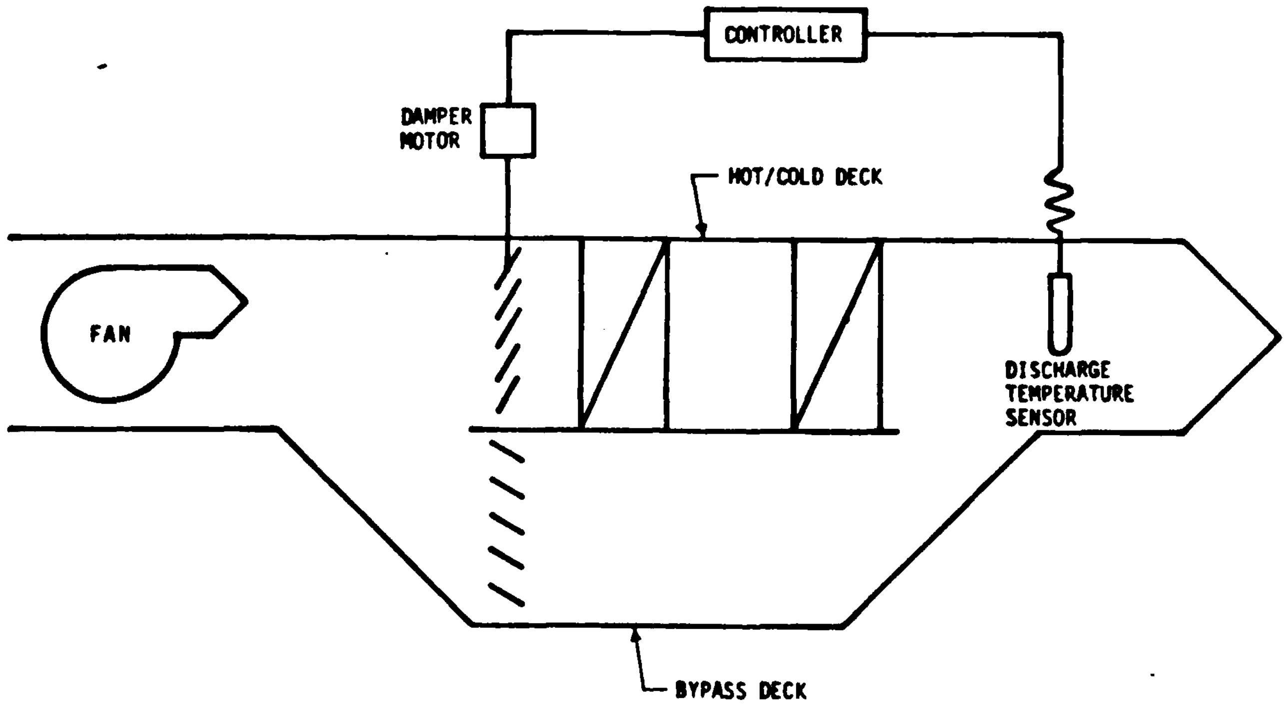
An alternate control mechanism commonly used on single zone air handling systems is the face and bypass control method. See Figure 1-21. With this system a set of dampers is located on the inlet side of the coil to be controlled. A section of ductwork connecting the coil inlet and outlet provides a bypass path around the coil. A control damper is also installed in this bypass section. By modulating the position of the damper on the face of the coil in conjunction with the damper in the bypass duct, the quantity of air passing through the coil may be reduced and then mixed with the bypass air in order to vary the final supply temperature from the coil.

A single thermostat controls the operation of the single zone system. This is the most inexpensive of the central fan systems, but spaces served by this system may be too hot or cold if the load in those spaces differs from the single space where the thermostat for the system is located. For example, if a thermostat is located in a space where full heating is



SINGLE ZONE AHU

Figure 1-20.



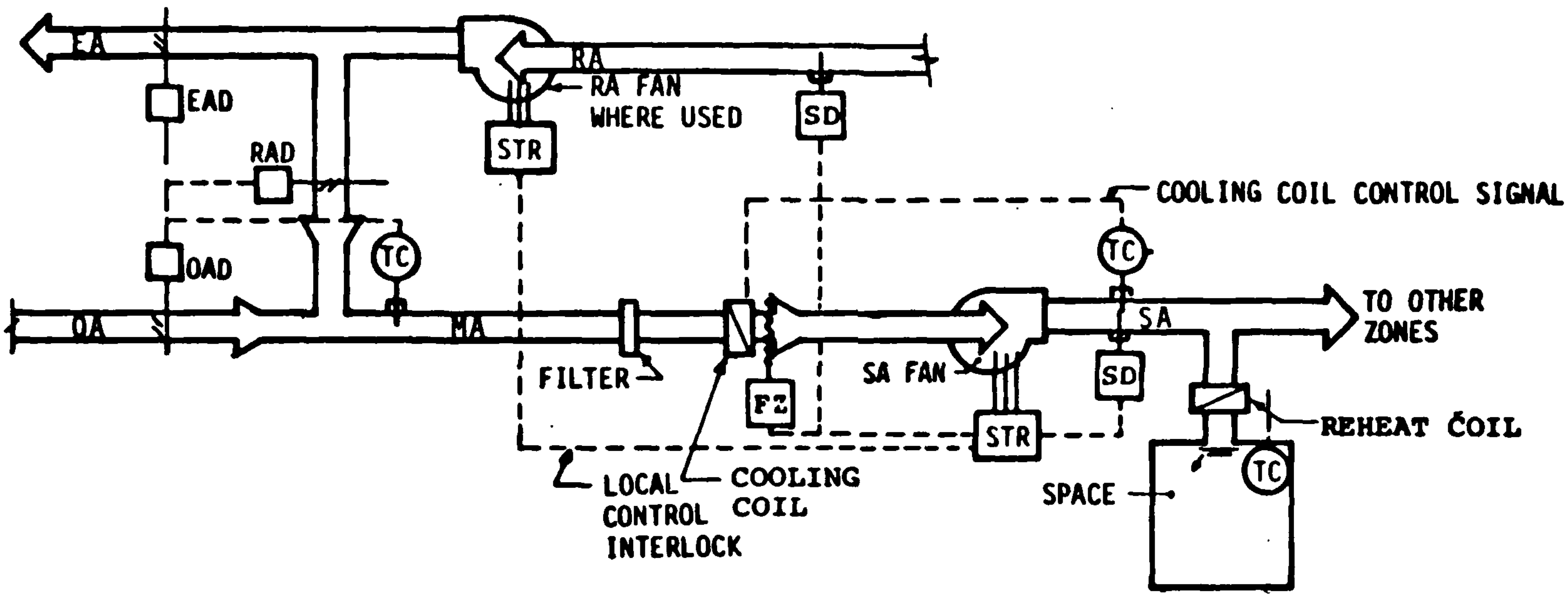
FACE AND BYPASS SECTION

Figure 1-21

required then other spaces which do not require full heating at that time will be overheated.

Terminal Reheat Air Handling Unit

A terminal reheat air handling unit can deliver different supply air temperatures to different areas of the building called zones. Each zone includes a thermostat which controls the temperature of the air supplied to that zone in response to the heating or cooling load within the zone. In a



TERMINAL REHEAT AHU SYSTEM

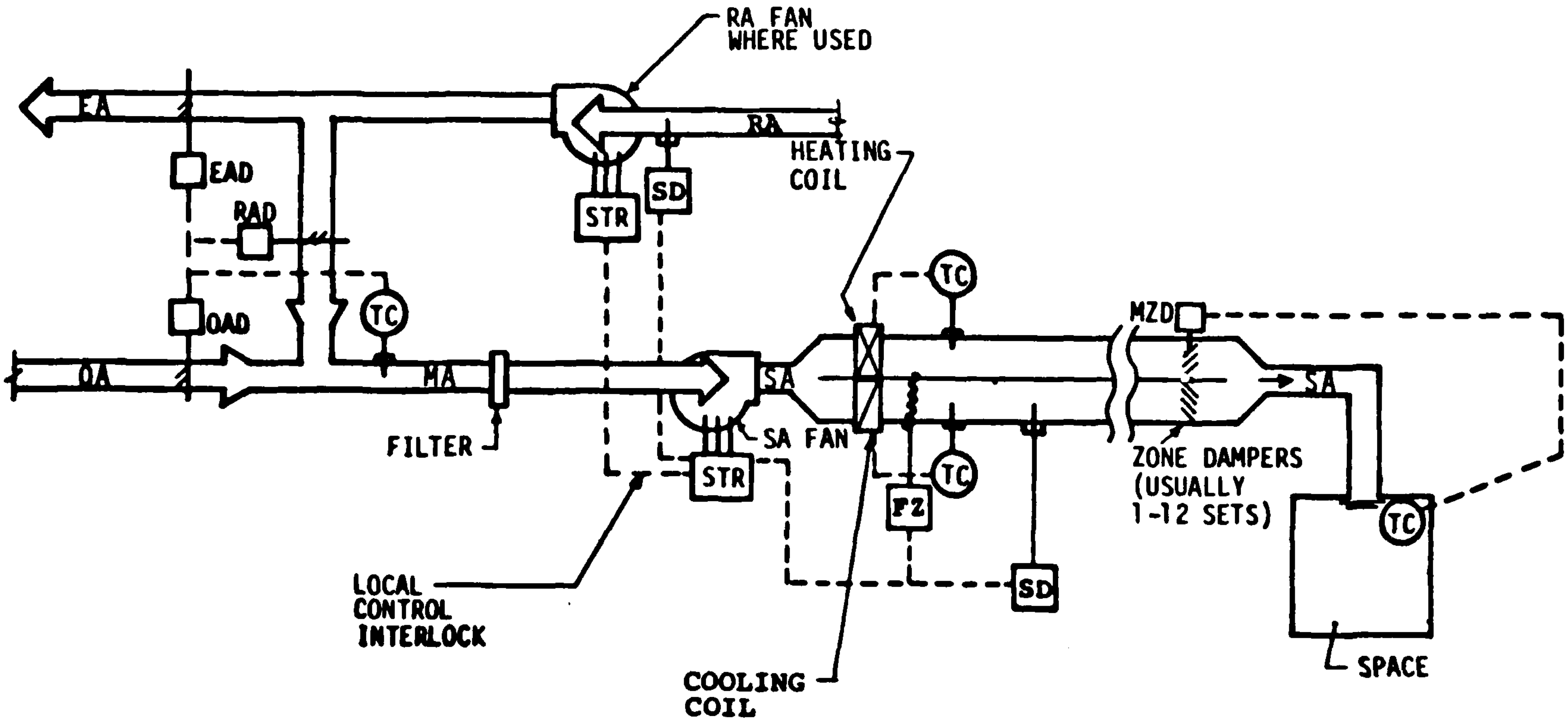
Figure 1-22.

terminal reheat air handling system, the cooling coil is located within the air handling unit, but heating coils are located within the duct work serving each individual zone. One heating coil is provided for each of the zones.

The cooling coil is controlled by a supply air temperature thermostat which maintains a constant cool supply air temperature to all the zone reheat coils. If the room thermostat for a zone senses the need for full cooling, then the heating coil serving that zone is turned completely off and the cold supply air is provided directly to the zone. If no heating or cooling is required within a zone, the thermostat controls the heating coil to add enough heat to the supply air to heat the supply air to room temperature. Thus, the supply air entering the room is at the same temperature as the room and no net heating or cooling is performed. If the thermostat senses the need for heating, then the reheat coil adds even more heat to the air stream to provide the heating energy required. Obviously, this type of system is extremely wasteful of energy, since energy is used to cool the air at the unit in the cooling coil and then energy is used by the reheat coils to reheat the same air. Terminal reheat systems are used very rarely today, in fact, their use in some states has been outlawed except in special situations (hospital operating rooms, computer rooms, etc.).

Multizone Air Handling Unit

A multizone air handling system is also capable of discharging different supply air temperatures to zones with different heating or cooling requirements. However, it accomplishes the variation in supply air temperature in a different manner than the terminal reheat system. Instead of reheating the supply air for each zone, the total air flow within the unit is divided into hot and cold air streams which are then mixed to provided the proper supply air temperature to the individual zones.



MULTIZONE AHU

Figure 1-23.

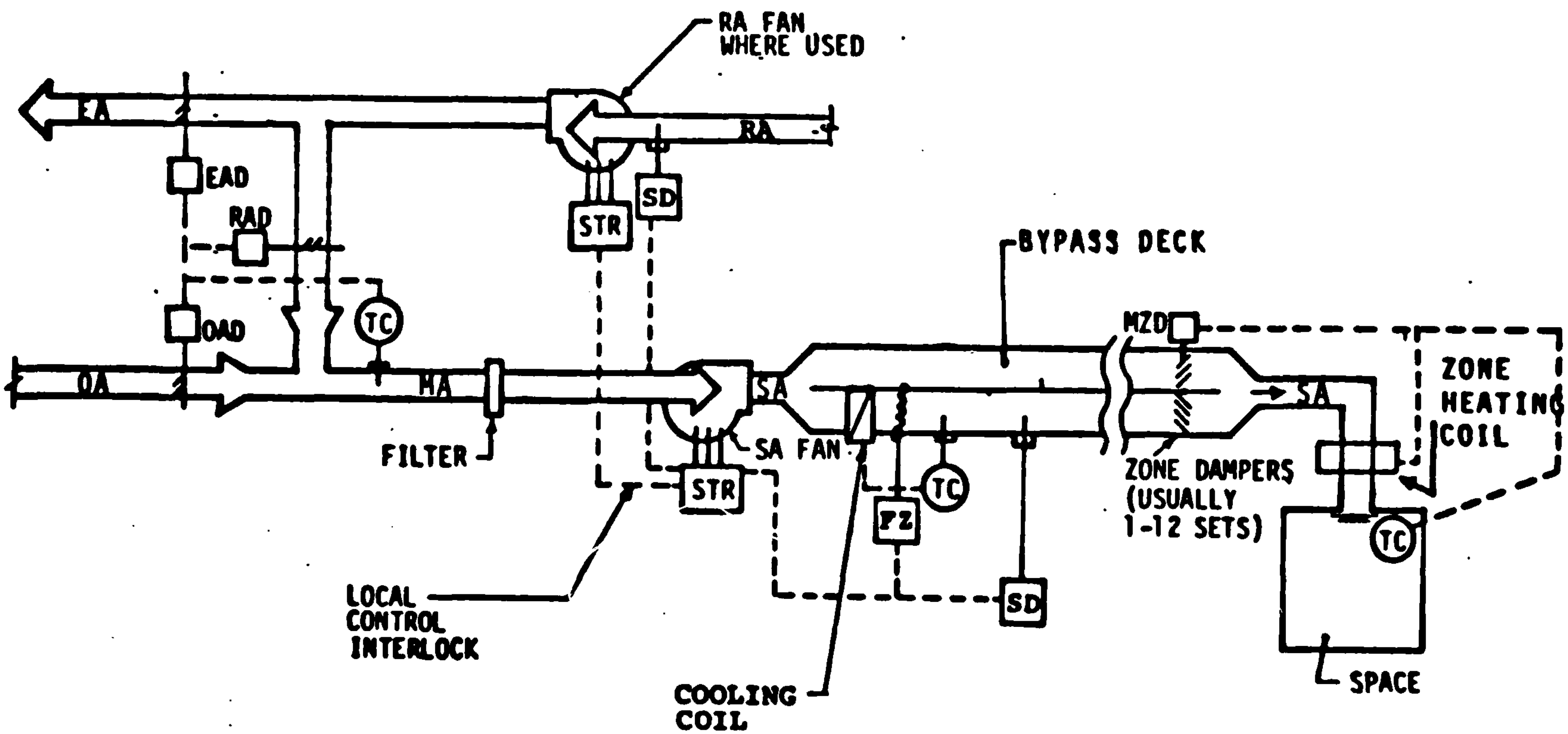
Air is blown through a heating coil into a plenum (called the hot deck) and through a cooling coil into a plenum (called the cold deck). Openings for each zone are provided in each of the two plenums. A damper in each of the zone openings regulates the amount of cold or hot air which is allowed to pass from the cold or hot deck into the supply duct for each individual zone. The hot and cold deck dampers for a single zone are controlled by a single damper motor such that when the zone requires full cooling the cold deck damper is fully open to the cold deck while the hot deck damper is completely closed. When the zone requires full heating, the hot deck damper is completely open and the cold deck damper is completely closed. When the zone requires neither heating or cooling then the dampers are positioned such that the supply air to that zone is maintained at the same temperature as the room. Separate controllers sensing the coil discharge temperatures modulate control valves serving the heating and cooling coils to maintain constant temperatures in the hot deck and in the cold deck.

While the multizone air handler is more efficient than a terminal reheat system, it still wastes large quantities of energy whenever zones being served are not at full heating or full cooling load, since heated and cooled air must be mixed in order to maintain the space temperature.

A more energy efficient variation of a multizone unit is called a bypass multizone. As can be seen in Figure 1-23A, no heating coil is installed in the hot deck (thus it is called a bypass deck) and instead individual zone heating coils are provided. These heating coils are only energized when the zone dampers are closed to the cold deck and open to the bypass deck, thus eliminating mixing of heated and cooled air streams.

Double Duct Air Handling Unit

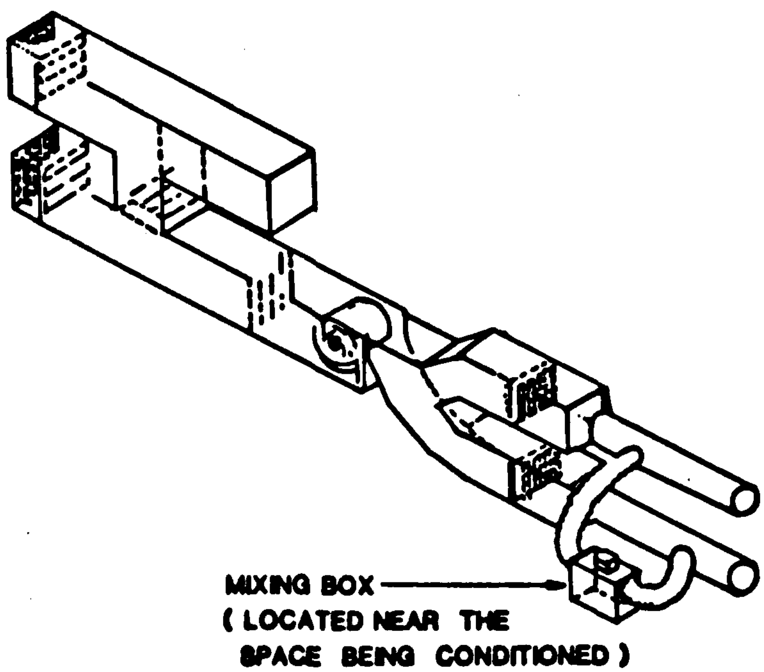
A double duct air system operates essentially the same as a multizone system except that the hot and cold air streams are mixed at the zone



BYPASS
MULTIZONE AHU

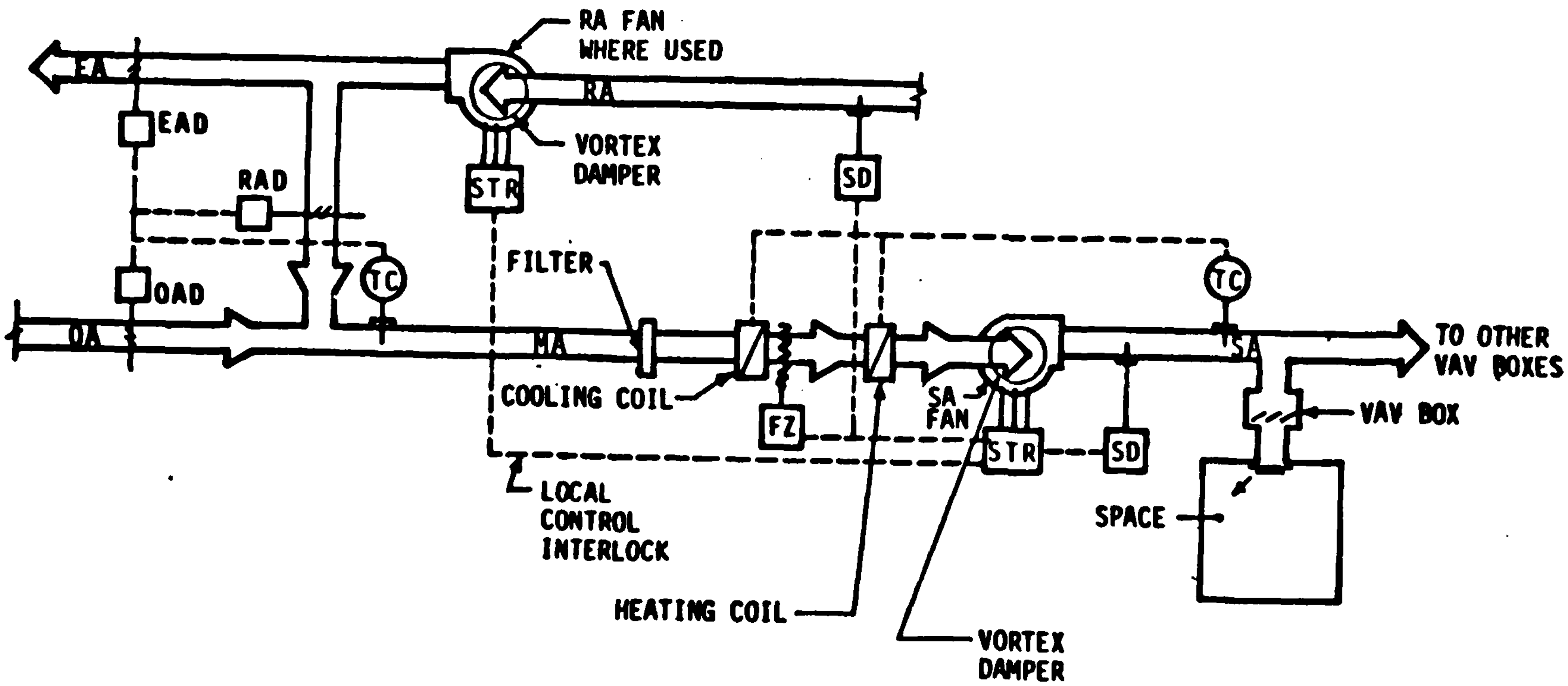
Figure 1-23A

location rather than at the air unit location. Hot and cold ducts are extended from the heating coil and cooling coil discharges throughout the building. At each zone a mixing box is provided which is connected to the hot and cold ducts. Dampers within the mixing box then mix the hot and cold air in response to a space thermostat in the zone they serve. This is accomplished in a manner similar to that described for the multizone unit. The heating and cooling coils are controlled to maintain constant supply air temperatures in the hot and the cold ducts that they serve. This system has the same inefficiency as a multizone system. It is primarily applied where more zones are required than a multizone unit can practically serve.



DOUBLE DUCT SYSTEM

Figure 1-24



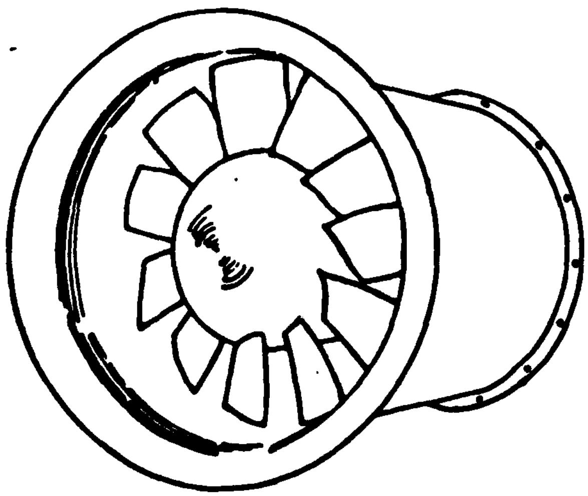
VARIABLE AIR VOLUME AHU

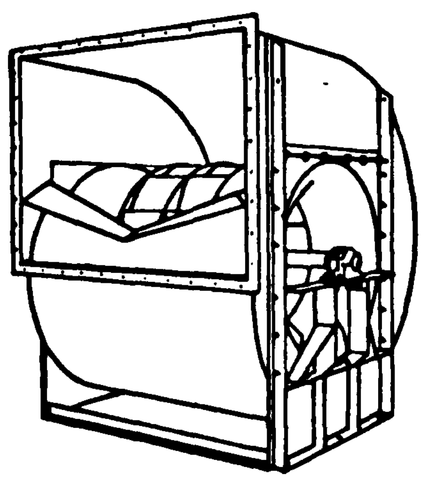
Figure 1-25

Variable Air Volume Air Handling Unit

All the other central air systems previously discussed have been constant volume, variable temperature type systems. A variable air volume (VAV) system meets differing zone heating and cooling loads by varying the quantity of air supplied to a space rather than the temperature of the air. A VAV system is designed primarily as a cooling system with a constant supply air temperature between 55° and 60°F. When less cooling is required for a particular zone then a control box or damper serving that zone closes thus reducing the quantity of air supplied to the zone.

Since most large buildings today are dominated by cooling requirements due to the large quantity of interior space versus perimeter spaces, variable air volume systems have become very popular. The VAV system consumes less energy than the previous three systems discussed by avoiding heating and cooling the same air. In addition, by varying the air flow rate, considerable energy savings may be obtained as a result of reduced supply fan horsepower requirements. VAV systems also offer added flexibility since the quantity of air supplied to a space may be easily adjusted by adjusting the controlling VAV box or damper unit.



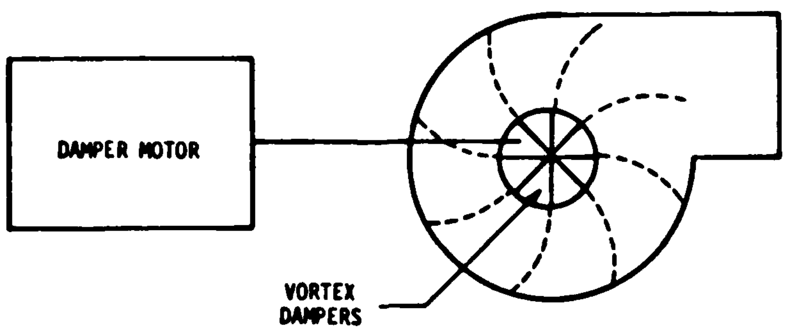


AXIAL FAN Figure 1-26 **CENTRIFUGAL FAN**

Additional control zones may be added after initial system installation by simply connecting another zone control box to the main VAV supply duct. Heating in perimeter zones supplied by VAV systems may be accomplished in a number of manners. Some perimeter VAV boxes include heating coils so when heating is required, the air volume is reduced to a fixed amount and then the heating coil is activated to reheat the supply air. Other approaches may provide a separate perimeter heating system (either air or radiation type) rather than reheat the supply air from the VAV system.

As the individual zone control boxes reduce air flow to the zones, the total air volume supplied by the VAV system must be reduced. The control system must monitor and control the pressure in the supply ducts to prevent over-pressurization or surge conditions as the zone control units reduce air flow. A static pressure sensor must be located in the supply duct to control the volume of air delivered by the supply fan.

Supply fan volume control depends on the type of fan. On a centrifugal fan, inlet or discharge dampers may be used to control fan volume. On a vane axial fan, the angle of the fan blades may be controlled to vary fan volume. In addition to damper control, an increasingly popular method for



CENTRIFUGAL VAV FAN

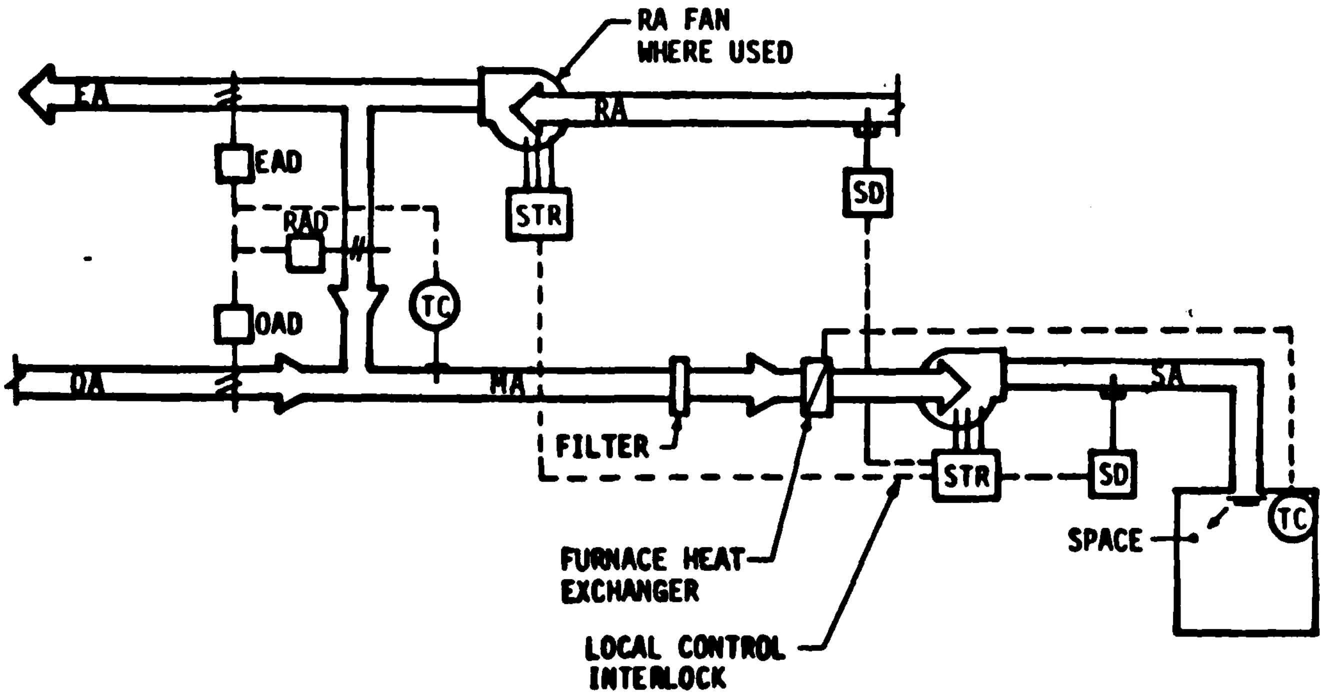
Figure 1-27

VAV control is the use of variable speed drives. These devices vary the fan speed to reduce air flow rates and generally result in more horsepower savings than damper or blade pitch control. Variable fan speed may be accomplished by mechanical speed control devices which utilize a constant speed motor through a varying speed drive device. Speed controllers may vary in motor speed to accomplish the same effect.

Direct Fired Furnace

There are two basic classifications of devices for conversion of fuel to heat. These are furnaces and boilers. A furnace is generally defined as a device which directly heats the air in a space or the air being supplied to the space. A boiler on the other hand, is generally a device which heats an intermediate medium such as water or steam which is then used to heat the air supplied to or in the space.

The common residential furnace is the most familiar example of a direct fired furnace. The thermostat within the space cycles the furnace on and off to control the temperature. Once the desired temperature is reached, the thermostat shuts the furnace off and the temperature is allowed to drop to some lower level at which time the thermostat restarts the furnace. In addition to the basic thermostatic control, most furnaces incorporate time delays and safety controls to ensure efficient and safe operation of the system. In a furnace, the fuel is ignited in some type of combustion chamber and the hot gases which are products of that combustion process then pass through a heat exchanger on their way out of the building through a flue or vent. The heat exchanger generally consists of some type of multi-path metal enclosure which allows the hot combustion gases to pass through one side of the heat exchanger while the air to be heated passes over the other side. Heat is transferred through the metal walls of the heat exchanger from the hot combustion gas to the cooler air. Heat exchangers are designed to provide the maximum surface area between the air to be heated and the combustion gases.



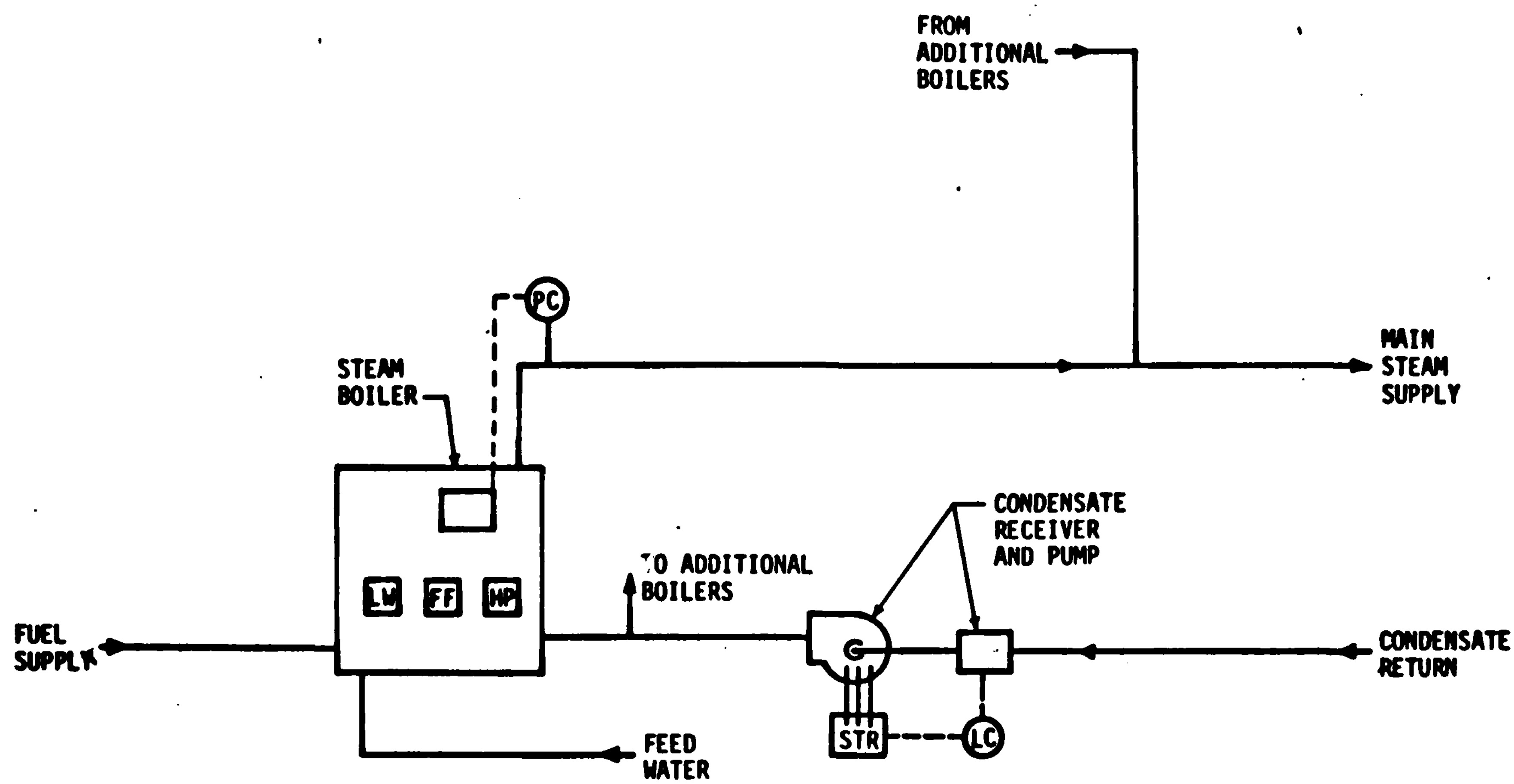
DIRECT FIRED FURNACE

Figure 1-28

Steam Boilers

A boiler uses the combustion process to heat an intermediate medium which is then used to heat the space or supply air. Where the intermediate medium is steam, this device is called a steam boiler. The process used within the steam boiler is exactly the same as boiling water in a pan on the kitchen stove. The surfaces of the pan are heated to a temperature greater than what's called the boiling point of the water within the pan (212°F at atmospheric pressure). When the water in the pan reaches this temperature, the temperature remains constant as the water changes form from the liquid state to the gaseous state. Water in a gaseous state is called steam. To convert one pound of liquid water into one pound of steam, roughly 1,000 btu's of heat energy are required. By the same token, if steam is cooled below the boiling point, it is converted back into water and releases roughly 1,000 BTUs per pound of steam which condenses. A steam heating system takes advantage of these principles by converting liquid water into steam and transferring that steam from the boiler through a piping system to the heating coils or radiators. There the steam is condensed back into a liquid form while heating the air passing through the coil or around the radiator surface. Thus, for every pound of water converted to steam at the boiler, 1,000 BTUs are transferred to the steam and for every pound of steam condensed in the room or heating system, roughly 1,000 BTUs of heat is transferred to the space.

As water is placed under pressure, its boiling point increases. For example, water at atmospheric pressure boils at 212°F. Water at 30 pounds per square inch pressure above atmospheric boils at 274°F. Water at 100 pounds per square inch above atmospheric boils at 338°F. All steam boiler systems operate above atmospheric pressure causing the steam to flow through the piping system to the location where it is to be used. Boilers are generally classified into as high pressure boilers or low pressure boilers. High pressure boilers generate steam at a pressure greater than 15 psi, while low pressure boilers generate steam at a pressure less than



STEAM BOILER

Figure 1-29

or equal to 15 psi. High pressure boilers are more efficient in that they deliver hotter steam at a higher pressure; however, they are more dangerous and may require on-duty operators for safety purposes.

Steam produced by steam boilers is used in heating devices such as radiators, convectors, heating coils, and heat exchangers. Within these devices, the steam is converted back to the liquid state as heat is transferred from the steam to the air or water to be heated. These devices are arranged such that as the steam condenses to form water, it drains to a lower level where it is collected. A device called a steam trap then allows the water condensed from the steam (condensate) to be discharged from the steam piping system. The condensate discharged may be wasted by allowing it to drain into the sewer system or it may be returned to the boiler and pumped into the boiler for reconversion to steam and recirculation. Wasting condensate was generally practiced before energy costs were high enough to justify the capital costs of installing a condensate return system. Condensate return systems may operate by gravity if the boiler is at a low enough elevation to allow condensate to drain back to it. Pumped condensate systems may use either a vacuum pump which places a pressure less than atmospheric on the condensate return system or a condensate return pump. The discharge of a number of traps is collected by gravity into a container called a condensate receiver and then pumped under pressure into a pressurized condensate return system.

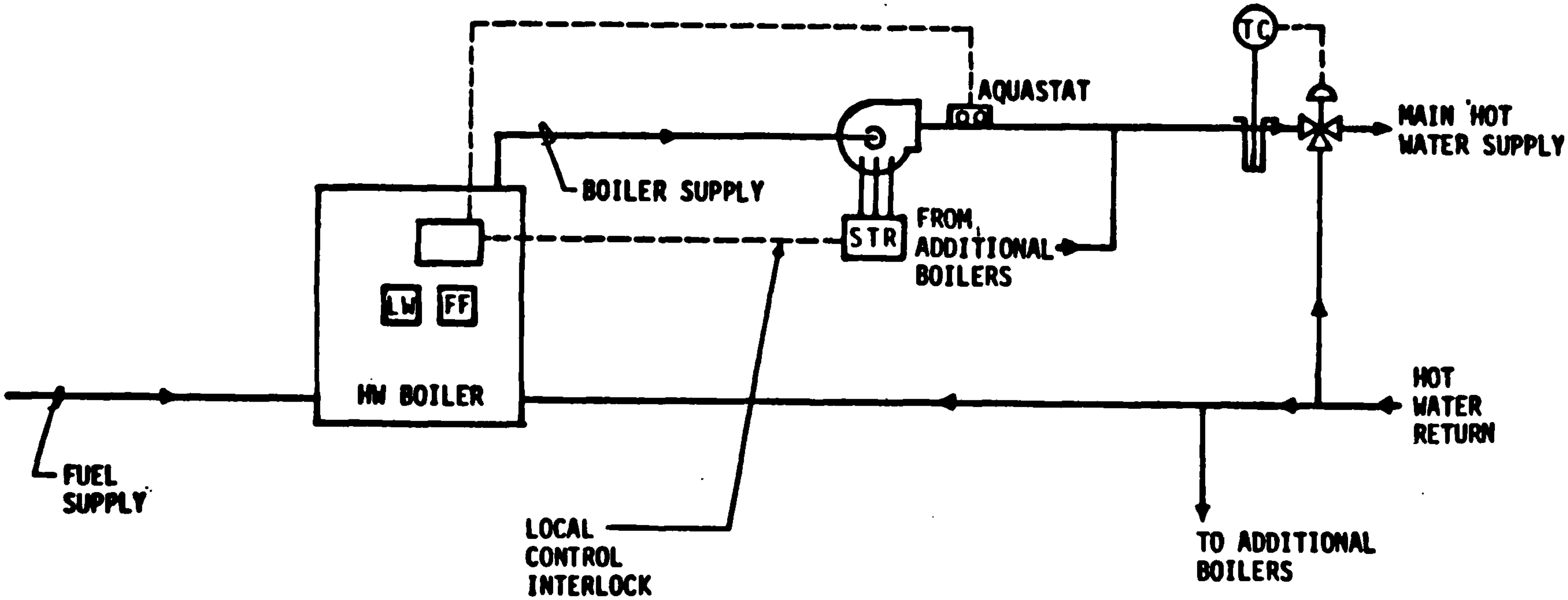
In steam boiler systems, the main operating control is based on the steam supply pressure from the boiler. As steam is condensed in heating coils, the heating pressure in the boiler supply line drops and a pressure control then fires the burners in the boiler to generate more steam. As steam is generated, if it is generated faster than it is used, the pressure within the boiler increases and the pressure controller shuts down or reduces the burner firing. Other boiler controls include a makeup water controller which keeps the water level in the boiler at a safe minimum. Some boilers also include combustion air damper controls. Because boilers can be very dangerous due to their combustion process, and operation at pressurized conditions, a great deal of effort and expense is spent on safety controls. High pressure limit controls shut down the fuel flow to the boiler if the steam pressure goes above a certain level. Low water safeties monitor the water level within the boiler and if it drops too low, the boiler will shut down. Flame failure monitoring devices monitor the status of the combustion process and shut down fuel flow if they detect problems. These are just a few of the many safety controls required on a steam boiler system.

Hot Water Boiler

In a hot water boiler, the boiler and piping system are completely filled with liquid water and arranged such that steam is never provided. The combustion process within the boiler is used to simply heat up the water being circulated through the boiler rather than converted to steam. Pumps are required to circulate the hot water through the boiler and through the heating system. Hot water operating controls generally consist of a thermostat which turns on and off the boiler burners in order to maintain a constant hot water supply temperature from the boiler. Safety controls are very similar to those for steam boilers except that they are adapted for water service, instead of for steam service. For example, in place of the high pressure limit control, a high temperature limit control shuts down the hot water boiler if the water temperature is too high. Generally, the hot water circulating pump is electrically interlocked with the boiler so that when the pump shuts down the boiler will be deactivated.

Convertors

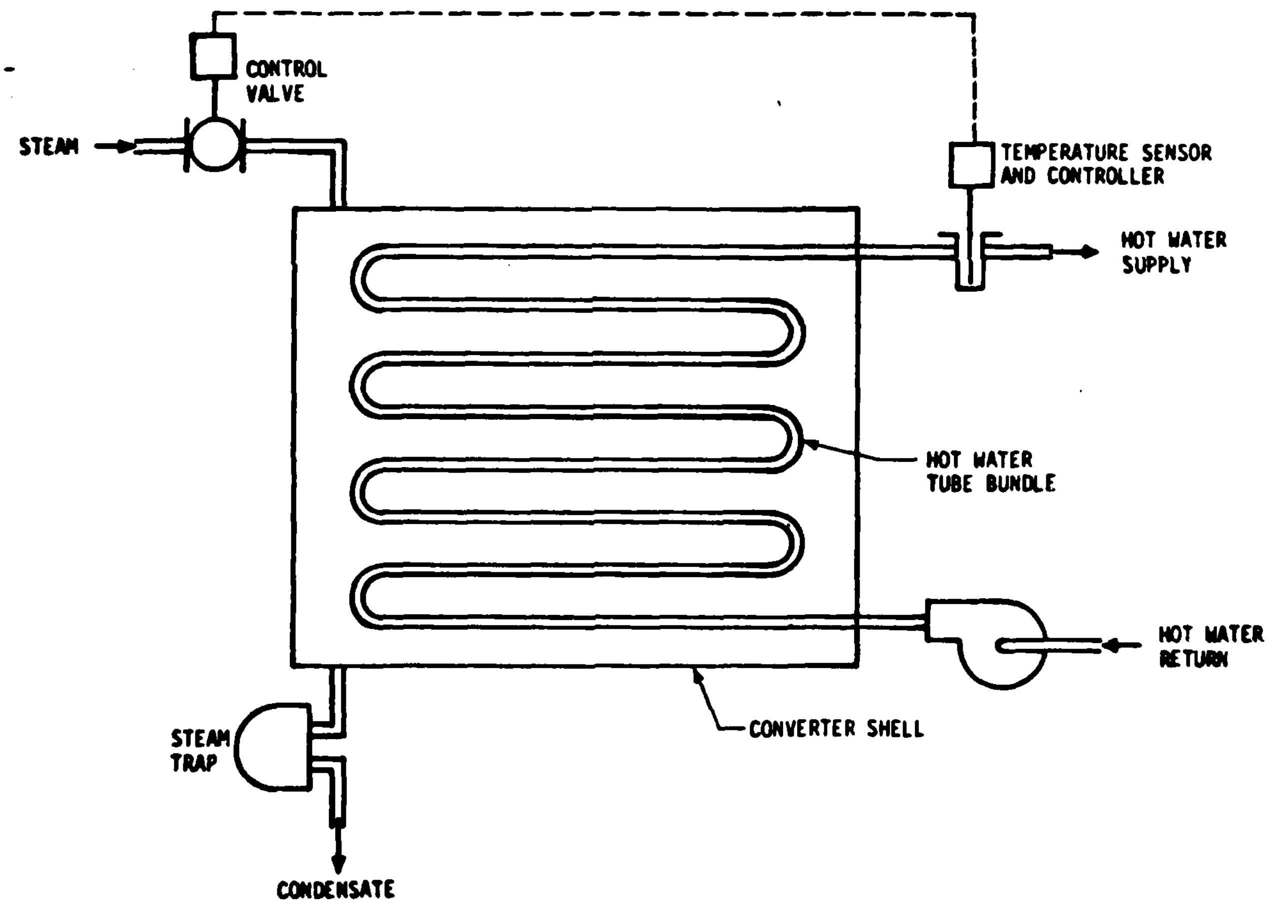
A convertor is a device which is used to transfer heat from one medium to another. Examples are the use of a convertor to transfer heat from steam to hot water, from high temperature hot water to low pressure steam, and from high temperature hot water to low temperature hot water. Basically, a



HOT WATER BOILER

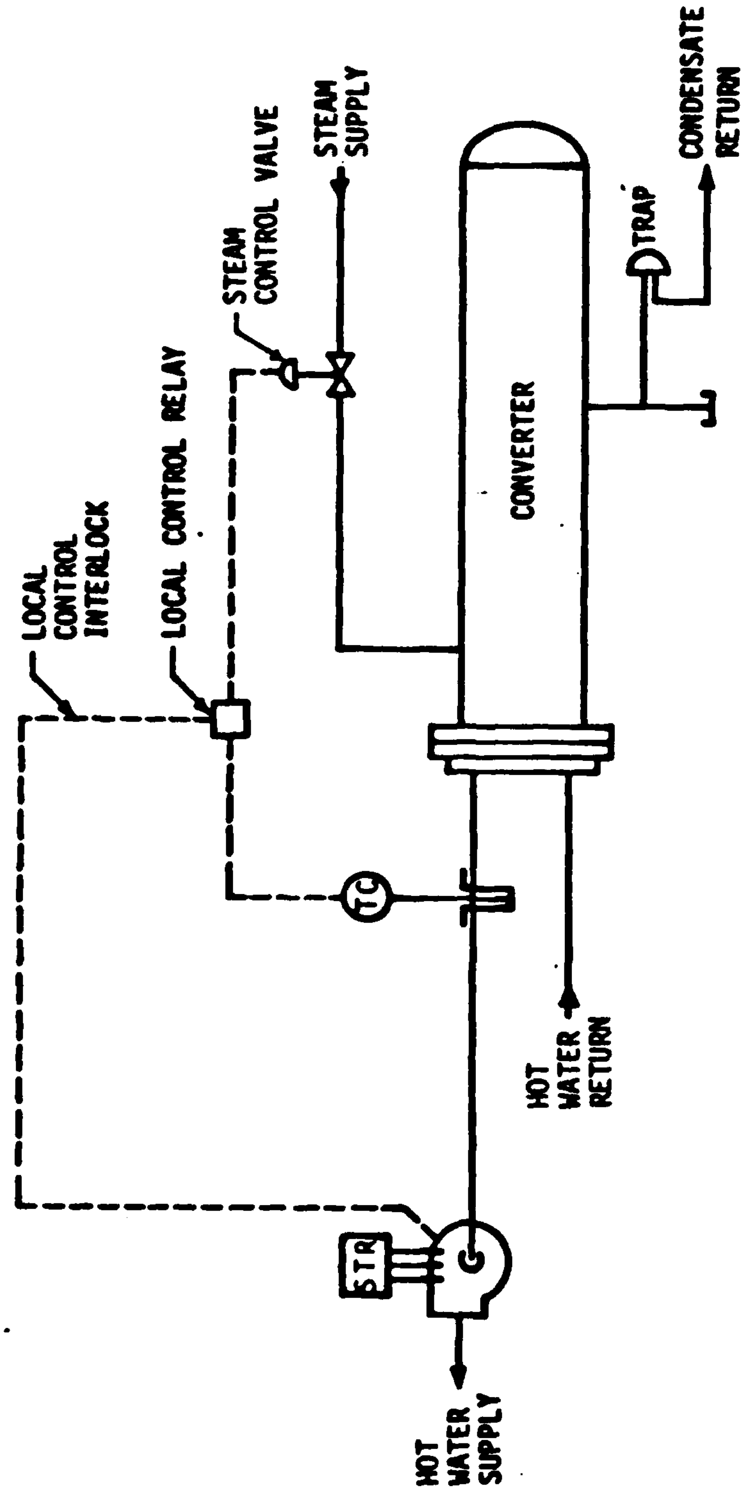
Figure 1-30

convertor consists of a shell with tubes running through it. One medium passes through the tubes of the convertor while the other medium passes through the shell and over the tubes. Thus, heat is transferred between the medium in the tubes and the medium in the shell. In a steam to hot water convertor, water is circulated through tubes in the convertor while steam is placed in the convertor shell. Heat is transfered from the steam



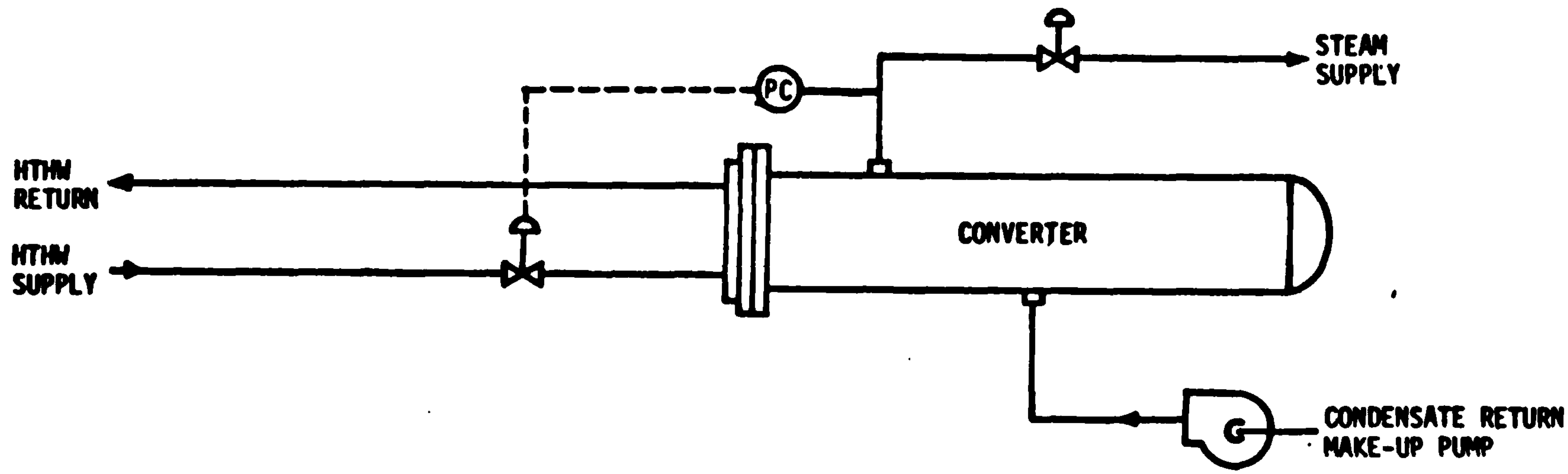
STEAM-TO-HW CONVERTER

Figure 1-31



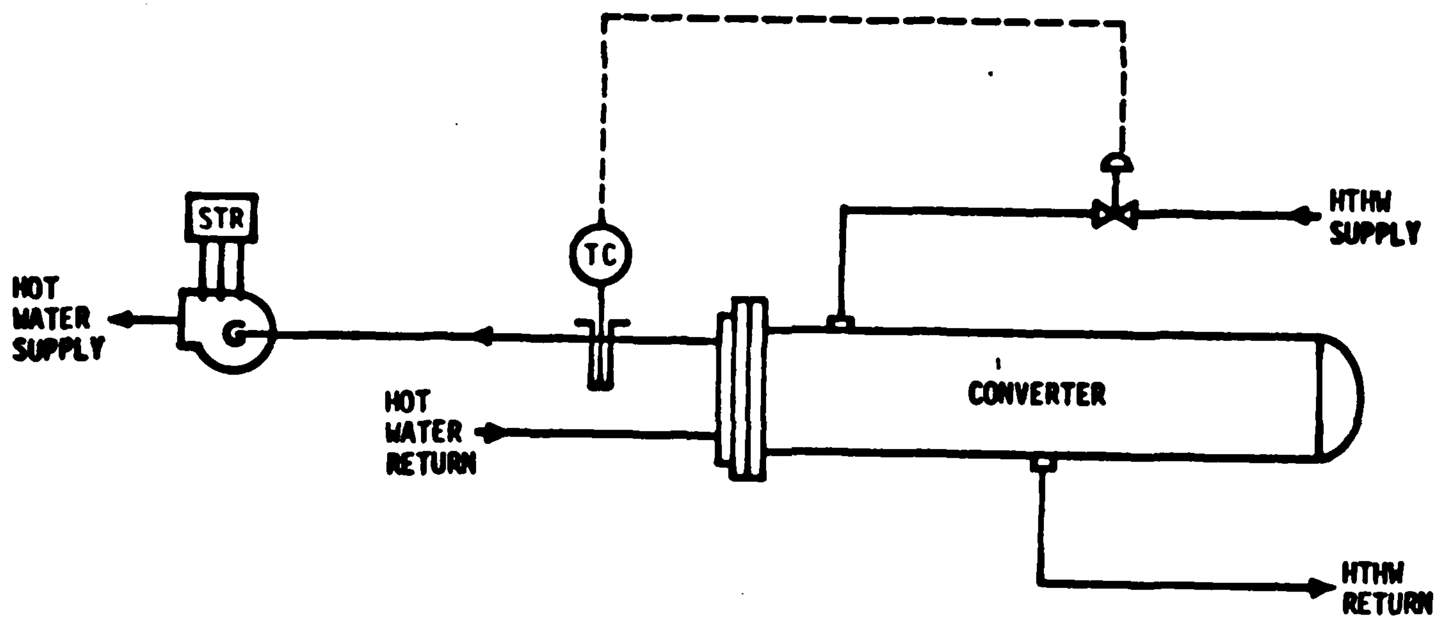
STEAM/HW WATER CONVERTER

Figure 1-32



HTHW/STEAM CONVERTER

Figure 1-33



HTHW/HW CONVERTER

Figure 1-34

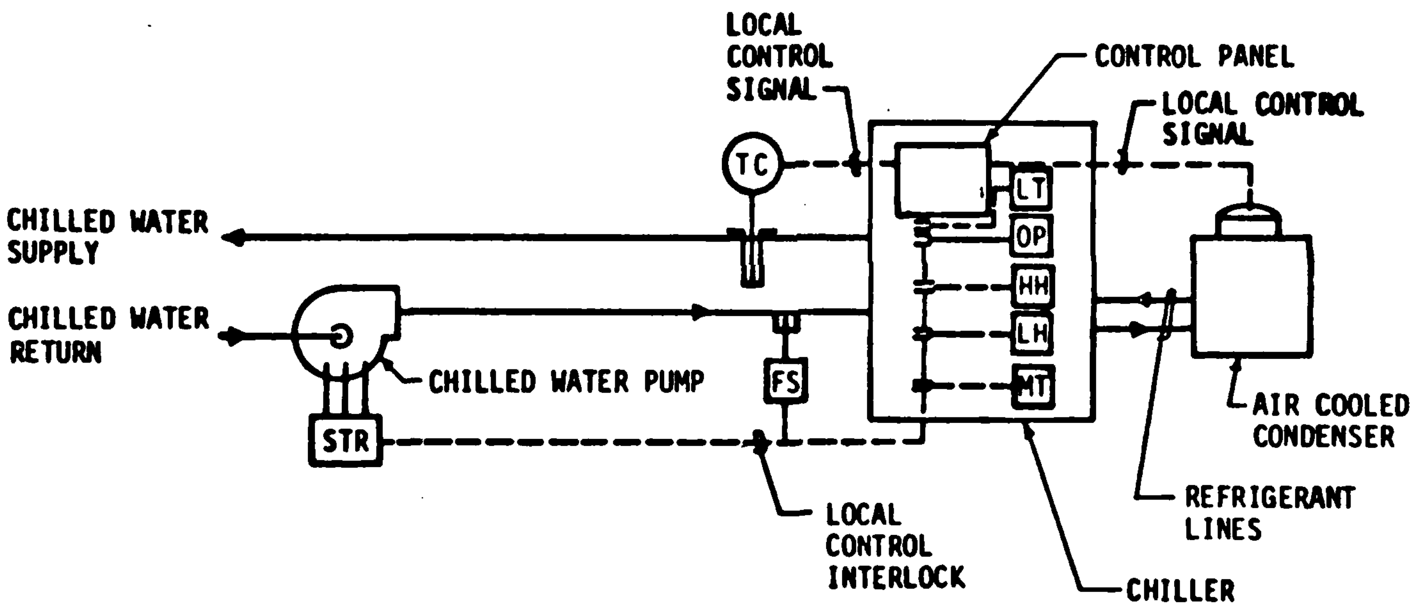
in the shell to the water in the tubes and the steam condenses. The condensate then may be returned through a steam trap to the condensate return or waste system. A steam to hot water convertor is controlled by a thermostat in the hot water piping leaving the convertor which controls a valve on the steam line entering the convertor. As the hot water supply temperature drops below the controller setpoint, the controller opens the steam valve to allow more steam to transfer into the convertor shell. As this happens, more heat is transfered to the water passing through the convertor to increase the supply water temperature. The controls in the hot water pump circulating water through the convertor are usually electrically interlocked such that if the pump is shut down, the steam control valve is closed.

Chillers.

A chiller is a refrigeration machine which produces chilled water for use as the cooling medium in HVAC fan systems and other equipment.

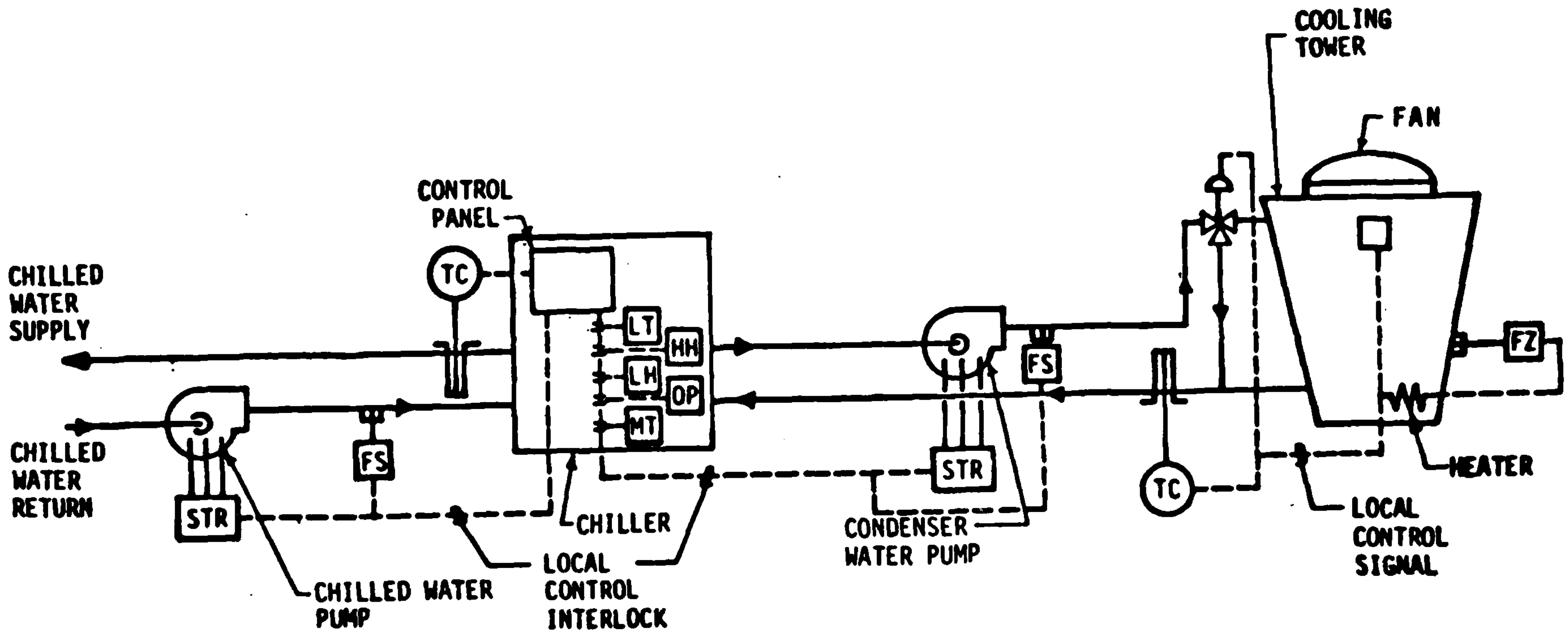
Recall that an air handling system may have either a direct expansion coil or a chilled water coil for cooling the return air stream. The DX coil is the evaporator in a refrigeration cycle. Heat is removed from the air stream passing over the coils as the low pressure refrigerant vaporizes. In a chiller, instead of removing heat from air, heat is removed from chilled water which flows over the refrigerant tubes in the evaporator chamber. The chilled water is then pumped to the cooling coils throughout a building.

During the condensing stage of the refrigeration cycle, heat must be removed from the refrigerant. This may be accomplished by passing either air or water over the condensing coil. Thus, we have either an air cooled chiller or a water cooled chiller.



AIR COOLED CHILLER

Figure 1-35.



WATER COOLED CHILLER

Figure 1-36.

Air cooled condensers are located outside where ambient air is forced across the condensing coils by either a propeller or centrifugal type fan. The condenser fan is controlled to start automatically whenever the chiller compressor runs. In some situations where low ambient temperatures might cause operating problems due to low condensing pressure, it is necessary to provide additional control. The simplest method uses modulating dampers to reduce air flow, based on changing refrigerant pressure. Other methods employ a variable speed fan or a throttling valve on the flow of liquid refrigerant to vary the cooling capacity of the condenser.

Water cooled condensers are located at the chiller and are supplied with condenser water from a cooling tower or some other source. In the condenser water loop, heat is rejected to the water in the condenser and then from the water to the outside air in the cooling tower. The principle of heat rejection in the cooling tower is evaporative cooling. As water falls down through the cooling tower a small amount of it is evaporated. The latent heat required for the evaporation process is supplied by other water droplets in the form of sensible heat. Thus, 99% of the water reaches the tower basin at about 10°F cooler temperature.

The cooling evaporative process is aided by the movement of air through the tower. Natural draft cooling towers are designed to take advantage of natural air currents and are therefore located in open spaces. Induced draft and forced draft cooling towers are provided with a fan to move atmospheric air through the tower.

In water cooled condensers, condensing pressure can be controlled by modulating water flow or controlling the condenser water supply temperature. Water temperature may be controlled by cycling the tower fan or bypassing some of the condensing water around the cooling tower, using a control valve and condenser water supply temperature sensor.

Chiller controls normally include water flow switches in the condenser and chilled water circuits to prevent the chiller from starting if the condenser or chilled water pumps are not running. Starters for the condenser water pump, compressor, compressor oil pump are normally interlocked with the chilled water pump. Safety cutoff relays also are provided to shut-off the chiller in case of low chilled water temperature, high condenser water temperature, high condenser pressure, low evaporator pressure or temperature, high motor temperature, etc. Usually these are internal controls supplied with the chiller by the chiller manufacturer. Also chillers are usually provided with relief valves or rupture disks, which are set to discharge the refrigerant in the event of high refrigerant pressure.

CHAPTER 2

ENERGY MONITORING AND CONTROL SYSTEMS

SECTION 1. INTRODUCTION TO EMCS

An Energy Monitoring and Control System (EMCS) is an energy management system which allows for centralized monitoring and control of dispersed energy consuming equipment.

Over the past thirty years, energy monitoring and control systems have undergone an evolutionary process. The evolution has basically been from strictly monitoring systems to control plus monitoring systems.

Prior to modern EMCS systems, building temperatures, pressure, etc., were monitored from a central location, generally the building engineer's office. Panel banks in the office were connected to sensors and controllers throughout the building. These systems were generally used only in large individual buildings. Other than to start and stop equipment, the central panel banks offered little control over the equipment they monitored.

The systems developed in the 60's provided scheduled start-stop and manual temperature control point adjustments. Temperatures and pressures were monitored, but instead of gauges and dials, digital displays were incorporated. One important feature of these systems was the provision for reporting alarm conditions. These were the first systems to utilize computers where monitored data was stored in memory (electronically recorded and retained for later use). The Central Processing Units (CPU) had numerous individual signal wire connections which came directly from each monitored component. Due to technological limitations, making changes to the systems was severely limited. The manufacturer had to make any changes. Possible changes were limited to circuitry provided during manufacturing.

Performance of the hardwired logic units improved significantly as a result of combining them with a means to transmit data between various system components. In these transmission systems, individual sensors and controllers were wired to a field panel installed near the sensor locations. From the field panel, the signals were sent on to the CPU. Technology had been developed such that a number of signals could be transmitted along the same conductor. Therefore, this system required the installation of only a two or fcur wire cable from the CPU to panels in mechanical rooms throughout a building instead of the many multi-conductor cables necessary for previously described systems. Once this system configuration was developed, multi-building complexes began to utilize the concept of central monitoring and control. The technical capability to combine or multiplex signals over a few wires has reduced tremendously the cost of data transmission media, thereby making the EMCS concept cost effective for DoD installations. This type system was common on college campuses and was used in early military base EMCS installations.

A major improvement in system flexibility and performance was the replacement of the hardwired logic CPU with a small general-purpose computer. This allowed the manufacturers to easily modify and program the system. It also provided for greater flexibility in utilizing the monitored information. Data was collected, calculations performed, and appropriate control commands or alarms sent to the field controllers. The ability to modify or program the systems was, however, not passed on to the customer. Consequently, from the customer's standpoint, it was a major project to have the manfacturer add a point to the system, change constants related to a point, or add specialized instructions for computer operation. In general, only the original manufacturer was capable of performing these actions, thus resulting in a non-competitive procurement situation.

The above evolution generally describes the process with which major conventional controls manufacturers developed the systems they are marketing today. A different group of manufacturers has appeared on the scene within the past five years. These manufacturers are generally smaller firms with backgrounds in process control applications or general computer systems applications.

Their approach has been to use off-the-shelf computer, data transmission, and sensor components. The components are combined with computer software to form an EMCS. These manufacturers claim to provide greater flexibility and adaptability to the customer for less cost. Their main support for this argument is that their systems generally allow the customer the capability to write programs, modify existing programs, and retrieve monitored data, which is not possible with most of the major conventional control systems. This has resulted in competition which is now causing a re-evaluation of the system design philosophy of the major control manufacturers.

The energy crisis and the advent of computer based systems also brought new interest and direction to central control applications. The rapid rise of energy costs, coupled with increased system capability to reduce energy consumption, has improved the economic feasibility of energy monitoring and control system application. Although the systems have not reduced manpower as expected, some manpower savings are possible and will be realized. More importantly, the energy conserving control aspects of the systems are of such value that they can be justified on that basis alone.

As described above, central control systems have evolved from systems whose principal value was the monitoring of points, to systems whose principal value is the control of equipment. Because of this process of evolution, with its inherent inertia, problems have occurred. The engineering design process has not kept pace with the change in purpose of the EMCS from monitoring to control. Many recently installed systems include a number of points whose only purpose is monitoring of equipment, which effect no direct energy savings.

Various military installations have been involved in all stages of the evolutionary process described above. Many large individual buildings, such as hospitals, contain the hardwired central panel systems. The first base-wide systems which instrumented multiple buildings were procured when the data transmission system in conjunction with the hard logic CPU became available. At that time the principal justification for procurement of such systems was the monitoring of equipment to reduce manpower requirements. Minimal control was available or emphasized in these early projects. The installations attained varied operational success, but virtually all of the systems failed in the manpower reduction objective.

Generally, insufficient funds are available at one time to purchase full capability for every building on a base. The result of this limitation is that a reduced system is procured by not connecting some or many of the buildings on a given base. This approach results in the selection of many monitoring functions with no associated energy savings in one building, while another building is not connected to the EMCS at all. An alternative to this approach is to delete monitoring points from the first building and connect energy conserving points, or energy control points in the second building. Whether or not to delete monitoring points is a decision of management that has to be looked at on an individual basis based on past experience.

Generally, the design philosophy for military EMCS programs has enlarged to include the energy conscious approach. Systems now under design are being configured on the basis of energy savings as well as O&M functions. A number of complex problems involved in determining the optimum configuration of an EMCS for a particular base have been defined as a result of this enlargement in design philosophy. The complexity of the problems stems from the inter-relationship of costs to perform alternative EMCS activities.

Purpose of an EMCS

The prime purpose behind the development and use of EMCS is conservation of energy. Energy conservation is accomplished primarily through close monitoring and control of HVAC systems. Traditionally, HVAC systems on military posts were installed building by building during construction or renovation. Even on posts with centralized steam and/or chiller plants, the buildings were widely dispersed making it impossible to maintain a close watch over energy consumption. It was nearly impossible to control energy consumption so as to conserve it. Heating and cooling equipment was energized at the start of the appropriate season, usually as a function of the calendar and with little regard for unseasonable weather conditions. The equipment was allowed to run continuously until the mandated end of the season. The usual result was that building occupants were either too hot or too cold and opened windows to regulate the temperature, thereby increasing energy consumption. Further, HVAC systems ran 24 hours a day because there was no feasible way to turn the widely distributed equipment on and off. There was also no provision for resetting space temperatures during unoccupied periods. The EMCS allows for both the centralized monitoring and control of energy consumption on a widely dispersed HVAC system. While the prime use for an EMCS is for monitoring and controlling HVAC equipment, it may also be used for lighting control, sewage lift station control, maintenance management, and fire and security alarms.

EMCS Attachment to the HVAC System

EMCS systems have been developed to provide centralized monitoring and control of dispersed energy consuming equipment. An EMCS connects to an HVAC system through monitor and control points. Monitoring and control functions are accomplished through use of a computer.

Where the EMCS and an HVAC system connect is called a point. There are two kinds of points:

1. Control points which allow the EMCS to send information to the HVAC system in the form of commands, and

2. Monitor points which sense temperatures, pressures, flow rates, etc., on the HVAC system and send information to the EMCS. There are typically five to ten times as many monitor points in an EMCS as there are control points.

There are two primary types of measurement and control used in HVAC applications: two position and modulating (proportional). Two position control devices designate one of two operational modes, such as on/off or open/closed. Two position measurement sensors detect if the equipment is on or off, open or closed. Two position type measurement also can be used to sense whether a measured variable is above or below a set value. For example, a freezestat can detect whether or not a temperature is above 40°F.

Modulating or proportional control devices set an actuator or motor at any position between on or off (open or closed). For example, a modulating control device may be used to position a valve to regulate the flow of water. As the valve position varies from open to closed, the flow rate of water varies from full flow to no flow. Proportional measurement produces a signal whose value is related to the value of a physical parameter. For example, a temperature sensor produces a output signal which is proportional to the temperature it is measuring. Such devices generally have a limited range over which they operate. For example, a temperature sensor designed to measure room temperature would be reasonably accurate over the range of 50° to 100°F, but would not be accurage for measuring boiler stack gas temperatures on the order of 1000°F.

The types of sensors or output devices used at the monitor and control points vary depending on their function. The following list presents examples of monitor point devices and what they monitor.

DEVICE	MONITORS
Air flow switch	Air flow status
Water flow switch	Water flow status
Freezestat	Provide warning when heating or cooling coils are in danger of freezing
Flame sensor	Flame failure
Auxiliary contacts	On/off status (motors, fans, etc.)
Analog sensors	Temperature Pressure Humidity Voltage Current

The following are examples of EMCS control points, the devices used and their function.

DEVICE	FUNCTION
Relays	Motor ON/OFF
Controllers	Temperature Pressure

Typical monitor and control points for a single zone AHU are shown in Figure 2-1. Monitoring and control point designations are defined in Figure 2-2.

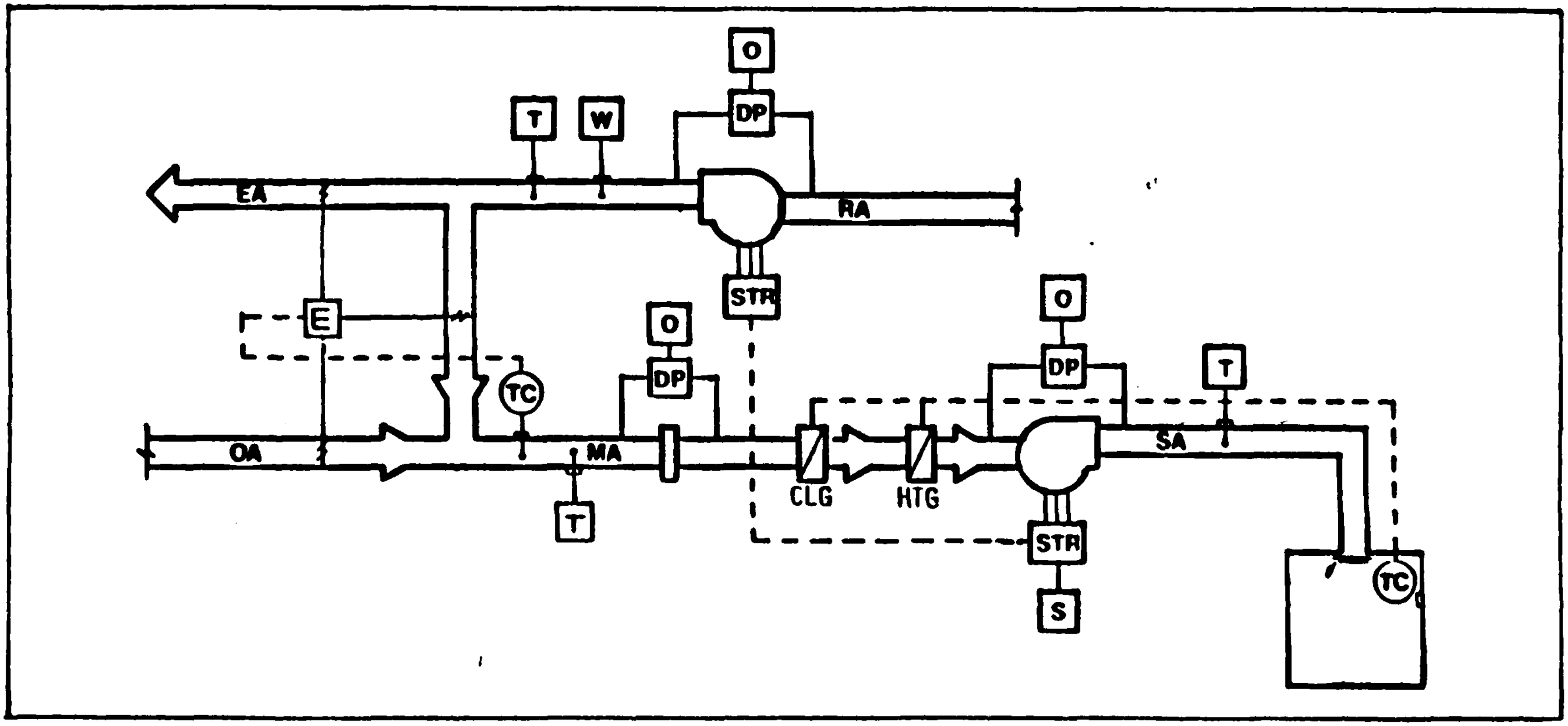


Figure 2-1
Typical Monitor and Control Points on Single Zone AHU

⟶ EMCS	SIGNAL TRANSMITTED TO EMCS
⟵ EMCS	SIGNAL RECEIVED FROM EMCS
A	ALARM CONTACT SIGNAL
C	GREATEST COOLING DEMAND
E	ENTHALPY/ECONOMIZER CONTROL INTERFACE
F	FLOW INDICATION
FL	FLAME INDICATION
H	GREATEST HEATING DEMAND
P	PRESSURE INDICATION
LV	LEVEL INDICATION
M	METER
O	ON-OFF STATUS SIGNAL
DP	DIFFERENTIAL PRESSURE SWITCH
R	CONTROLLER RESET INTERFACE
S	START-STOP INTERFACE
T	TEMPERATURE INDICATION
V	VENTILATION/RECIRCULATION CONTROL
W	HUMIDITY INDICATION
PS	POSITION

TC	TEMPERATURE CONTROLLER
DS	HIGH-LOW DEMAND SIGNAL SELECTOR
STR	MOTOR STARTER
	SENSOR INSTALLED IN THERMOMETER WELL
	SENSOR INSTALLED IN DUCT OR PLENUM
CHW	CHILLED WATER
EA	EXHAUST AIR
PC	PRESSURE CONTROLLER
SA	SUPPLY AIR
RA	RETURN AIR
OA	OUTSIDE AIR
MA	MIXED AIR
WB	WET BULB
DB	DRY BULB
OAD	OUTSIDE AIR DAMPER
RAD	RETURN AIR DAMPER
EAD	EXHAUST AIR DAMPER
MZD	MULTIZONE DAMPER
RH	RELATIVE HUMIDITY

Figure 2-2
Point Designations

To accomplish the tasks of monitoring and control, the EMCS uses a computer, HVAC system instrumentation and controllers, and some type of communications link between the EMCS computer and the HVAC system. Figure 2-3 shows the system concept.

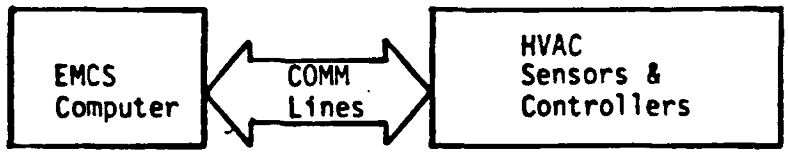


Figure 2-3
EMCS/HVAC COMMUNICATION LINK

With an EMCS, it is possible for one operator, working from an operator's console at the EMCS computer site, to monitor the operation of all connected HVAC systems on the military post. Likewise, the operator may send out HVAC system control commands to any piece of attached HVAC equipment.

EMCS Architecture

An EMCS is classified according to the total number of monitoring and control points connected to the system as follows:

1. Over 2000 points .... large EMCS
2. 500-2500 points .... medium
3. 50-600 points .... small
4. Less than 125 points .... micro

Basically the functions of the combined system operations are to monitor all data points, excecute energy conservation programs, and produce control signals to operate equipment in the real-time environment.

Large EMCS Architecture

A modern large EMCS consists basically of several small computers, peripherals, and monitor/control equipment. A computer is defined as any device which can receive and store a set of instructions, and then act upon them in a predetermined and predictable fashion. Also, the data and instructions can be changed. Computer software are the programs which instruct the computer. Figure 2-4 shows the layout of a large size EMCS.

Computers

Large EMCS use several computer systems including the Central Control Unit (CCU), Central Processing Unit (CPU), and Central Communication Controller (CCC).

The Central Control Unit is a small computer that functions as the overall system coordinator. It implements the energy conservation programs, performs, complex calculations, and controls peripheral devices. The Central Processing Unit is the portion of the computer that interprets and executes instructions. The software controls operations of the CPU and its peripheral devices.

While operating under energy conservation programs, environmental conditions and power consumption rates are predicted. Proper equipment operating point settings are calculated and control signals are produced to operate the equipment in actual-time. Data and programs are stored in memory or mass storage devices such as magnetic tape or disk systems. For high speed transfer of data between the CCU and mass storage device, the CCU has direct memory access (DMA) controllers. The DMA transfers data in blocks. The CCU has designated connections, called Input/Output (I/O) ports, for specific equipment, such as printers and terminals. It provides the interface between the operator and the EMCS. During normal operation, the CCU coordinates operation of all the EMCS components, except safety interlocks.

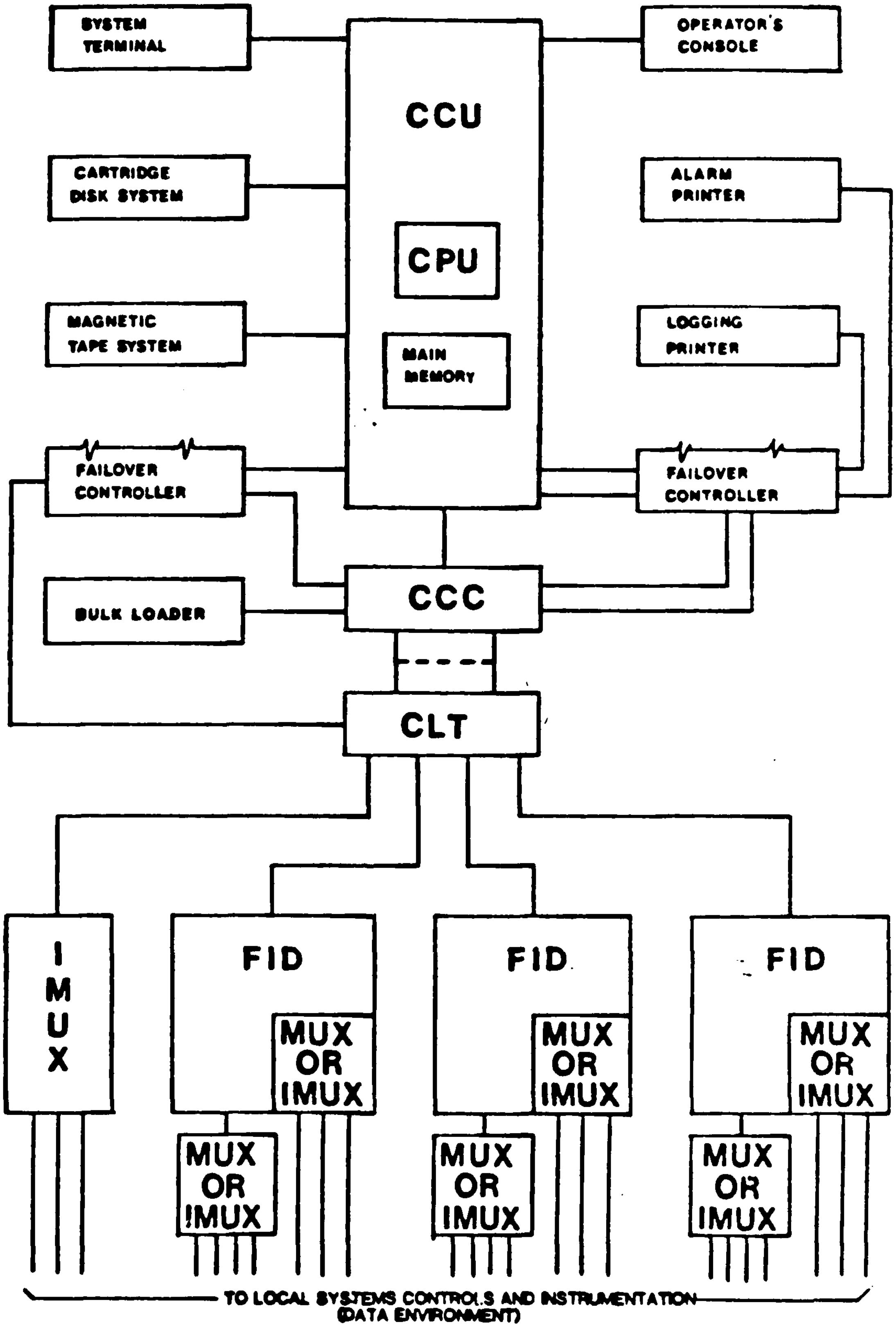


Figure 2-4
Large EMCS Architecture

The Central Communication Controller is a small computer that collects and disseminates data to and from control and monitoring points. In addition to transferring data, it can change the format of data presentation, check for errors, and retransmit data between the CCU and other equipment. In the event of CCU failure, it provides limited backup. The CCC relieves the CCU of time consuming communications with other equipment; allowing the CCU to devote its full capabilities to the execution of control, monitoring, and applications software programs. In the event of CCU failure, the CCC provides for limited backup.

Peripherals

Peripheral equipment controlled by the CCU includes the following:

The system terminal is a television screen or cathode ray terminal (CRT) which displays letters and numbers and is used to perform system commands, develop and modify system programs, and run software diagnostic tests.

The operator's console is an eight color CRT terminal that displays shapes and colors in additional to numbers and letters. It is the primary operator-system interface. It graphically displays equipment schematics, system status, operating parameters such as temperatures and pressures, and operational-data.

The console contains a dedicated keyboard for entry of operator commands. Trends of selected equipment variables can be plotted, enabling the operator to make strategy decisions regarding equipment operation. Graphic displays may be brought up automatically when an alarm is activated, or upon operator command.

Data Storage Devices store data for later use. Disk and tape systems are utilized. The disks or tapes store information on their magnetic surfaces like a tape recorder. Disks are either hard or flexible (diskettes) and spin like a record. A device called a drive, spins the disk or winds the tape. It contains a device called a head, which can read information from the magnetic surface as well as write information. The computer can move the head to any location on the surface of a disk. This is called random access. The storage systems used in an EMCS include:

The cartridge disk is a high density mass storage system with random access and removable disk capability. It is used to store the EMCS system, command, and applications programs.

The Winchester disk can also store the EMCS operational programs and instructions. It is a high density mass storage system with random access. The disks are extremely susceptible to dust, dirt, and cigarette smoke. Therefore, the system is sealed and the disks cannot be removed. Because of manufacturing technology, Winchester disks are more reliable than cartridge disks.

A flexible or floppy disk is a medium density storage system with random access and removable disk capability. They are utilized for giving start-up instructions to the computer and historical data storage. The diskettes are circular vinyl disks, enclosed in rigid plastic envelopes. The envelope protects the diskette during handling and use. Openings in the envelope allow the head access to grip the diskette surface. The diskette spins freely inside the envelope and is driven by the head. The diskette should never be removed from its envelope.

A magnetic tape system is a nine-track high density mass storage system, with removable tape capability. Data is stored and accessed sequentially, making data retrieval slower than from a random access disk system. They are used when large amounts of data is stored but will be accessed only periodically.

Two key-board printers are provided with a large EMCS. They are used to obtain permanent copies of data or system operations. The alarm printer is dedicated to reporting alarms. The logging printer logs data and prints reports. Each must be capable of serving as a backup for the other.

The EMCS system clock must be synchronized with an actual-time clock at regular intervals. This is done with the System real-time clock (RTC) which is provided with a battery backup.

A failover controller is provided for automatic and manual switching of the CCU, CCC and printers to the backup mode of operation should the CCU, CCC or printers fail.

A bulk loader is a mass storage device used to load EMCS software into the system.

The central control unit, central communication controller, operator's console, system terminal, data storage devices, printers, and other peripherials are located in the master control room (MCR).

The Communications link termination (CLT) is the communications interface between field equipment and Master Control Room (MCR) equipment. It concentrates data, as required, for interface to the CCC/CCU.

Field Equipment

The following components make up the field equipment, which is located in the vicinity of the data environment, (sensors and control devices connected to a single FID/MUX/IMUX from the equipment and systems sampled or controlled).

- Field Input Device (FID)
- Multiplexer (MUX) Panels, and
- Intelligent Multiplexer (IMUX) Panels.

The Field Interface Device (FID) is a small computer which collects data from sensors within its Data Environment (DE) and generates commands to control operating devices such as electric motors, valves, and relays. The FID controls parameters such as temperature, and humidity without input from the CCU. Commands from the CCU and the operator console will cause the FID to adjust operating parameters such as: temperature and humidity set points, and start/stop times. The FID transmits equipment operating data and status, as well as alarm messages, to the CCU.

The FID has sufficient computer capability to operate without communications with the central computing system. Failure of the FID does not adversely affect performance of the rest of the system except for those optimization programs performed at the central computing system, which require data from the FID. The FID can perform optimization routines normally performed by the CPU when there is a cost or operational advantage. FIDs can be added, as required, to incorporate additional buildings or systems.

Multiplexer (MUX) Panel. MUX panels serve as I/O devices for a FID and its DE, and are considered to be extensions of the FID. The number of remote MUX panels connected to a single FID is limited by (a) the maximum number of panels addressable by a FID, (b) the number of points allowed on a single DTM, or (c) by the alarm response time. The remote MUX panels continuously transmit data to the FID via a MODEM or line drivers. The MUX panel contains I/O fuctions to handle digital and analog data, digital data error detection, and message transmission. Failure of a MUX must return the attached HVAC equipment to local loop control or to a pre-determined failure mode. MUX panels usually have a battery backup to sustain operation during a power failure.

Intelligent Multiplexer (IMUX) panels are similar to MUX panels, but operate in a "report by exception" mode, i.e. the IMUX scans its DE and compares the data received against the last value and reports only the data that has changed. IMUX panels perform all functions of a MUX panel and, depending on manufacturer, are used in place of the MUX panel. The IMUX is allowed to communicate with the CCU/CCC in large and medium systems in a monitoring role only, thereby retaining the distributed intelligence inherent in the FID - CCU/CCC architecture. The IMUX is allowed to perform both monitoring and control functions in the small and micro systems. The IMUX also performs data communications checking and retransmission to the CCU/CCC. Failure of the IMUX returns the attached HVAC equipment to local loop control or to a predetermined failure mode. I/O IMUX panels usually have a battery backup to sustain operation during a power failure.

Medium, Small, and Micro EMCS Architecture

A medium EMCS, approximately 500 to 2500 points, consists of the following major components:

1. Minicomputer based CCU (16 bit minimum).

2. Color graphics CRT based operator's console.

3. Alphanumeric CRT based system terminal.

4. Alarm printer with keyboard.

5. Logging printer with keyboard.

6. Cartridge disk systems.

7. Bulk software loading device.

8. System RTC.

9. FID, MUX, and IMUX panels.

10. Magnetic tape system (optional).

11. CLT.

The three components of a large EMCS, not incorporated into the medium system are the central communication controller, failover controller, and bulk loader. The typical medium EMCS architecture is shown in Figure 2-5.

A small EMCS, approximately 50 to 600 points, consists of the following major components.

1. Minicomputer or microcomputer based CCU.

2. Alphanumeric CRT based operator's console.

3. Alarm and logging printer.

4. Bulk software loading device.

5. System RTC.

6. FID, MUX, and IMUX panels.

7. CLT.

A typical configuration is shown in Figure 2-6.

A micro EMCS, less than 125 points, consists of the following major components.

1. Microcomputer based CCU.

2. System RTC.

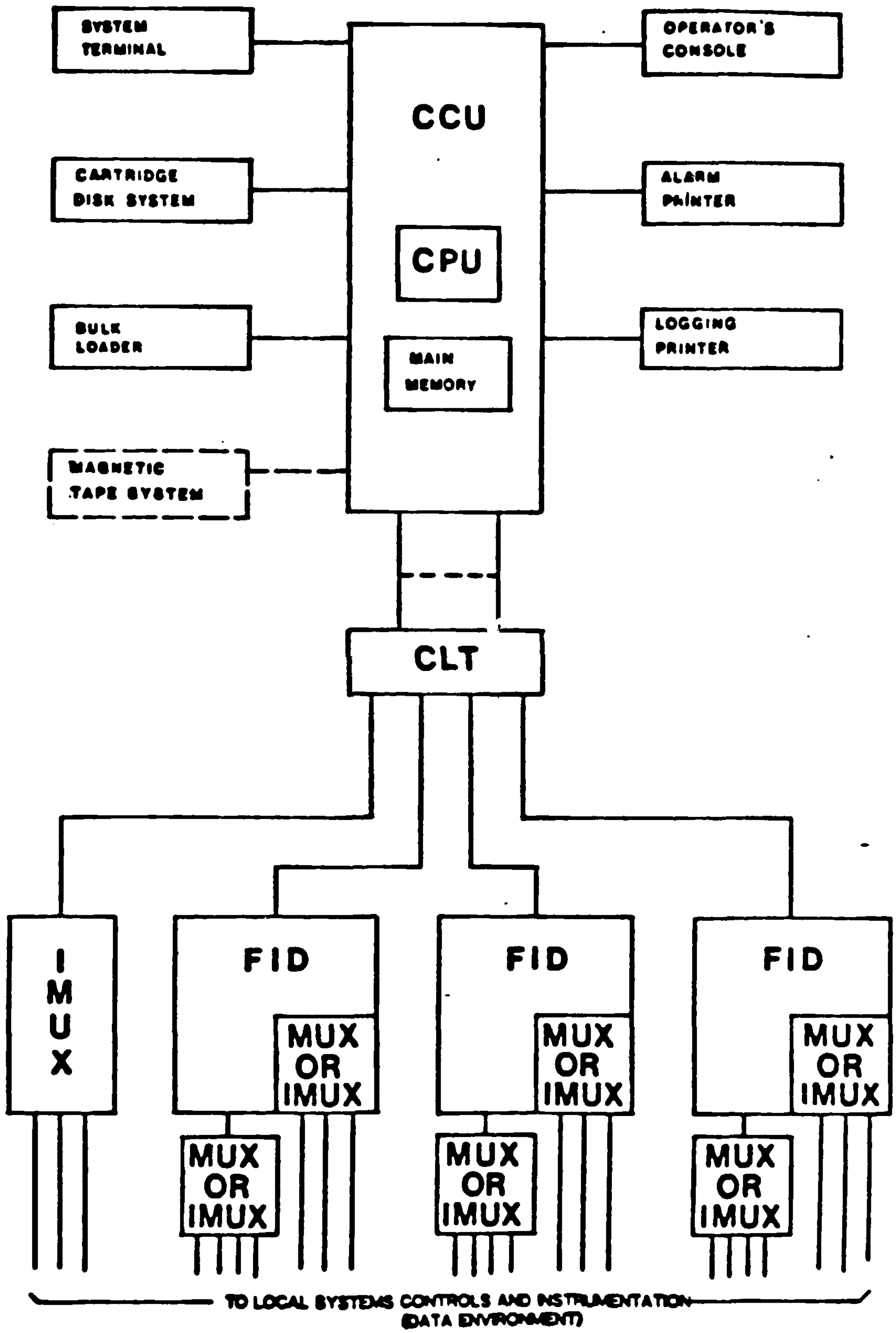


Figure 2-5
Medium EMCS Architecture

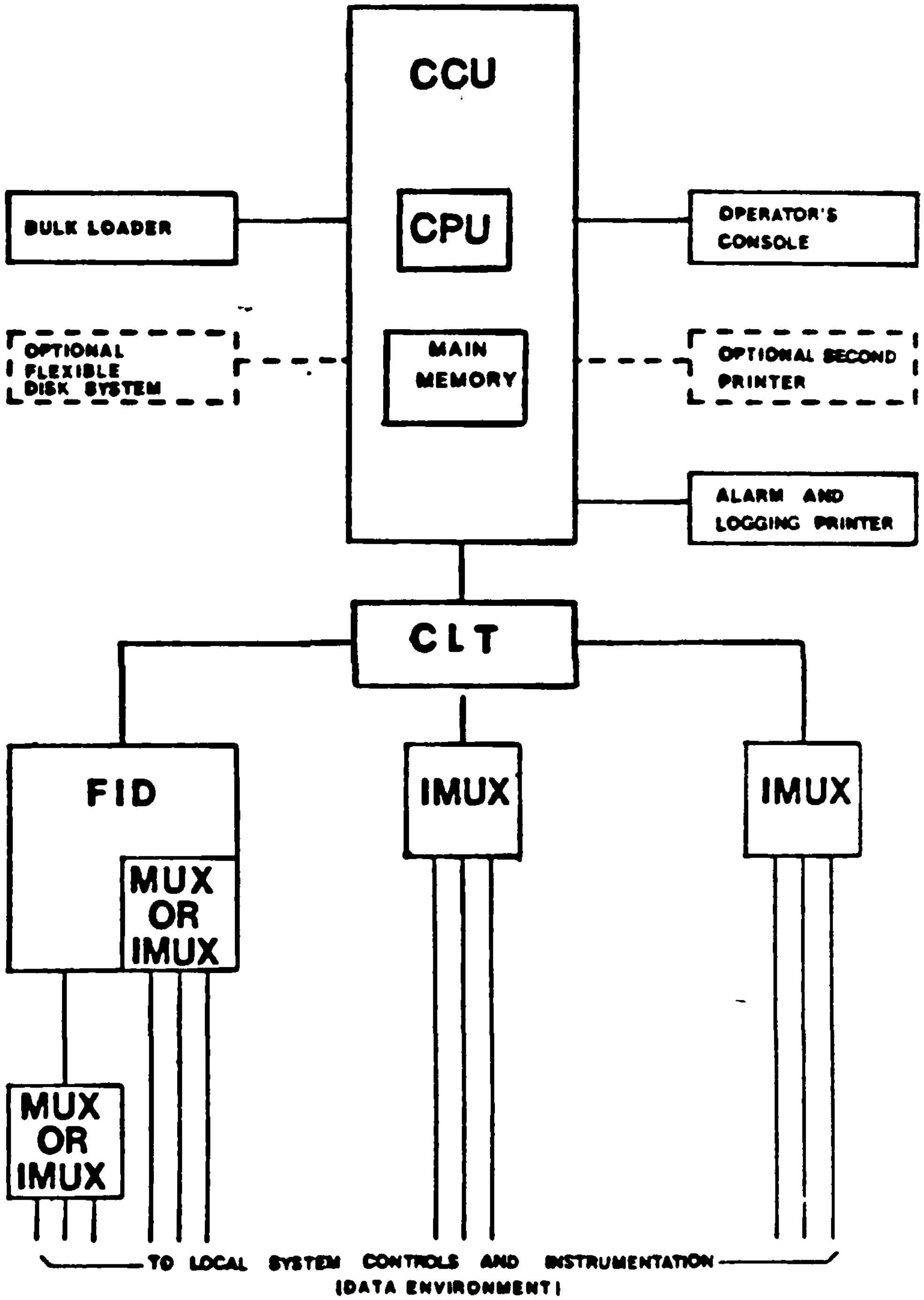


Figure 2-6
Small EMCS Architecture

3. IMUX panels.

4. Programming and service panel (removable).

5. CLT.

A typical configuration is shown in Figure 2-7.

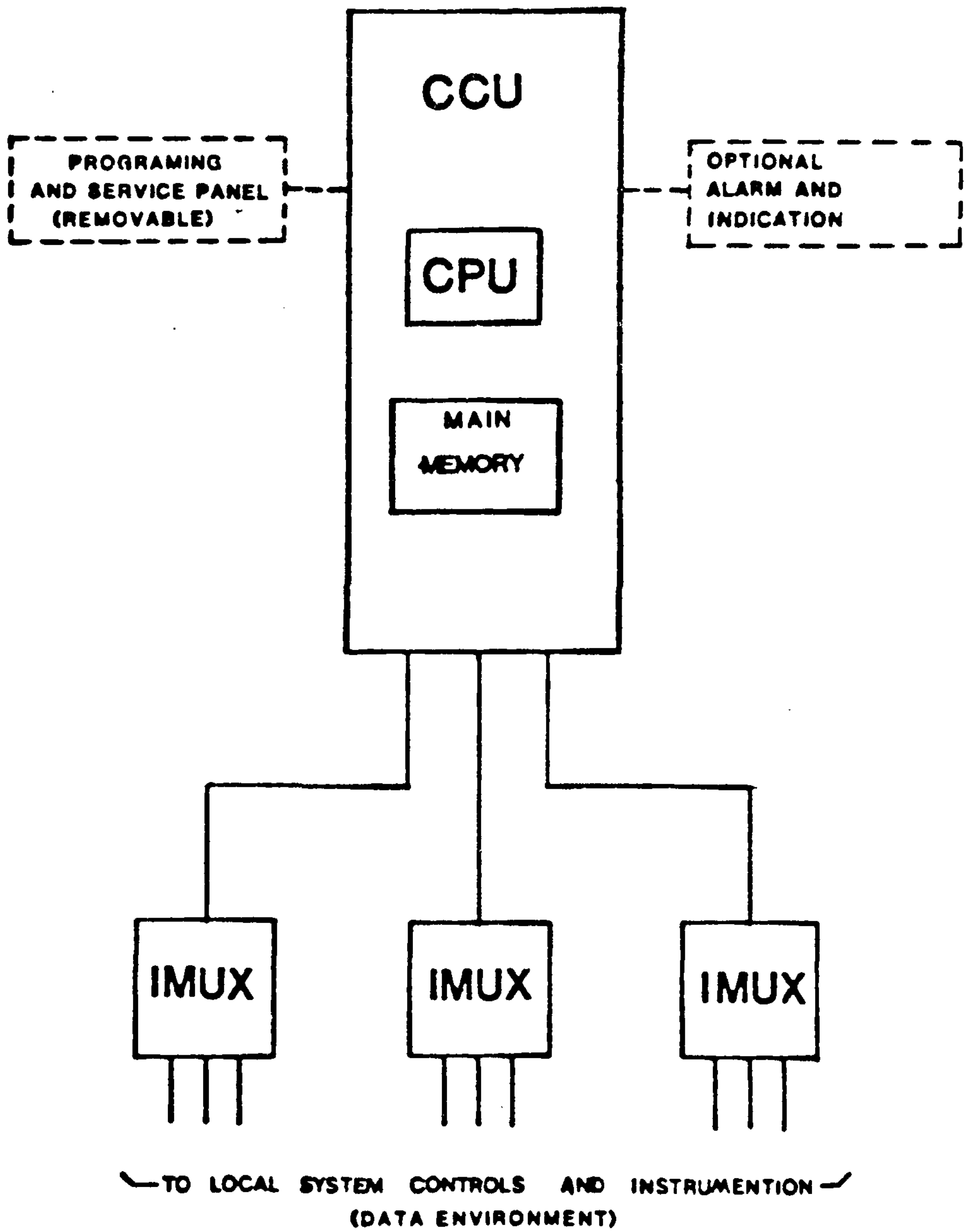


Figure 2-7
Micro EMCS Architecture

SECTION 2. OPERATOR INTERACTION WITH THE EMCS

The operator's terminal is the communication link between the operator and the EMCS equipment. Even though an EMCS is computer controlled, there is still a need for human intervention. The console accepts operator commands and displays data and graphical representations of systems controlled or monitored by the EMCS. Using the console the operator may initiate software programs, control various equipment, and adjust setpoints. The EMCS monitors and controls energy consuming equipment such as motors, fans, water chillers, etc. Should equipment malfunction, an alarm is relayed to the operator.

There are four basic types of operator interfaces which may be encountered on EMCS's. The four different types include command language, command line mnemonic, menu penetration and interactive color graphics.

Command Language

The command language interface technique uses a black and white CRT terminal. The basis of the command language interface is a command library, consisting of abbreviated (2 to 5 characters) symbolic "words", or commands. A basic command word will usually have associated with it a number of modifiers or arguments, which follow the command word and are separated by some type of punctuation symbol, such as a comma, semicolon, or slash mark. Figure 2-8 shows some examples of typical commands.

```
KIL, LOOP NAME/ALL
TIM,HOUR, MINUTES
LOC, L1,<L2>, <L3>
LOG, <L1>,<L2>,<L3>,<OUTPUT DEVICE>
RM, L1, L2, L3, <DEL>
CHL, L1, L2, L3, <DEL>
AHU, L1, L2, L3, <DEL>
FSI, <DEVICE>
```

Figure 2-8
Sample Command Library

The operator controls the HVAC system by typing on the CRT keyboard the appropriate command for the desired function. Command libraries can contain hundreds of different commands, and these must be learned by the operator, or looked up in some reference book, for the operator to be able to use the EMCS. The EMCS responds to the operator by displaying similar symbolic words on the CRT screen. The command language technique features a very precise, rapid interaction with the EMCS computer. However, this precision of interaction has the undesirable side effect of making the technique inflexible and unforgiving. If the operator mistypes a command, omits a required modifier, or misplaces even a comma, the EMCS will not recognize the command and will respond only with an error message like "syntax error". The command language interface technique was the first one to be used with EMCS's and will be found in a large majority of operating systems.

Command Line Mnemonic

The command line mnemonic (pronounced nee-mon'-ic) interface technique represents a step taken towards improving the "friendliness" of the operator interface with the EMCS computer, i.e., making the system easier to use. The command line mnemonic (CLM) interface also uses a black and white CRT terminal, but unlike the command language interface, the CLM prompts the operator for necessary inputs with plain English phrases or words. The operator initiates the input sequence with an English-like command word. The EMCS computer thereafter prompts the operator for command modifiers or arguments until all input requirements are met. The operator then presses the "ENTER" key, which terminates the current input routine and sends the input commands on to the EMCS computer. In the computer, a software program called a CLM interpreter (CLMI) reads and translates the input command sequence. The CLM interface is much slower to operate than is the command language interface. This is because with the CLM, the computer generates multiple cues and responses for each input command sequence, and the CLMI must translate each command sequence. Thus, the trade-off for ease of operation with CLM is reduced operating speed. Conversely, the very precise input commands in the command language interface allow for rapid input entry, but require the operator to memorize unnatural symbolic command words and any associated modifiers or arguments.

Menu Penetration

The menu penetration interface technique is an attempt at regaining the speed of operation associated with the command language interface, while retaining the ease of operation of the CLM interface. Menu penetration uses a black and white or color CRT terminal which displays menus or lists of commands and input values from which the operator simply selects the desired item. Figure 2-9 shows a sample menu of buildings or data environments.

1. BLDG 21
2. BLDG 23
3. BLDG 67
4. BLDG 68
5. BLDG 329
6. BLDG 602

Figure 2-9
Sample Menu-First Level

To select an item from a menu, the operator need type in only the number of the desired item. With the command language and CLM interfaces, the entire command word or symbol, including modifiers and arguments must be entered. Thus, the menu penetration interface allows more rapid operator input from a given menu. Selection of an item from the first level building menu shown in Figure 2-9, results in the system displaying a second level menu of equipment types, shown in Figure 2-10.

1. General
2. Air Handling Equipment
3. Heating Equipment
4. Refrigeration Equipment

Figure 2-10
Equipment Menu-Second Level

Operator selection of an item from the equipment menu causes the EMCS computer to display a third level air handling equipment menu, Figure 2-11.

1. AHU # 1
2. AHU # 2
3. AHU # 3
4. AHU # 4
5. RELIEF FANS

Figure 2-11
Air Handling Equipment Menu-Third Level

This process of penetrating from menu level to menu level continues until all of the required inputs to accomplish a desired function have been completed. The process of penetrating through the levels of menus takes additional time compared to the very precise command language inputs, however, the simple single key stroke entry saves time and requires almost no typing skill on the part of the operator.

Interactive-Color Graphics

The interactive color graphics (ICG) interface technique is the latest development in operator interface technology, and promises to provide the fastest and easiest to operate interface produced to date. The ICG interface uses a color CRT terminal equipped with a touch interactive feature on the CRT screen. Figure 2-12 shows the presentation provided on the ICG interface CRT. The basis for operator interaction with the terminal is a schematic-like diagram of the data environment HVAC system, and a set of touch-activated "push-buttons". By simply touching the appropriate "push buttons" and EMCS point interactive touch targets on the CRT screen, the operator can accomplish all of the typical control functions listed in Figure 2-13. The only typing required is the inputting of numerical values when called for by cues to the operator appearing along the lower edge of the ICG screen. None of the three previously described interface techniques (command language, CLM, menu penetration) has incorporated any type of diagram of the HVAC system being controlled. In early systems, the only way for an operator to identify devices and equipment within the controlled HVAC system was by reference to a computer-printed table. Tabular data does not provide a very graphic description of a system and is certainly not the type of presentation familiar to typical EMCS operators. Most EMCS operators come from the ranks of HVAC mechanics, and thus are accustomed to working with schematic-like diagrams of systems. To overcome the lack of graphic information associated with early EMCS operator interfaces, manufacturers provided 35 mm slides of system diagrams in projector devices located in the EMCS control room. Thus, to identify a given air handler in a building, the operator would have to flip through the slides to find the appropriate building diagram. As EMCS operator interface technology moved to the menu penetration scheme, vendors began to provide color graphic CRT's for the EMCS control room upon which could be displayed full color HVAC system diagrams as called by the operator from a menu. The next logical step in interface development was to combine the necessary

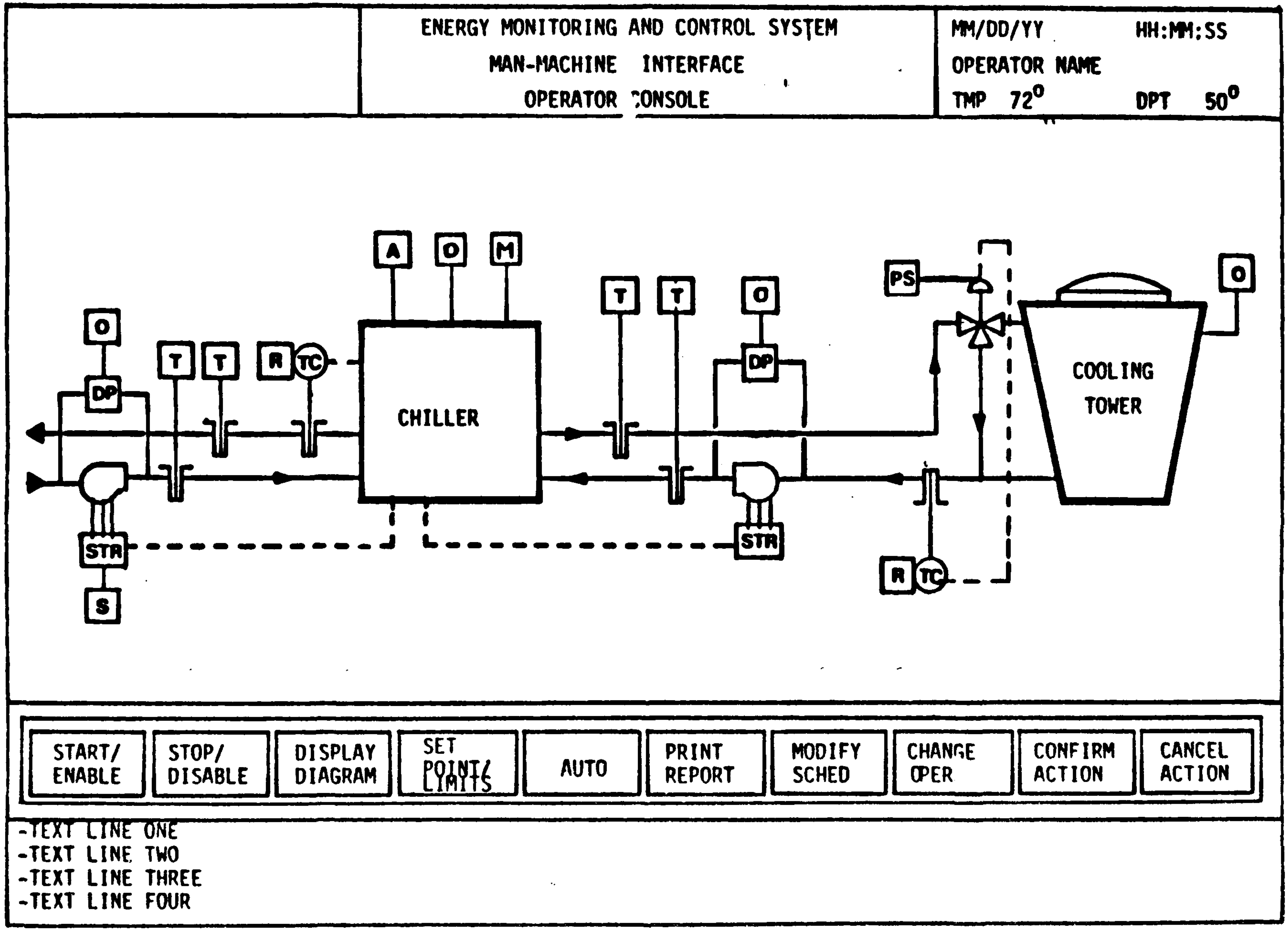


Figure 2-12
Interactive Color Graphics Screen

diagrammatic HVAC system display with the required operator command input capability. Thus, the ICG interface uses elements from all of the previous interface techniques to make the EMCS fast and easy to operate.

- Request a display of any digital or analog point, or any group of related points in the system.
- Startup and shutdown of selected systems or devices.
- Initiate reports.
- Request graphic displays.
- Modify time and event scheduling.
- Modify analog limits.
- Adjust setpoints of selected controllers.
- Select manual or automatic control modes.
- Enable and disable individual points; disabling shall take precedence over all other actions.
- Enable and disable individual FIDs.
- Enable and disable individual MUX or IMUX panels.
- Point definition.

Figure 2-13
Operator Tasks

Operation of the ICG Terminal

The operator's terminal consists of a keyboard and CRT display screen. The display screen is equipped with an interactive touch panel. Approximately one inch in front of the screen is an array of infrared beams which are continuously sent from the top to bottom of the screen area. The beam can be interrupted by an object such as a pencil or finger. This allows the operator to interact directly with information presented on the screen. This minimizes the need for typing.

The screen is divided into five major areas:

1. Date/time/operator (continuously displayed)

2. Graphics display area

3. Special function keys

4. Message/text area, and

5. Alarm indicator.

The screen layout is shown in Figure 2-14.

The alarm area will be blank under normal conditions. Under an alarm condition the area will flash in red. The date, time, and operator's name are entered from the keyboard.

SPECIAL FUNCTION KEYS

Ten Special Function keys allow the operator to instruct the computer to perform complicated commands by simply touching the screen.

The START/ENABLE key is used to manually start mechanical equipment and to enable monitoring and control components such as a FID, MUX, or data point.

The STOP/DISABLE key is used to manually stop mechanical equipment and to disable monitoring and control components.

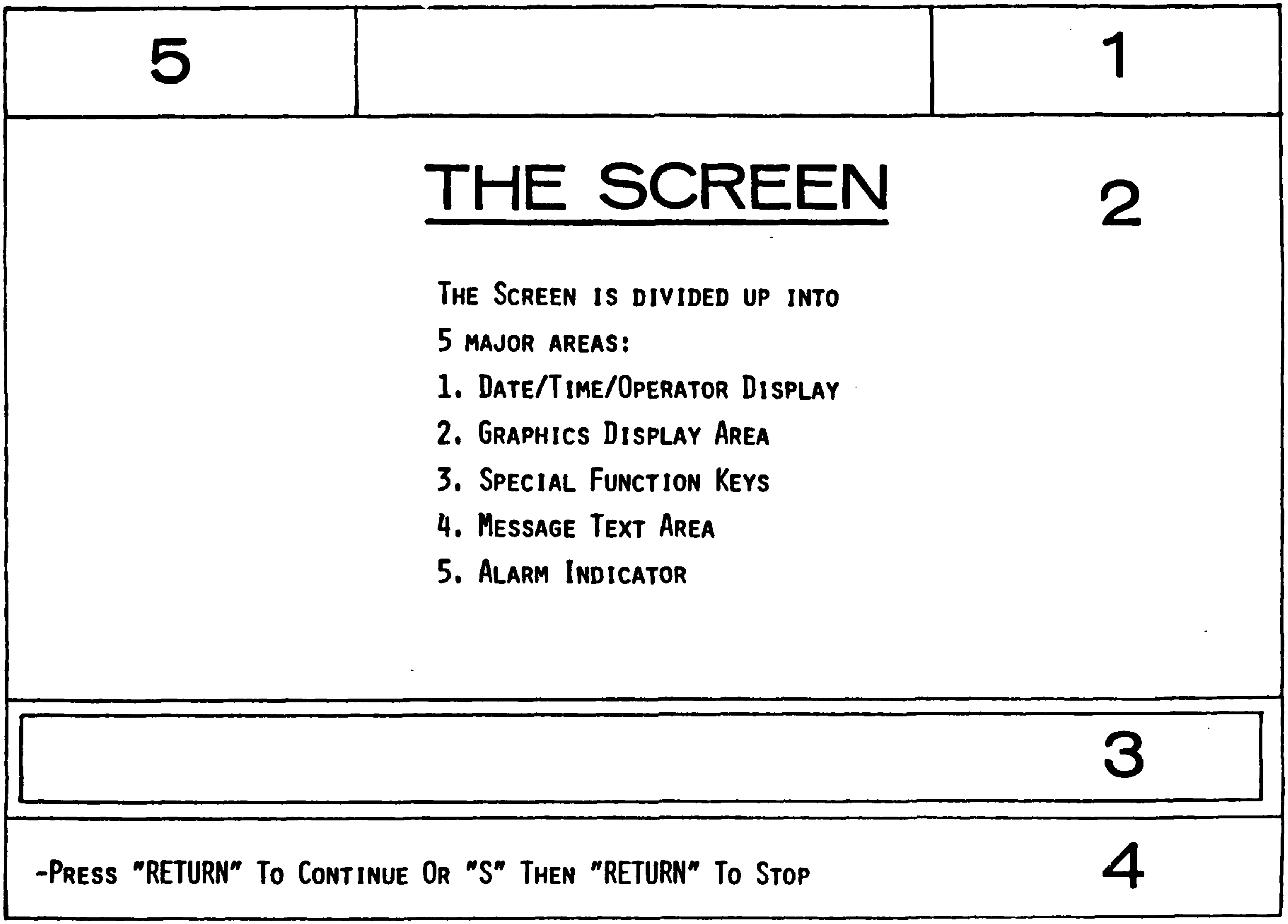


Figure 2-14
Interactive Screen Layout

The DISPLAY DIAGRAM key is used to display HVAC diagrams of specific data environments (DEs) in the graphics display area. When the DISPLAY DIAGRAM key is touched a list of the DEs possible for selection is presented in the graphics display area. When the square beside the desired area is touched, the square will change color to indicate that it has been selected. When the CONFIRM ACTION key is touched it becomes backlighted, the DISPLAY DIAGRAM key backlight extinguishes, and the selected diagram is presented in the graphics area.

The AUTO/MANUAL key is used to select or indicate the operating mode of a particular data environment. This key has three different representations on the screen:

1. When no DE is being displayed, the key will read "AUTO" or "MANUAL" in black letters.
2. When a DE running in an automatic mode is displayed, the key will have "AUTO" printed on it in blue letters.
3. When a DE is operating in a manual mode, the key will read "MANUAL" in green letters. To change the mode of a device touch the device to be changed then to the CONFIRM ACTION key to execute.

The PRINT REPORT key allows the operator to initiate printing of special reports. Touching the key will result in a list of available reports to be displayed on the screen. The message "Touch Square Beside Desired Report" will appear in the text area. Touching the CONFIRM ACTION key will result in the report being printed.

The MODIFY SCHED key is used to modify the automatic schedule of operation for a particular data environment. When a DE is displayed, touching the MODIFY SCHED key results in a list of schedule selections being displayed on the screen. The procedure to modify a schedule is the same as that for changing point settings or limits: touch the square beside the desired selection; type in the changes; after all changes have been made, touch the CONFIRM-ACTION key.

The CHANGE OPER key is a multipurpose function key for changing operator or operation. It allows the operator to shut down the system, request the HELP program, or change operators. When the key is touched these messages are displayed, "Ready to Change Operator/Operation" and "Enter Command or New Operator Name From Keyboard." The system will then accept one of three commands: Operator Name, HELP, or STOP. Type in the desired command followed by the Return Key. When an operator's name is typed in, the system assumes that an operator change is taking place and that future commands should be recorded under a new name. The HELP command is used to enter the on-line HELP program. The STOP command may be used to shut down the EMCS.

The CONFIRM ACTION key is used to assure the system that the desired command sequence has been entered and ready to be executed.

The CANCEL ACTION key performs the opposite function of the CONFIRM ACTION key. It can be used any time prior to touching the CONFIRM ACTION key, to signal the system to abort the current command and return to the previous state.

To adjust setpoints or limits of a point of an HVAC system displayed in a diagram, the SET POINTS/LIMITS key must be touched. The key will become backlighted, and "Touch Appropriate Device Symbol" will appear in the text area. When the device symbol has been touched the message "Touch CONFIRM ACTION" will be presented in the text area. Once the confirm action key is touched, a list of set point, low limit, and high limit with touch sensitive squares will be presented, as shown in Figure 2-14. The low and high limits being the minimum and maximum desired values for a points.

One or all points or limits can be changed one at a time. Limit changes are made by touching the desired selection and typing in the desired value after the message "Please Type In the New Value" appears in the text area.

The confirm action key must be touched after the final limit has been changed.

Floppy Disk Drive Operation

In many EMCS's, the computer software programs are loaded into the machine from a floppy diskette. The diskette comes in two envelopes. The outer one must be removed to load the diskette, the inner envelope is permanently fixed and must never be removed. The first step in loading a diskette is to open the loading slot door on the disk drive unit. This door will usually have some simple type of latching mechanism which is released by a pinching motion with the fingers. Remove the diskette from its outer envelope, and hold it in the right hand with the thumb on top of the diskette label. Gently push the diskette all the way into the loading slot, then close the disk drive door by pushing on the handle. To remove a diskette, simply release the latch on the door and the diskette will pop out of the slot. The disk drive power switch must usually be actuated manually. When handling a diskette, do not touch the plastic diskette surface with the fingers. Diskettes must be stored away from high heat sources and magnetic devices.

Additional Operator Functions

In addition to monitoring and controlling HVAC equipment through use of the operator's console, an EMCS operator has several other functions or duties to perform. From time to time the operator will be required to perform minor equipment maintenance, such as replacing ribbons and paper on the printer, trouble shooting equipment in the main control room (MCR), possibly replacing circuit boards to restore equipment to normal operating condition. An operator will also occasionally have to "boot-up" or restart the EMCS computer programs. Equipment maintenance and program restart procedures are site peculiar, and will be governed by local operating instructions and taught as part of the vendor's training. the EMCS operator is also responsible for safeguarding of the EMCS computer programs. In most EMCS installations, the computer programs are the proprietary material of the system contractor and may not be given out to any unauthorized individuals. Locking cabinets are usually provided in the MCR for storing this proprietary material.

Another important factor is that the EMCS operator is only one part of a team of individuals who must work in a coordinated manner if the EMCS is to fulfill its goal of energy conservation. The EMCS operator in the MCR is the focal point, but interaction with both base management and HVAC maintenance personnel is vital. Base management personnel must be informed as to the capabilities, limitations and objectives of the installed EMCS, so that they will be supportive in establishing necessary operating policies which are not always popular with base tenants. Likewise, HVAC maintenance personnel must understand what the EMCS can do for them, how it can help them in locating the cause of trouble calls and in doing preventive maintenance.

SECTION 3. EMCS APPLICATIONS SOFTWARE

The EMCS applications software consists of a group of programs, residing in the memory of the central processing unit (CPU), that monitor and control the operations of various HVAC, mechanical, and electrical systems. Each program attacks a different aspect of a base's energy consumption. While the primary function of this software is to reduce energy consumption, other programs may be included in a particular installation to provide functions such as maintenance management and security alarms.

The identification used for a particular energy conservation program varies among individual manufacturers. Their methods and approach to a particular task may also vary. The strategy used depends on the particular software or hardware a manufacturer uses to accomplish each task, rather than the task itself. Generally, the applications software is provided by the manufacturer in standardized packages, but custom energy saving programs may be included to accomplish a specific task peculiar to the site.

Discussed below are nineteen applications programs which are required by the Tri-Services specifications for large EMCS installations. Each will be described in terms of what it is designed to do, how it conserves energy, and how it interacts with the operation of typical equipment. Figure 2-15 lists various mechanical and electrical systems and the applications software applicable to each. Whether a program is employed in the control of an individual system depends on many factors which affect the EMCS design, such as economic feasibility, special environmental requirements, and safety considerations. For instance, although the Scheduled Start/Stop program can be applied to a single zone air handler, it would not be implemented on an air handler serving a microbiology laboratory which requires a room temperature of 65°F to 70°F at all times.

No.	HVAC System Type	Scheduled Start/Stop	Optimum Start/Stop	Duty Cycling	Demand Limiting	Day/Night Setback	Lighting Control	Economizer	Enthalpy	Ventilation/Recirculation	Hot/Cold Deck Temp. Reset	Reheat Coil Reset	Boiler Optimization	Hot Water OA Reset	Chiller Optimization	Chiller Water Temp. Reset	Condenser Water Temp. Reset	Chiller Demand Limit ◆
1	Single Zone AHU	●	●	●	●	●		●	●	●								
2	Terminal Reheat AHU	●	●	●	●	●		●	●	●		●						
3	Variable Air Volume AHU	●	●	●	●	●		●	●	●								
4	Multi-Zone AHU	●	●	●	●	●		●	●	●	●							
5	Single Zone DX-A/C	●	●	●	●	●		●	●	●								
6	Multi-Zone DX-A/C	●	●	●	●	●		●	●	●	●							
7	Two Pipe Fan Coil Unit	●	●	●	●	●												
8	Four Pipe Fan Coil Unit	●	●	●	●	●												
9	Heating Ventilating Unit	●	●	●	●	●				●								
10	Steam Unit Heat					●												
11	Electric Unit Heater	●	●	●	●	●												
12	Hot Water Unit Heater					●												
13	Steam Radiation		●			●												
14	Electric Radiation	●	●	●	●	●												
15	Hot Water Radiation		●			●								●				
16	Steam Boiler												●					
17	Hot Water Boiler												●					
18	Direct Fired Furnace	●	●	●	●	●												
19	Direct Fired Boiler	●	●	●	●	●												
20	Steam HW Converter	●	●											●				
21	HTHW Steam Converter													●				
22	HTHW HW Converter	●	●											●				
23	Water Cooled DX Compressor	●	●	●	●												●	
24	Air Cooled DX Compressor	●	●	●	●													
25	Air Cooled Chiller	●	●	●	●										●	●		●
26	Water Cooled Chiller	●	●	●	●										●	●	●	●
27	Lighting Control				●		●											
28	Domestic HW Electric	●	●	●	●													
29	Domestic HW Gas or Oil	●	●															

*Select Economizer or Enthalpy
◆Centrifugal Chillers only

Figure 2-15

Scheduled Start/Stop

The Scheduled Start/Stop program consists of starting and stopping equipment based on the time of day and type of day. Type of day refers to weekdays, Saturdays, Sundays, holidays, or any other day which has a different schedule of operation. This is the simplest of all EMCS functions to implement. In this application, the EMCS serves as a time clock. However, whereas a time clock has limited capability to provide varied schedules for large numbers of buildings, the EMCS scheduled start/stop program is very adaptable. Most EMCS provide an eight day schedule, the five normal workign days (Monday-Friday), two normal weekend days (Saturday and Sunday), and a holiday. This scheme provides flexibility in scheduling on a day-to-day basis and allows the system to easily accommodate schedule changes due to holidays by simply designating a particular week or weekend day as a holiday, rather than reprogramming all data environment schedules.

This program provides potential for energy conservation by turning off equipment or systems during unoccupied hours. Automatic scheduling of HVAC equipment saves energy in three primary areas:

- Electric energy for fans and/or pumps
- Cooling energy for ventilation air and heat gain into the space
- Heating energy for ventilation air and heat loss from the building

To get a feel for the amount of energy which can be saved by Scheduled Start/Stop, let's look at a central air handling system with a fan that draws 2 kw of electricity. The unit serves office space which is normally occupied from 8:00 to 5:00, Monday through Friday. The EMCS can be programmed with a weekly schedule to operate during occupied periods plus two hours each morning before people arrive, and skip all holidays. If prior to EMCS installation the system as allowed to run continuously the fan alone would consume

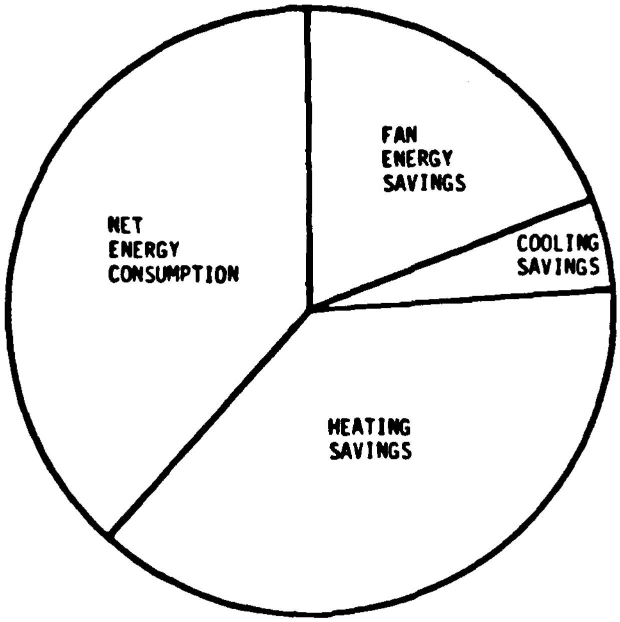
2 KW X 8760 hr/yr = 17,520 kwh per year.

Under control of the EMCS the fan would consume

2 KW x (55 hr/wk x 52 wk/yr - 11 hr/day x 9 holidays/yr) = 5,522 kwh per year

Therefore, the fan would use less than one-third of the energy previously consumed.

In addition to fan energy savings, less fuel would be burned at the boiler serving the air handler during the winter, and less electricity would be consumed by the refrigeration equipment providing cooling medium to the unit in the summer. The schematic in Figure 2-16 illustrates the relative annual savings possible from the example in a location such as Washington, D.C.



SCHEDULED START/STOP SAVINGS OF ENERGY CONSUMED FROM CONTINUOUS OPERATION OF HVAC EQUIPMENT

Figure 2-16

The points generally included for each system under the Scheduled Stop/ Start program are:

Monitoring-

(1) Equipment status, provided by a differential pressure switch, a flow switch, or auxiliary contacts.

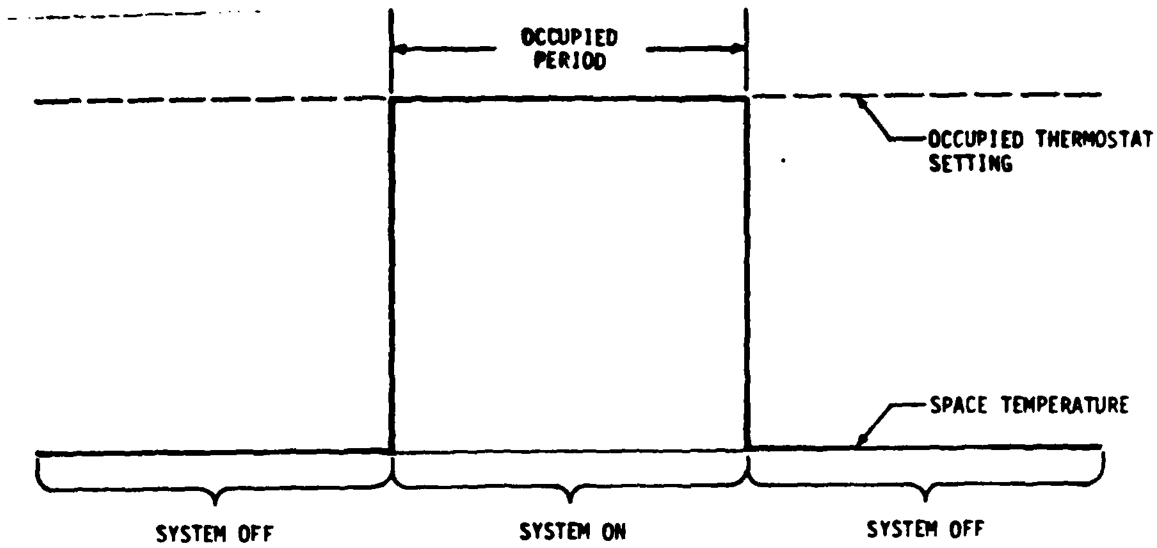
Control-

(1) Start/Stop control signal to interposing relays.

The equipment status, although not mandatory, verifies that the command has been carried out and provides the EMCS operator with an alarm when the equipment fails or is locally started or stopped. HVAC systems connected to the EMCS generally include a space temperature sensor which prompts the EMCS to over-ride the shutoff if the temperature drops below a certain level. The EMCS operator needs to continually update the equipment schedules for each system based on current occupancy schedules and seasonal mode of operation. It is recommended that some procedure be established for communicating occupancy schedule changes to the EMCS personnel.

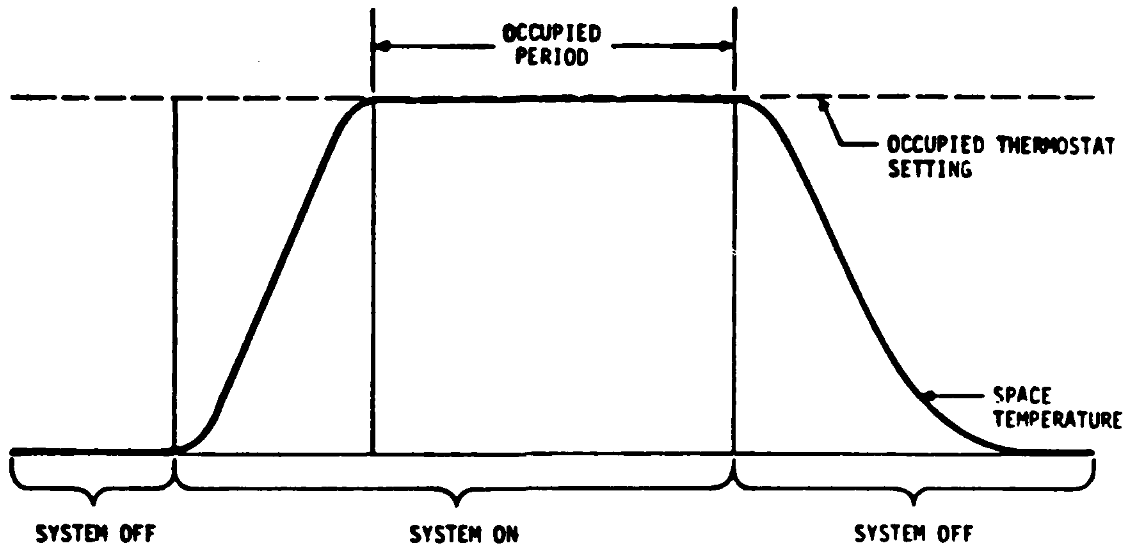
Optimum Start/Stop

An ideal HVAC system, which could instantly create comfortable environmental conditions, would save the maximum amount of energy when controlled under the Schedule Start/Stop program. The operation of the ideal HVAC system is demonstrated in Figure 2-17. In actuality the HVAC requires a finite amount of time to bring the conditioned space to the desired temperature as in Figure 2-18; therefore, the HVAC system needs to be started before occupancy.



IDEAL HVAC SYSTEM OPERATION

Figure 2-17



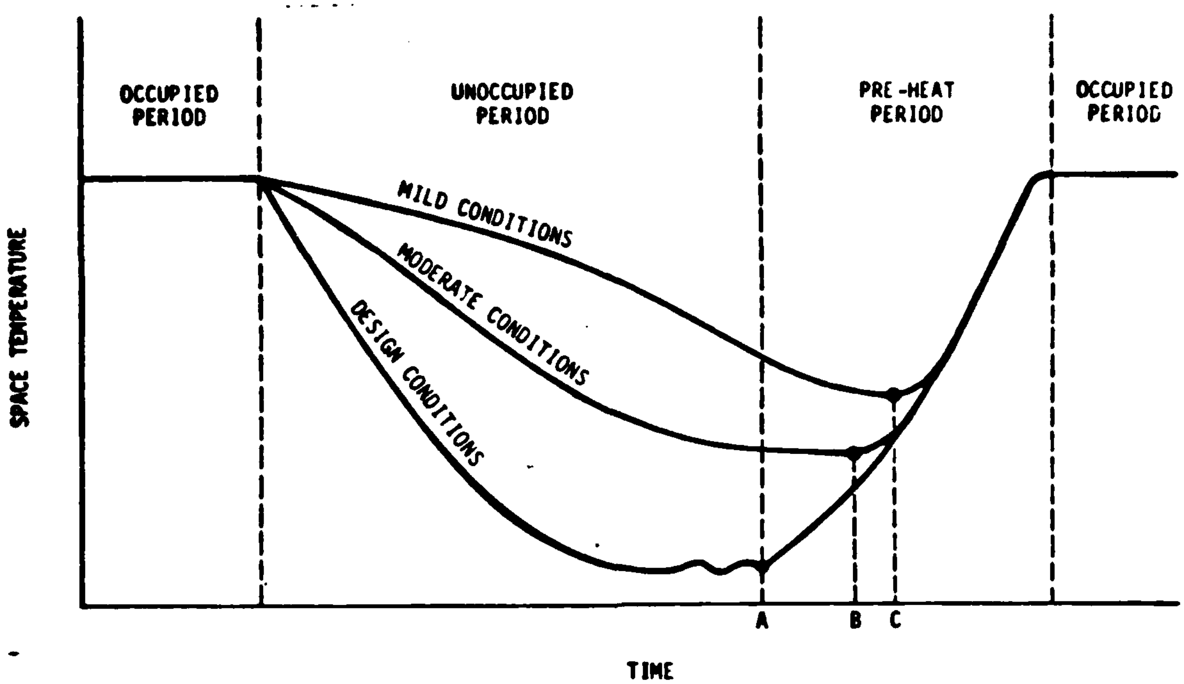
ACTUAL HVAC SYSTEM OPERATION

Figure 2-18

With a conventional timeclock or a straight Scheduled Start/Stop program the system is set to start and stop the same time every day. Due to the variation in weather conditions, the actual amount of time required for warm-up or cool-down varies from day to day. It also may not be necessary to operate the HVAC system up until the scheduled departure of the occupants, because buildings are capable of retaining comfortable space conditions for short periods without heating or air conditioning. This is due to the heat storage capability of building materials which creates a "flywheel effect".

The Optimum Start/Stop program can save additional energy by automatically starting and stopping the system on a sliding schedule. The program will adjust start/stop times by taking into account the thermal characteristics of the building, the capacity of the HVAC system to either increase or reduce space temperatures, outside air temperature, and current space temperatures.

Figure 2-19 tracks the space temperature fluctuations of a typical system for three different weather conditions during the heating season. Points A, B, and C represent the latest possible start times for the different conditions, such that the space will reach a satisfactory temperature by the scheduled arrival of occupants. Under conventional timeclock control or the Start/Stop program the system would have to be scheduled on at a fixed time A each morning. Under control of the Optimum Start/Stop program, the EMCS computer can calculate the optimum start times and save energy by delaying system startup until those times, such as B and C.



OPTIMUM START TIMES

Figure 2-19

The EMCS computer is capable of improving predicted start/stop times based on past history of start/stop times and resulting space temperature profiles. The successful implementation of the Optimum Start/Stop program can increase the savings achievable by Scheduled Start/Stop by 10%.

The points generally included for each system under the Optimum Start/Stop program are

Monitoring-

(1) Equipment status, provided by a differential pressure switch, a flow switch, or auxiliary contacts.
(2) Space dry bulb temperature sensors, at least one.
(3) Space relative humidity sensors, needed only if humidity control is required.
(4) Outside air dry bulb temperature sensor, one for entire EMCS is sufficient.

(5) Outside air relative humidity sensor, one for entire EMCS is needed if humidity control is required.

(6) Chilled water supply temperature, if applicable.

(7) Hot water or steam temperature, if applicable.

Control-

(1) Start/stop control signal to interposing relays.

Generally, the EMCS operator will not have to make any parameter changes to the program. An occasional check on the start-up and shut-down space temperature profiles will be adequate to ensure that the maximum energy savings are being achieved. However, in some systems the operator has an additional input parameter value called a multiplier. By varying the value of the multiplier, the operator can manually fine tune the optimum start/stop program to maximize energy conservation. In some installations it may be necessary for the operator to adjust the program parameters when switching from heating to cooling mode and vice versa.

DUTY CYCLING

The duty cycling program saves energy by turning energy-consuming loads on and off periodically when their continuous operation is not necessary. This program is normally only applicable to heating, ventilating, and air conditioning systems. Some typical applications for duty cycling are

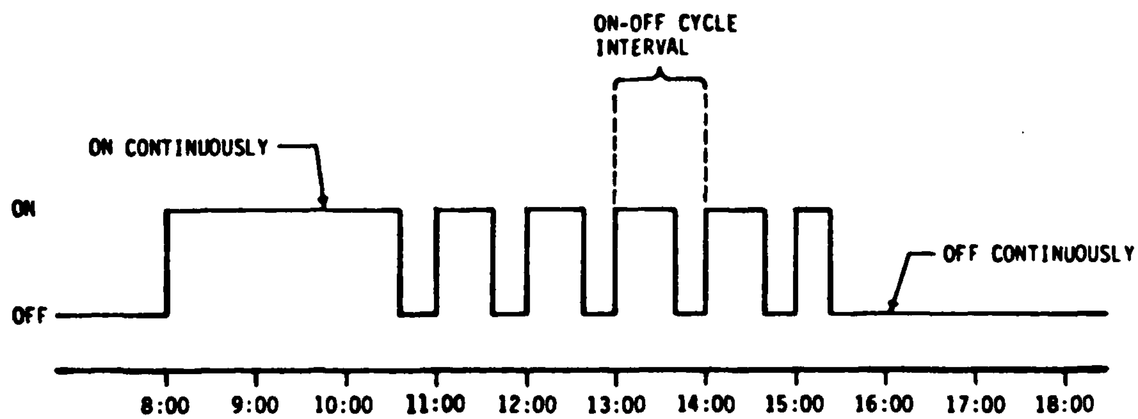
- supply fan motors
- return fan motors
- exhaust fan motors
- pumps

Fan systems serving areas where ventilation is critical, such as hospital operating rooms, should not be duty cycled.

Recall that HVAC equipment is sized so that it is capable of providing comfortable inside environmental conditions during extremes of weather. These outside design conditions only occur for 1 to 5% of the time. The rest of the time the full capacity of the HVAC system is not needed, and duty cycling is possible. If the system is shut off for a short period of time, it has enough capacity to overcome the slight temperature drift which occurs during this shutdown. Although the interruption does not reduce the consumption of space heating or cooling energy, it does reduce energy input to constant auxiliary loads such as fans and pumps. Duty cycling also reduces outside air heating and cooling loads since the outside air intake damper is closed while an air handling unit is off.

The duty cycling program controls a system based on many parameters, which reside in computer memory or are continuously received from the system monitoring points. Typical data which needs to be input into the EMCS by the EMCS programmer or operator for each system are:

- Equipment on-off cycle interval
- Equipment schedules
- Maximum temperature during summer occupied periods
- Minimum temperature during winter occupied periods



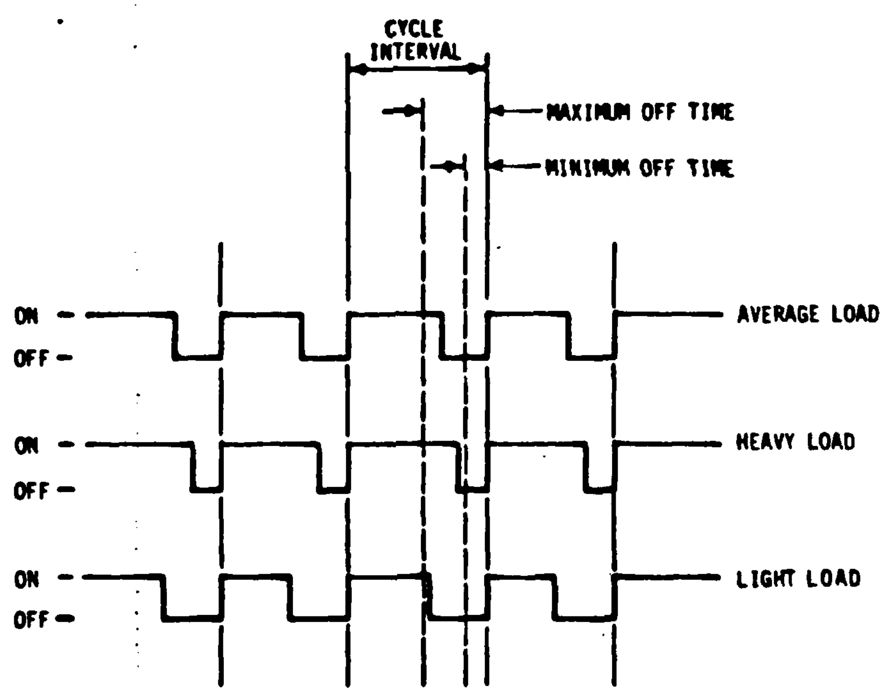
A DUTY CYCLE SCHEDULE

Figure 2-20

- Maximum equipment off time
- Minimum equipment off time

The specific information and the way it is entered into the computer will vary depending on the manufacturer of the EMCS central hardware. A sample duty cycle schedule for an HVAC system is shown in Figure 2-20.

The Duty Cycling program works in conjunction with the Scheduled Start/Stop and Optimum Start/Stop programs. After the Start/Stop program has started a system based on the current occupancy schedule the Duty Cycling program then controls the system until the end of the occupancy period. The length of the on-off cycle interval may be different based on time of day, day of the week, or season. This is determined by the EMCS personnel and is programmed into computer memory. The on-time duration and off-time duration may vary within a cycle interval, based on changing space conditions and requirements of the Demand Limiting program (to be discussed

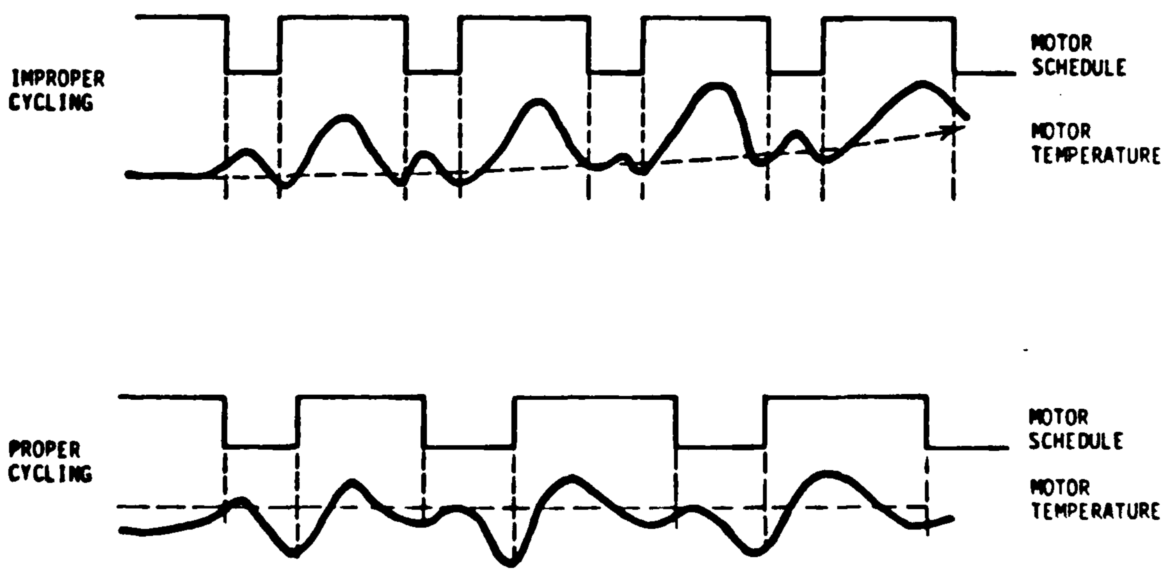


VARYING ON/OFF TIMES

Figure 2-21

next). Off times are automatically decreased if space temperature conditions are not satisfied, or increased if space temperature conditions remain satisfied.

Varying on/off times are illustrated in Figure 2-21 for different heating or cooling loads. In addition, the figure indicates the maximum and minimum off-times which must be established for each system being duty cycled. Maximum off time prevents loss of control of space conditions. Minimum off time assures that motors are protected from extreme thermal and mechanical stress. Frequent cycling produces additional wear on fan belts and bearings. Electric motors can be damaged by not allowing time for the motor windings to cool between cycles. Note the increase in motor temperature due to insufficient off-time, illustrated in Figure 2-22. The solid line represents the instantaneous motor temperature; the dashed line represents the average motor temperature. Large horsepower motors, above about 30 hp, are usually not duty cycled because of the increased wear and possible thermal damage.



THERMAL DAMAGE TO MOTORS DUE TO INSUFFICIENT DUTY CYCLE OFF-TIME

Figure 2-22

The potential energy savings through duty cycling is proportional to the length of time the equipment can be turned off, since the electrical energy consumption is equal to the amount of power required by an electrical load multiplied by the amount of time the load is operating.

Kilowatt-hours (Kwh) = Kilowatts (Kw) x hours (hr)

For example, if a motor draws 2 Kw and operates 10 hours per day, 5 days a week, the yearly energy consumption will be

(2 Kw) x (10 hr/day) x (5 day/wk) x (52 wk/yr)

= 5200 Kwh/yr

If the motor is cycled off for an average of 15 minutes per hour for 10 hours per day the following energy will be saved

(2 Kw) x (15 min ÷ 60 min/hr) x (10 hr/dy) x (5 dy/wk)

x (52 wk/yr) = 1300 Kwh/yr

or a 25% savings.

The EMCS points usually included for implementation of the Duty Cycling Program on each system are

Monitoring-

(1) Equipment status, differential pressure switch, flow switch, or auxiliary contacts.

(2) Space dry bulb temperature sensors, at least one per HVAC system.

Control-

(1) Start/stop control signal to interposing relays.

If Scheduled Start/Stop and Optimum Start/Stop are also applied to the same system, the points are not duplicated. Signals to or from the same field sensors or control relays operate the system under control any of several applications programs.

DEMAND LIMITING

One function of an EMCS which has little to do with saving energy but can significantly reduce electric bills is the Demand Limiting program. Since utility companies bill large consumers on "peak demand" as well as consumption, users can lower their costs by leveling off their demand. Electric demand of an installation or system may be defined as the power load at the receiving terminals averaged over a specified interval of time. To differentiate between demand and consumption, consider a 1000 watt lightbulb. The lightbulb has an electric demand of 1000 watts or 1.0 kilowatts any time it is on and consumes 10 kilowatt-hours of electric energy over a 10 hour period. Generally, industrial and commercial customers, but not residential users, are billed on the basis of demand as well as energy use.

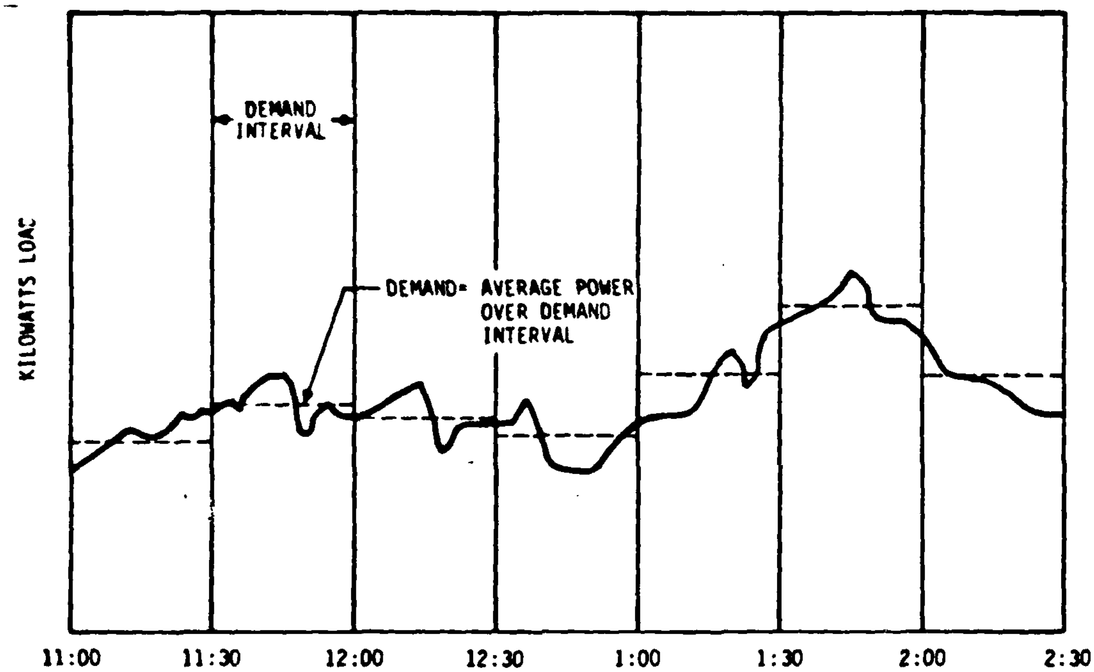
In order to determine the peak demand (the highest Kw load) which occurs during a billing period, the utility establishes a demand interval. This is a fixed period of time over which the power is averaged, usually 15, 30, or 60 minutes long. The demand for each interval is determined from the amount of energy consumed over that period,

$$\text{Demand (Kw)} = \frac{\text{Energy (Kwh)}}{\text{Interval (h)}}$$

For example, assume a 30 minute demand interval. At 3:00 PM the meter reads 55,422 Kwh; at 3:30 PM the meter reads 55,447 Kwh. The energy consumed is 55,447 - 55,422 or 25 Kwh, and therefore the demand is

$$\text{Demand} = \frac{25\ \text{Kwh}}{0.5\ \text{h}} = 50\ \text{Kw}$$

Figure 2-23 illustrates how peak demand is determined. For the period of time shown, the peak demand occurred during the 30 minute demand interval ending at 2:00.

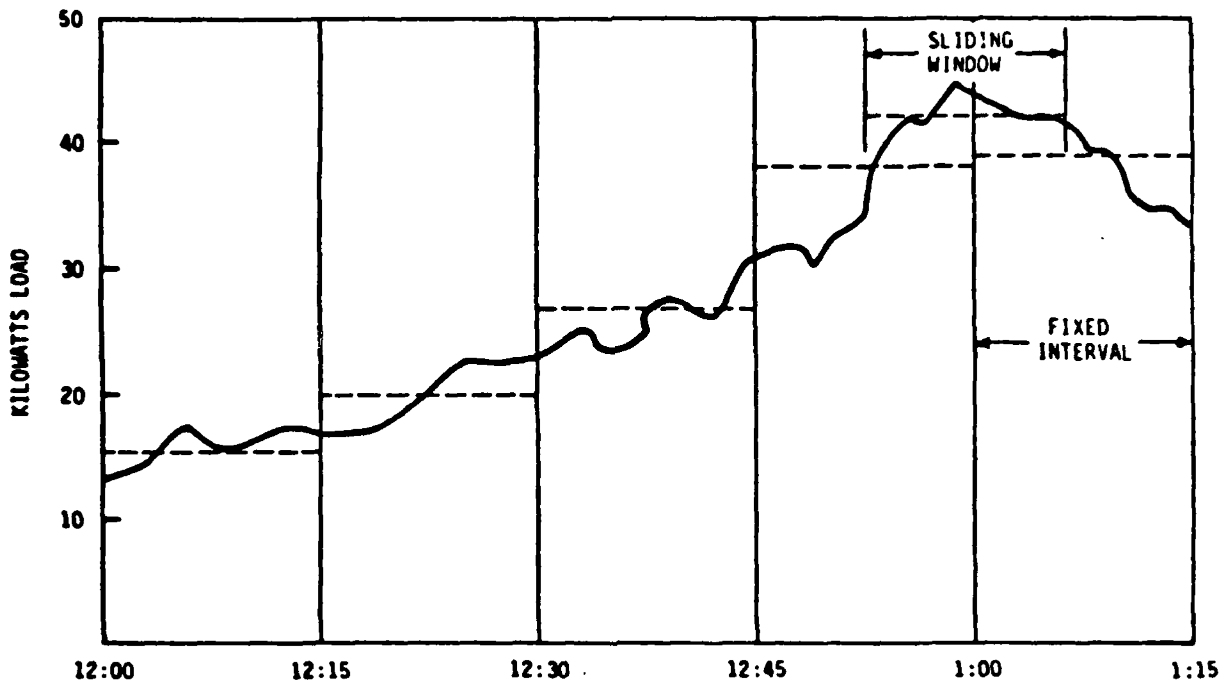


DETERMINING PEAK DEMAND

Figure 2-23

Some utility companies determine peak demand based on a sliding window interval, rather than a fixed interval. The period of time over which the power is averaged is a set number of minutes; however, the interval acts as a "sliding window" which moves with time. Figure 2-24 illustrates this concept. Note that based on a fixed interval the peak demand would be 38 Kw; however, based on an interval that is allowed to "slide" the peak demand is 41 Kw. The utility may also vary the rate of demand charge based on the time of day or the season.

A common method of billing for demand is the inclusion of a ratchet clause in the rate schedule, by which maximum past or future demands are taken into account to establish billings. The ratchet clause makes it possible for a power company to increase their customer's demand charge based on a



SLIDING WINDOW INTERVAL

Figure 2-24

peak value and leave it at the new level for as long as 11 months. For example, consider a building which sets a demand peak of 3000 Kw in July. With a 11 month 90% ratchet clause the customer's demand charges will be based on at least 90% of 3000 Kw or 2700 Kw for the next 11 months. For example, where the average monthly demand equals 2290 KW:

Annual bill with ratchet clause would be:
(3000 kw x .9) x ($10.00/kw) x (12 mo.) = $324,000

Annual bill without ratchet clause would be:
(2290 kw) x ($10.00/kw) x (12 mo.) = $274,800

Additional cost due to ratchet = $49,200

Each utility company has its own method for determining a customer's bill. In fact each utility probably has several different rate schedules for

GEORGIA POWER COMPANY

Power and Light

SCHEDULE "PL-4"

AVAILABILITY:

Throughout the Company's service area from existing lines of adequate capacity

APPLICABILITY:

To all electric service of one standard voltage required on Customer's premises, delivered at one point and metered at or compensated to that voltage.

TYPE OF SERVICE:

Single or three phase, 60 hertz, at a standard voltage.

MONTHLY RATE—Energy Charge Including Demand Charge:

Base Charge		$8.00
First 3,000 kWh	@	7.07¢ per kWh
Next 7,000 kWh	@	7.01¢ per kWh
Next 190,000 kWh	@	5.23¢ per kWh
Over 200,000 kWh	@	3.89¢ per kWh
All consumption (kWh) in excess of 200 hours and not greater than 400 hours times the billing demand	@	0.715¢ per kWh
All consumption (kWh) in excess of 400 hours and not greater than 600 hours times the billing demand	@	0.489¢ per kWh
All consumption (kWh) in excess of 600 hours times the billing demand	@	0.320¢ per kWh

FUEL COST RECOVERY:

The amount calculated at the above rate will be increased under the provisions of the Company's effective Fuel Cost Recovery Schedule.

Minimum Monthly Bill:

A. $8.00 Base Charge plus $7.00 per kW of billing demand in excess of 30 kW, plus excess kVAR charges.

B. Metered Outdoor Lighting: The lesser of (1) that determined from paragraph "A" above, or (2) $27.00 per meter for metered outdoor lighting installations, provided service is limited to the lighting equipment itself and such incidental load as may be required to operate coincidentally with the lighting equipment.

DETERMINATION OF BILLING DEMAND:

The Billing Demand shall be based on the highest 30-minute kW measurements during the current month and the preceeding eleven (11) months. For the billing months of June through September, the Billing Demand shall be the greatest of (1) the current actual demand or (2) ninety-five percent (95%) of the highest actual demand occurring in any previous applicable summer month or (3) sixty percent (60%) of the highest actual demand occurring in any previous applicable winter month (October through May). For the biling months of October through May, the Billing Demand shall be the greater of (1) ninety-five (95%) of the highest summer month (June through September) or (2) sixty percent (60%) of the highest winter month (including the current month). In no case shall the Billing Demand be less than the greater of (1) the contract minimum, (2) 50% of the total contract capacity, (3) 5 kW.

Where there is an indication of a power factor of less than 95% lagging, the Company may at its option, install metering equipment to measure Reactive Demand. The Reactive Demand shall be the highest 30-minute kVAR measured during the month. The Excess Reactive Demand shall be kVAR which is in excess of one-third of the measured actual kW in the current month. The Company will bill excess kVAR at the rate of $0.27 per excess kVAR.

SPECIAL APPLICABILITY:

Construction Service

Construction power shall be considered as a part of permanent service and will be provided in accordance with the Applicability section of this schedule. The Company will obtain a payment in advance for each metering point to be served in the amount currently on file with the Georgia Public Service Commission.

Non-demand Service

Any customer receiving electric service at one point and metered at or compensated to that voltage who uses less than 3,000 kWh monthly and having a maximum 30-minute measured demand of less than 30 kW is not subject to the billing demand and kVAR charges in the minimum monthly bill provision in this schedule. Billing under this option shall be designated PL-4-N.

Unmetered Service

Where the installation of metering equipment is impractical or uneconomical, monthly kWh may be estimated by the Company and billed at the above monthly rate. Billing under this option is designated as PL-4-U.

TERM OF CONTRACT:

Not less than one year up to and including 500 kW maximum anticipated 30-minute kW, nor less than five years over 500 kW maximum anticipated 30 minute kW.

Service hereunder subject to Rules and Regulations for Electric Service on file with the Georgia Public Service Commission.

Effective with meter readings on and after December 29, 1981.

Figure 2-25

different types of customers. A sample commercial rate schedule from the Georgia Power Company is reproduced in Figure 2-25 to show how complex one can be. In addition to charging for Kw demand and Kwh consumption, bills may also include charges for fuel adjustment, taxes, low power factor, and other riders. It would be useful for the EMCS operator to review a copy of the electric rate schedule which applies to their EMCS facility.

The Demand Limiting program prevents unnecessarily high electric peak demand and corresponding utility costs in installations where demand-oriented rate schedules apply. There are many complex schemes for accomplishing this function. Generally, they all monitor the facility electric demand continuously. Based on the monitored data, demand predictions are made by the EMCS. When these predictions exceed preset limits, certain scheduled electric loads are shut off by the EMCS to reduce the rate of consumption and the predicted peak demand. Additional loads are turned off on a priority basis if the demand is not reduced sufficiently to satisfy the program requirements. Generally, the loads to be turned off or "shed" are HVAC items. Loads are restarted based on priority or a rotational scheme as the continually monitored data allows. The demand prediction method, load shedding scheme, and program inputs required for a particular EMCS installation depend on (1) the peculiarities of the EMCS vendor software, (2) the EMCS design, and (3) the power company rate schedule.

It should be evident by now, that the Demand Limiting program does not save energy but reduces the facility electric bills. On a monthly basis, the savings can be anywhere from $1.00 to $8.00 per kilowatt which is shaved off the peak demand. The possible reduction of peak demand depends on the type of loads which are under control of the EMCS, but typically is in the range of 20 to 25% of the total Kw draw of the controlled loads. For the utility company, the Kw savings translates to a reduction in the need for new power generating facilities.

The EMCS points required to implement the Demand Limiting program are

Monitoring-

(1) Equipment status for each piece of equipment that may be shed; differential pressure switch, flow switch, or auxiliary contacts.

(2) Instantaneous kilowatt measurement for each electric meter.

(3) Start of demand interval signal, one per site.

Control-

(1) Start/stop control signal to interposing relays, one for each piece of equipment that may be shed.

Program parameters which may need to be changed by the EMCS operator or programmer are

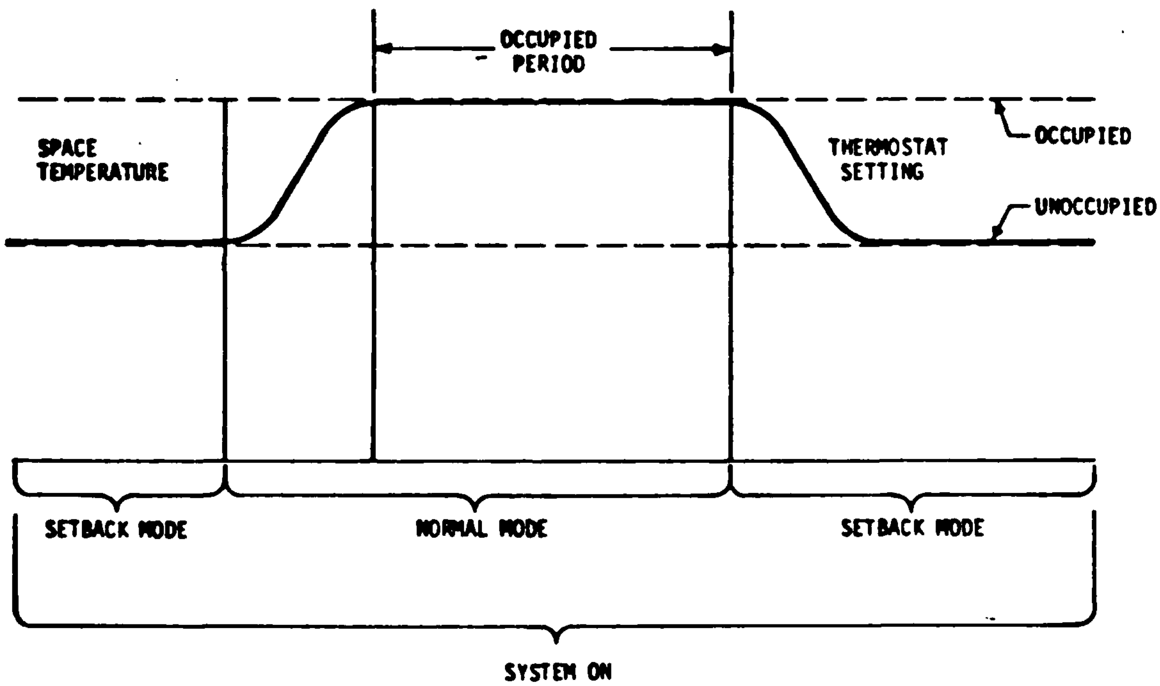
(1) Peak demand limit target
(2) Equipment priority schedule
(3) Length of demand interval
(4) Maximum temperature during summer occupied periods
(5) Minimum temperature during winter occupied periods
(6) Equipment constraints, such as minimum off-time

The last three items have the same purpose as for the Duty Cycling program, although the values could be different for the two programs.

The Demand Limiting program is used in conjunction with the Duty Cycling program to prevent any one load from being cycled on or off during the wrong time interval or an excessive number of times. The Demand Limiting program is also used in conjunction with scheduled start/stop, optimum start/stop, and chiller optimization programs.

DAY/NIGHT SETBACK

Unlike the Scheduled Start/Stop program, Day/Night Setback can be applied to HVAC systems which have no auxiliary fans or pumps, such as steam radiators. By lowering the heating setpoint from normal winter inside design temperature during unoccupied periods, heating energy consumption can be reduced. The magnitude of savings will be proportional to the number of degrees of setback. The program is also applicable to fan systems which serve critical areas that have a temperature, humidity, or pressure requirement during unoccupied hours. In spaces that require air conditioning, but can allow a higher setting than the normal summer inside design temperature, the setpoint can be reset upwards to a temperature compatible with the special requirements.



DAY NIGHT TEMPERATURE SET BACK FOR HEATING

Figure 2-26

The outside air damper on a fan system is generally set at a fixed position or automatically opens and closes due to a control interlock with the fan starter. When a system continues to run during the unoccupied period, ventilation normally is not required. As a result energy is consumed unnecessarily in the process of heating or cooling the outside air. The Day/Night Setback program saves additional energy by independently controlling the outside air dampers. The EMCS sends a signal to close the outside air dampers at the same time that it resets the space temperature setpoint prior to the unoccupied period.

The EMCS points generally included for each system to implement this program are

Monitoring-

(1) Equipment status, differential pressure switch, flow switch, or auxiliary contacts, if applicable.
(2) Outside air intake damper position indicator, one per OA damper, if applicable.
(3) Space dry bulb temperature sensors, minimum of one per HVAC system.

Control-

(1) Day/night signal to interposing relays.
(2) Control signal to close outside air damper, one per OA damper, if applicable.

LIGHTING CONTROL

About 30% of a building's energy is consumed in lighting alone. The goal of lighting control is to allow lights on only when and where they are necessary. This is accomplished basically in the same way as Scheduled Start/Stop and in conjunction with that program; lights are turned on and off based on the time of day and the day of the week. A method of overriding the programmed schedule usually is provided for overtime use of lighting.

Additional off commands may be generated at regular intervals to assure that lights are off. An alternative to this method is to initiate only the off function and require that the lights be turned on manually. Emergency lighting will not be controlled by this program.

EMCS points which are required for implementation of this program are:

Monitoring-

(1) Lighting status, auxiliary contacts, one for each controlled lighting zone.

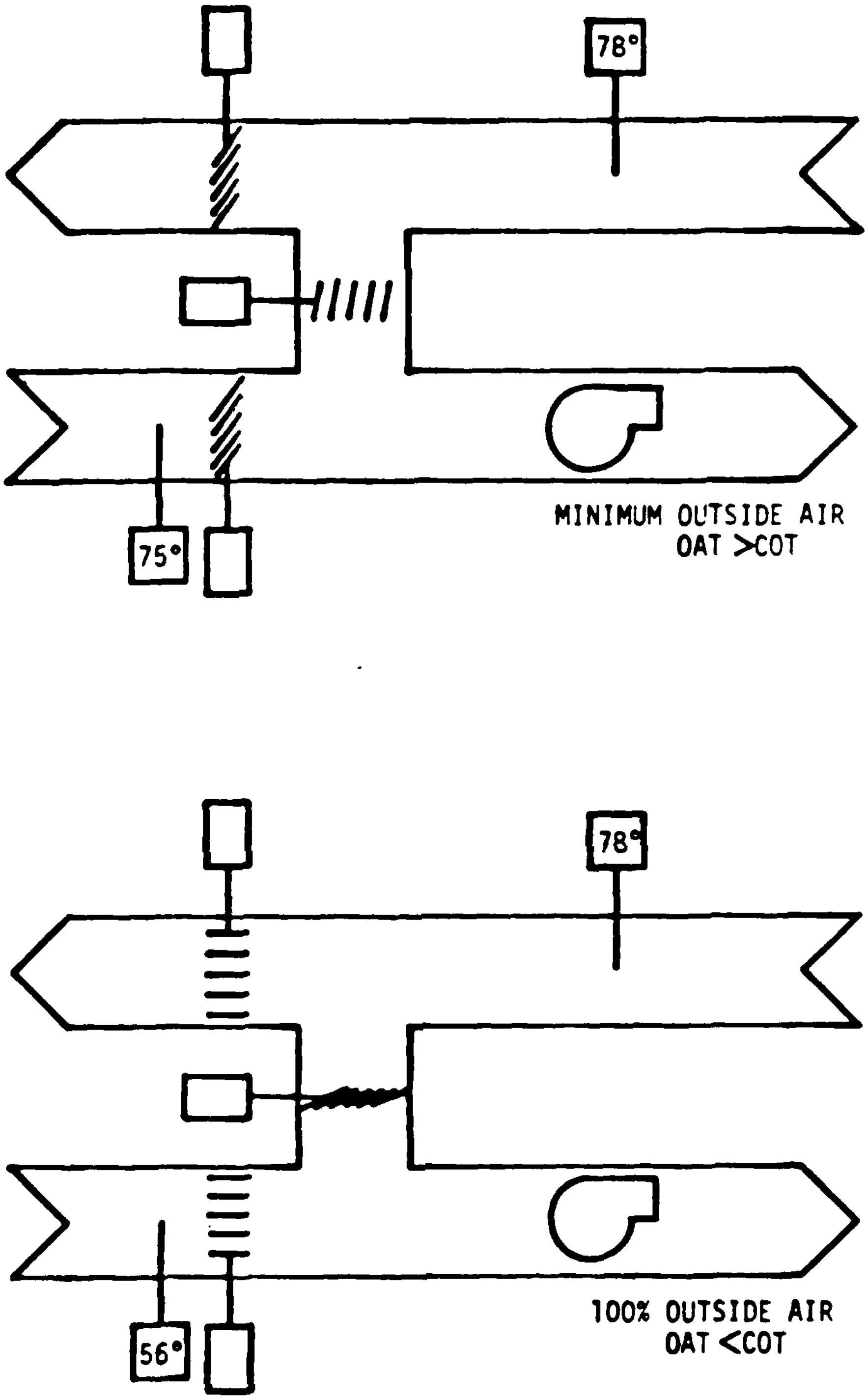
Control-

(1) On/off control signal to interposing relays, one for each controlled lighting zone.

The EMCS operator at times may need to adjust the lighting schedules based on changing occupancy schedules. As with the Scheduled Start/Stop program, it is important that EMCS personnel maintain good communication with building supervisors to ensure that the programmed on/off schedules correspond with building requirements.

ECONOMIZER

In Section 1 of Chapter 1 it was stated that in most commercial buildings cooling is required year-round in the interior zones. This situation provides an opportunity for energy savings by using outside air to aid mechanical refrigeration whenever the outside air is cool enough. Economizer control is activated whenever the outside air temperature is below a set changeover temperature. The changeover point is a design consideration and will vary according to location. For instance, more humid climates will require a lower changeover temperatures. Recall that the air conditioning process consumes energy in the removal of water from the air as well as lowering the temperature. Therefore humid air, although at a lower dry bulb temperature than return air could result in an additional refrigeration load.



DRY BULB ECONOMIZER CONTROL
(CHANGEOVER TEMPERATURE (COT)= 70 F)

Figure 2-27

Under economizer control the EMCS will open the outside air and exhaust air dampers and close the return air damper to allow 100% outside air to enter the air handling system. If a mixture of outside and return air is the best choice from an energy standpoint, the program will calculate the desired mixture and adjust the outside air dampers, return air dampers, and exhaust air dampers accordingly. Recall that generally the relative positions of the outside, exhaust, and return air dampers are interlocked to maintain a constant air flow rate. When the outside air dry bulb temperature is above the changeover temperature, the dampers are positioned to provide minimum required outside air.

The energy savings potential of the Economizer program is dependent on the climate of the site as well as the cooling load of the building. Figure 2-28 lists the percentages of cooling energy which can be saved when economizer control is applied to a hypothetical fan system. The numbers are based on a 55°F supply air temperature, 20% minimum outside air, 75°F and 50% RH return air, 16 hours a day and 7 days a week operation. The first column under savings is for the Economizer control, the second is for Enthalpy control which will be discussed next.

CITY	% COOLING SAVINGS	
	ECONOMIZER	ENTHALPY
Atlanta	30	32
Chicago	39	41
Cleveland	40	43
Dallas	25	27
Denver	54	55
Detroit	39	42
Houston	18	19
Indianapolis	35	38
Los Angeles	42	44
Miami	5	6
Milwaukee	44	47
Minneapolis	39	42
New York	44	46
Phoenix	23	24
Portland	65	66
Sacramento	45	46
San Francisco	65	66

Figure 2-28

The EMCS points which are required for each system to implement the Economizer program are

Monitoring-

(1) Outside air intake damper position indicator.

(2) Outside air dry bulb temperature sensor, one per site.

Control-

(1) Damper position control signal to local control loop.

Program parameters which may need to be changed by the EMCS operator are the changeover dry bulb temperature and minimum outside air damper position.

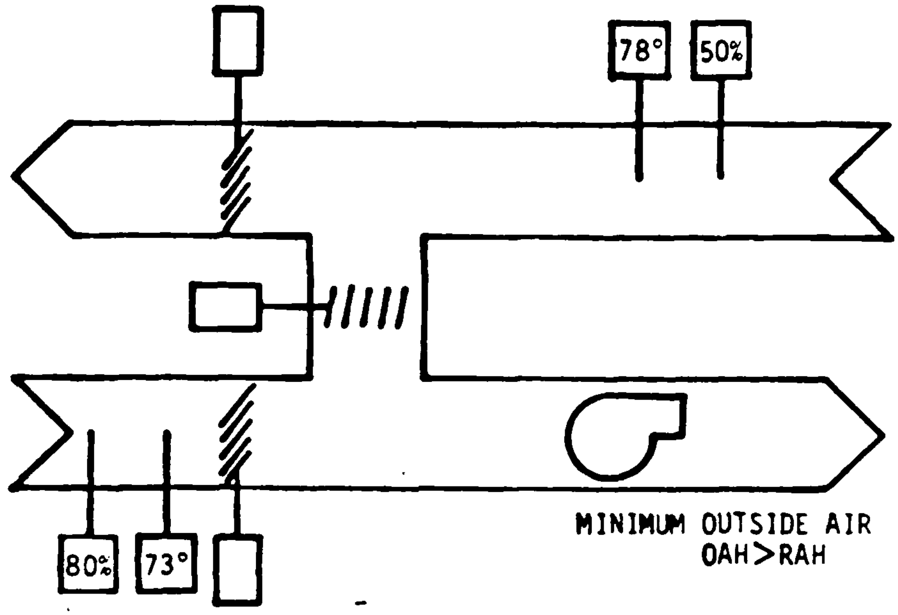
ENTHALPY

The Enthalpy program has the same function as the Economizer program; that is, to permit use of outside air for cooling. They differ, however, in how they determine if use of additional outside air will be advantageous. Either program, but not both, will be applied to a system.

Enthalpy may be defined as a measure of the heat content of a substance and is normally designated by the letter "H". For air the total heat content, or enthalpy, is made up of two components, the sensible heat and the latent heat of water in the air.

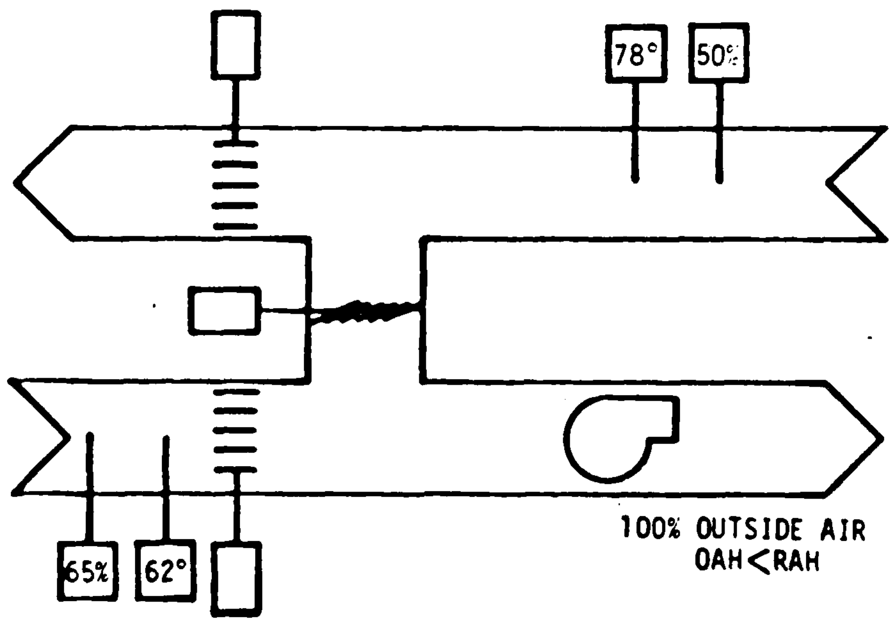
ENTHALPY	= SENSIBLE HEAT	+	LATENT HEAT OF
(TOTAL HEAT)	OF AIR		WATER IN AIR

Dry bulb temperature is a measure of sensible heat in the air. Relative humidity is a measure of latent heat (moisture) in the air. By measuring temperature and relative humidity the enthalpy of air can be determined. A chart illustrating this relationship is called a "psychrometric" chart and can be seen in the Appendix.



ENTHALPIES (Btu/lb)

78°, 50%	29.91
73°, 80%	32.73
62°, 65%	23.22



ENTHALPY ECONOMIZER CONTROL

Figure 2-29

To determine the optimum amount of outside air to allow into an air handling system the Enthalpy program calculates the enthalpy of the outside air and the enthalpy of the return air stream. If the enthalpy of the outside air is less than the enthalpy of the return air, and cooling is desired, then the outside air and return air dampers air allowed to modulate, and sufficient outside air is admitted to minimize the cooling load and maintain required mixed air conditions. If the outside air enthalpy is greater than return air enthalpy then the program positions the outside air dampers, return air dampers, and exhaust air dampers to provide minimum required outside air.

Note in the top example in Figure 2-29 that in spite of the fact that the dry bulb temperature of the outside air is less than that of the return air, the enthalpy is not, due to the higher humidity. The program in this case would maintain minimum outside air damper position. The OAH and RAH in Figure 2-29 stand for outside air enthalpy and return air enthalpy, respectively.

There is more potential for energy savings from the Enthalpy program than the Economizer program due to a more accurate changeover point. Enthalpy control is more costly to implement, however, due to the addition of humidity or dewpoint sensors. Comparing the percentage savings of the two strategies in Figure 2-28, we see that enthalpy control achieves an additional 1 to 3% savings over economizer control.

The EMCS points which usually are included for each system to implement the Enthalpy program are

Monitoring-

(1) Outside air intake damper position indicator.
(2) Return air dry bulb temperature sensor.
(3) Return air relative humidity or dewpoint sensor.
(4) Outside air dry bulb temperature sensor, one per site.
(5) Outside air relative humidity or dewpoint sensor, one per site.

Control-

(1) Damper position control signal to local control loop.

VENTILATION AND RECIRCULATION

The Ventilation and Recirculation program, like the Economizer and Enthalpy programs, reduces energy consumption by controlling outside air dampers. Required ventilation for conditioned spaces needs to be supplied only when they are occupied. Many fan systems are required to run continuously during unoccupied hours to meet 24-hour temperature, humidity, or pressure requirements. Other air handlers cycle on during unoccupied times to maintain a minimum setback temperature. Also, all systems have to be started before occupancy to bring the space to comfort conditions. In these situations the outside air dampers can be closed and 100% return air recirculated. The result is unnecessary outside air is not heated or cooled and thus less energy is used by the HVAC equipment. During occupied periods, the outside air, return air, and exhaust air dampers are under local control. The Ventilation and Recirculation program works in conjunction with the Economizer or Enthalpy program so that during unoccupied periods when outside air would not impose an additional thermal load on the system, but would help condition the space, the outside air dampers are opened.

Heating savings which might be achieved by this program for a 5000 ft^2 electronics lab which requires 68°F, year-round, 24-hours a day are listed in Figure 2-30 for various locations.

EMCS points usually included for each system to implement the Ventilation and Recirculation program are

Monitoring-

(1) Outside air damper position indicator.

(2) Outside air dry bulb temperature sensor, one per facility.

Control-

(1) Open/close damper control signal interfaced to local controls.

LOCATION	ANNUAL SAVINGS CF OF GAS	$
Atlanta	55,700	$287
Chicago	106,050	546
Denver	100,860	520
Los Angeles	16,570	85
Louisville	72,750	375

Ventilation and Recirculation Savings
(5000 ft^2 electronics lab, 24-hr operation)

Figure 2-30

HOT DECK/COLD DECK TEMPERATURE RESET

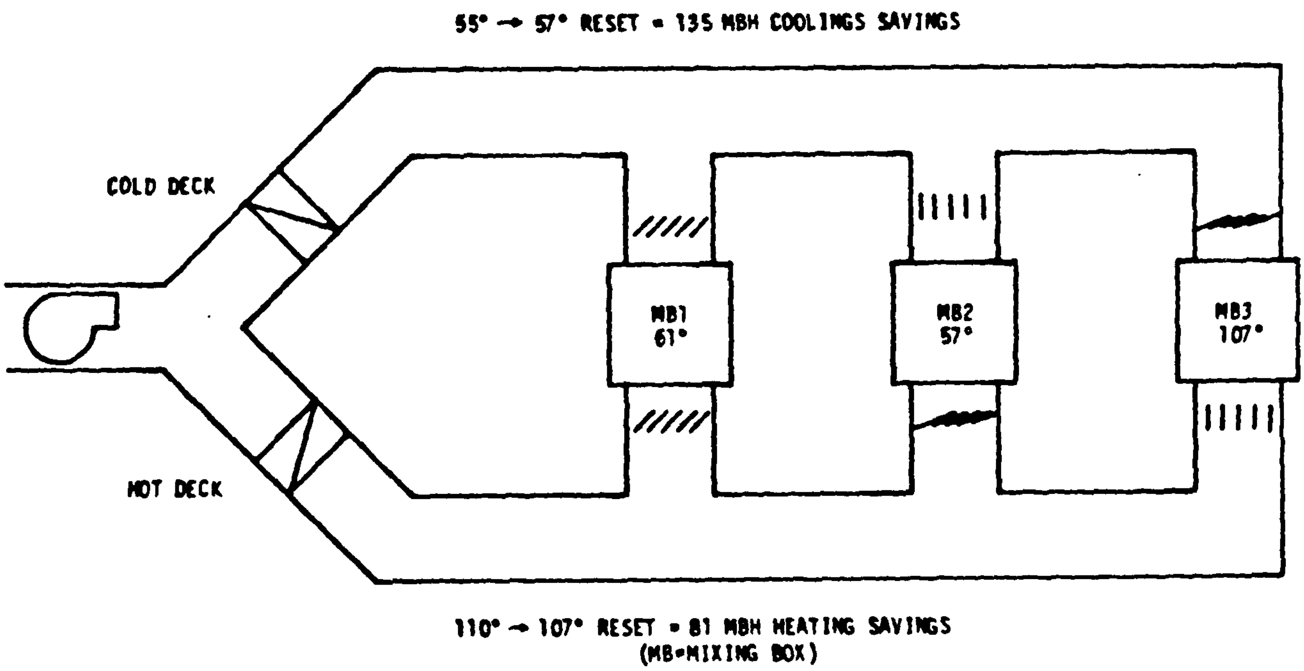
Most HVAC systems are sized to maintain comfort levels during design conditions, even though these conditions may only occur a few times a year. The rest of the time, substantially less heating and cooling output will do the job. Dual duct and multizone systems are designed so the coil capacities and the hot and cold deck discharge setpoints will meet the heating and cooling demands at design conditions. Considerable energy is wasted at all other times due to the mixing of hot air and cold air to provide the required temperatures for all the zones.

The objective of the Hot Deck/Cold Deck Temperature Reset Program is to maintain the minimum temperature difference between the hot and cold supply ducts consistent with zone demands. The EMCS resets the hot deck discharge to a temperature just high enough to satisfy the zone needing the most heat. Likewise, it resets the cold deck discharge to a temperature just low enough to satisfy the zone needing the most cooling. The program accomplishes this task by sensing the positions of all or the most critical zone dampers. The hot and cold deck temperatures are adjusted until the dampers on one zone provide 100% cold air and the dampers on another zone provide 100% hot air. Where humidity control is required, the program will prevent the cold deck temperature from exceeding the point at which the space humidity reaches its maximum setpoint.

Consider the following example of a dual duct system.

50,000 cfm
25,000 cfm flow through hot deck
25,000 cfm flow through cold deck
55°F cold deck setting
110°F hot deck setting

Assume the zone with the highest heating load requires a 107°F supply air temperature and the zone with the highest cooling load requires a 57°F supply air temperature. The program would reset the hot deck at 107° and the cold deck at 57°F. The resulting savings would be



HOT DECK/COLD DECK TEMPERATURE RESET

Figure 2-31

$$(25{,}000 \text{ cfm})(1.08 \text{ Btu/hr°F-cfm})(110°-107°) = 81{,}000 \text{ Btu/hr}$$

$$(25{,}000 \text{ cfm})(4.5 \text{ lb/hr-cfm})(0.6 \text{ Btu/16°F})(57°-55°) = 135{,}000 \text{ Btu/hr}$$

The EMCS points which are usually included for each system to which the Hot Deck/Cold Deck Temperature Reset program is applied are

Monitoring-

(1) Hot deck discharge temperature sensor.
(2) Cold deck discharge temperature sensor.
(3) Space dry bulb temperature sensors, one per zone up to 40% of the zones.
(4) Space relative humidity sensor, one per zone requiring humidity control.
(5) Mixing box damper position indicators or proportional signal, one per zone.

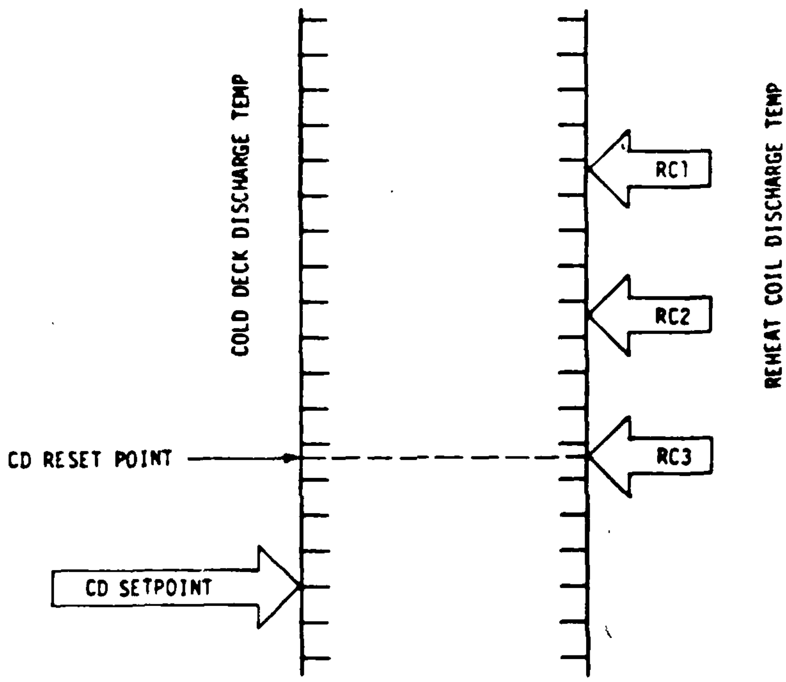
Control-

(1) Hot deck temperature control point adjustment.
(2) Cold deck temperature control point adjustment.

REHEAT COIL RESET

Terminal reheat systems operate with a constant cold deck discharge temperature. Air supplied at temperatures below the individual space temperature requirements is elevated in temperature by reheat coils in response to signals from individual space thermostats. If every zone is reheating supply air, the cold deck is too cold and cooling energy, as well as reheat energy, is being wasted.

The Reheat Coil Reset program reduces energy consumption in a fashion similar to the Hot Deck/Cold Deck Temperature Reset program. The program measures the discharge temperature or the reheat coil valve position of each zone and selects the reheat zone with the highest cooling demand (the zone with the least amount of reheat required). The cold supply air temperature is set upward until the critical zone no longer needs reheat, thus minimizing the total reheat energy required. Where humidity control is required, the program will prevent the cooling coil discharge temperature from being set higher than the maximum allowable humidity will allow.



COLD DECK TEMPERATURE RESET

Figure 2-32

For a reheat system that operates 50 hours per week and for which an average 5° reset of the cooling coil is achievable, the annual reheat energy savings would be about 22 cubic feet of gas per cfm. The annual cooling savings would vary relative to the climate and would range between 0.2 and 2.2 kwh per cfm.

The EMCS points which are usually included for each system to which the Reheat Coil Reset program is applied are

Monitoring-

(1) Cooling coil discharge temperature sensor.

(2) Reheat coil valve position indicator or proportional signal, one per zone.

(3) Space dry bulb temperature sensor, one per zone up to 40% of the zones.

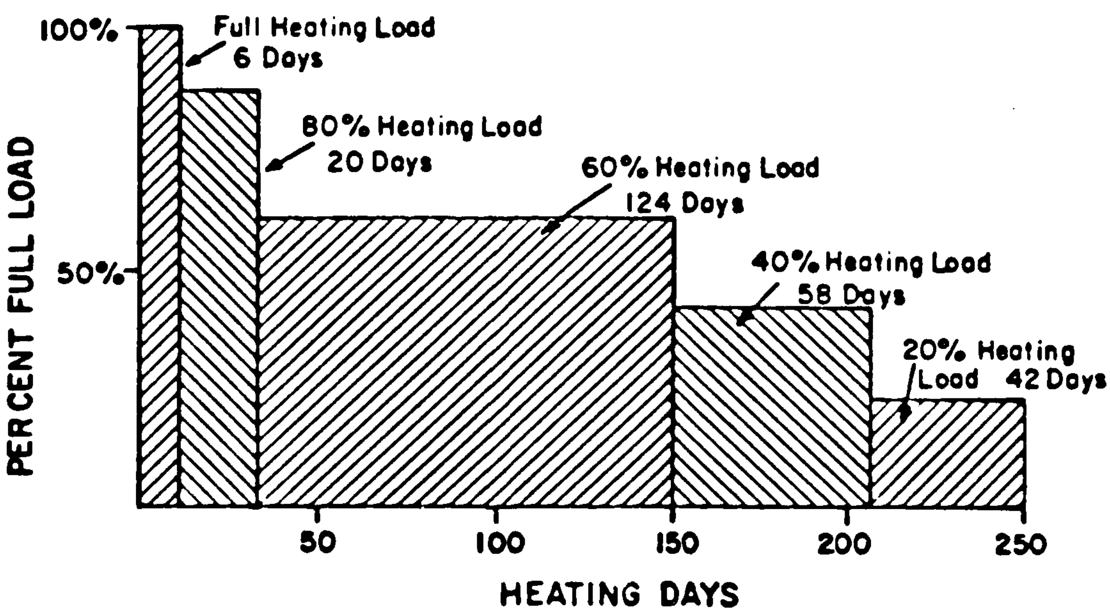
(4) Space relative humidity sensor, one per zone requiring humidity control.

Control-

(1) Cooling coil discharge temperature control point adjustment.

BOILER OPTIMIZATION

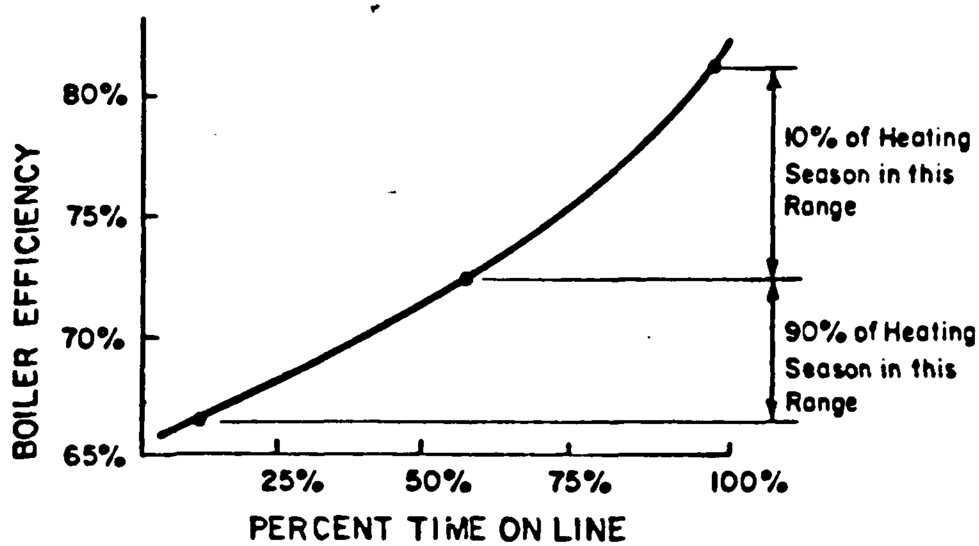
- Most boilers achieve maximum efficiency only when running at their rated output. In most cases, however, full boiler capacity is seldom required because the heating load is 60% or less than full load, 90% of the time (see Figure 2-33).



TYPICAL HEATING LOAD DISTRIBUTION
(250-DAY SEASON IN 6000 DEGREE ZONE)

Figure 2-33

Given this situation, single large capacity boilers operate intermittently for the major part of the heating season. Although high-low firing capabilities may reduce cycling, the boilers can reach their design efficiency only for short periods, resulting in low seasonal efficiencies (see Figure 2-34). Seasonal efficiency can be improved with a multiple boiler plant. Each boiler is fired near its capacity as much as possible. As the heating load increases, the separate boilers are brought on line in sequence until the load is satisfied.



EFFECT OF CYCLING TO MEET PART LOADS

Figure 2-34

The Boiler Optimization program may be implemented for multiple boiler plants with either hot water or steam boilers to effect the above described savings. By monitoring fuel input as a function of the output, the EMCS develops profiles for each of the units in a central plant. Based on the operating history indicated in the efficiency profiles, the boiler or combination of boilers with the highest efficiency at a given heating load can be selected. Boilers may be started manually by a boiler operator or automatically by the EMCS depending on facility requirements. The seasonal efficiency of the central heating plant can be improved by 5 to 10% with implementation of this program.

The EMCS points which may be included for implementation of the Boiler Optimization program are

Monitoring-

(1) Boiler status (auxiliary contacts), one per boiler alarm point.

(2) Flame status, one per boiler.

(3) Steam supply pressure sensor, one per steam boiler.

(4) Steam or hot water supply temperature sensor, one per boiler.

(5) Steam or hot water flow sensor, one per boiler.

(6) Fuel flow sensor, one per boiler.

(7) Fuel temperature sensor, one per boiler.

(8) Feed water flow sensor, one per boiler.

(9) Feed water temperature sensor, one per boiler.

(10) Oil temperature sensor, one per boiler if oil is heated.

(11) Hot water return water temperature sensor, one per hot water boiler.

(12) Boiler pressure, one per hot water boiler.

(13) Boiler water level sensor, one per hot water boiler.

(14) Flue gas analyzer, one per boiler.

(15) Common steam supply pressure sensor, one per steam plant.

(16) Common steam or hot water supply temperature sensor, one per heating plant.

(17) Common condensate return total flow sensor, one per steam plant.

(18) Common condensate or hot water return temperature sensor, one per heating plant.

(19) Total hot water flow sensor, one per hot water plant.

Control-

(1) Start/stop automatic control signal to interposing relays or start/stop signal to boiler operator for manual control, one for each boiler.

REMOTE BOILER MONITORING AND SUPERVISION

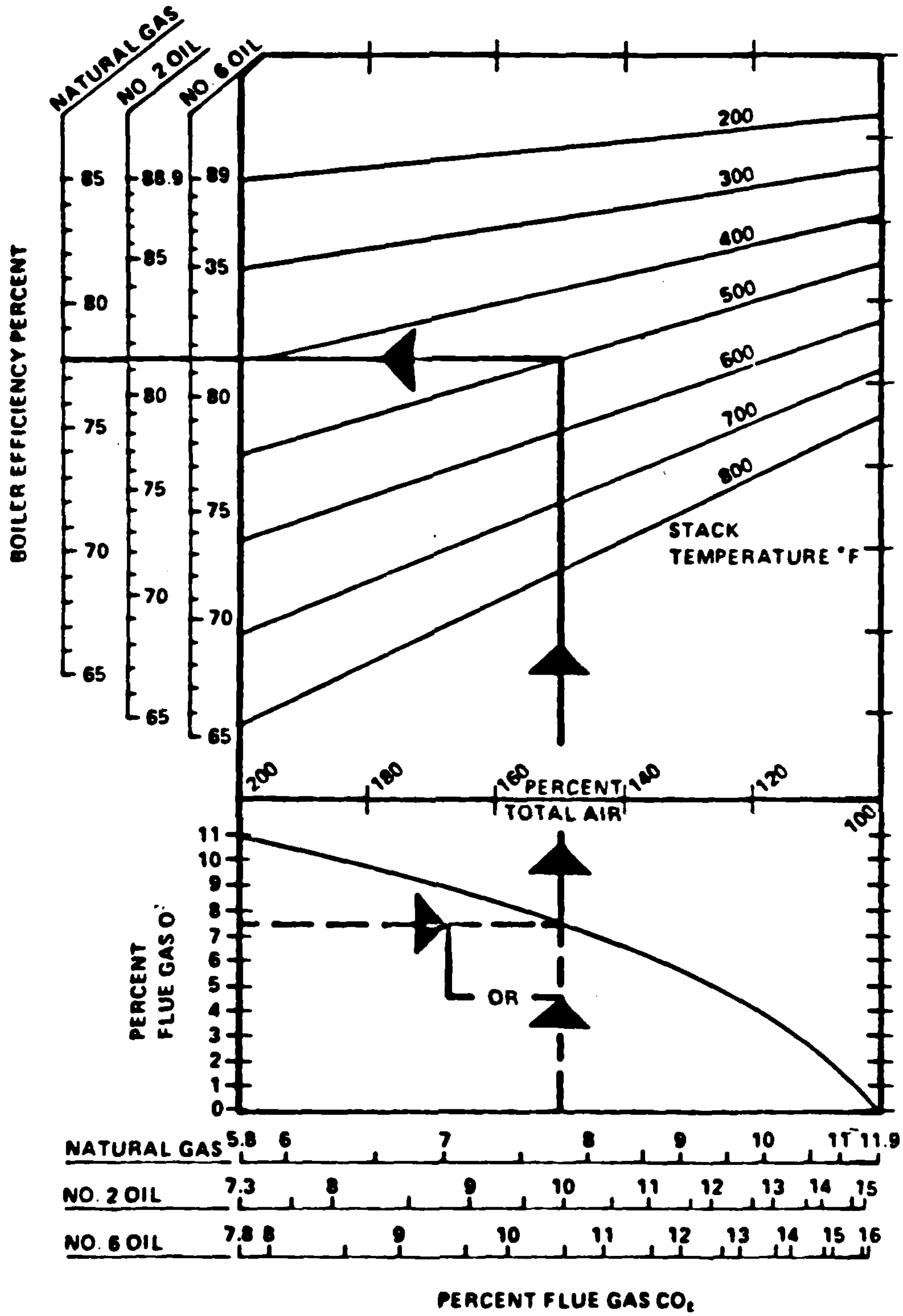
The cost of fossil fuels for heating far outweighs cooling costs for buildings in the United States. So it is important to get the most heat out of each gallon, pound or cubic foot of fuel possible. All boilers, regardless of size, should have routine measurements of stack temperatures and flue gas analysis at frequent intervals. Based on monitored data the air-fuel mixture should be adjusted to maximize the combustion efficiency.

Figure 2-35 displays the relationship of flue gas composition, stack temperature, and boiler efficiency. The ideal oxygen (02) concentration in flue gas is between 3 and 5%. Lower than that is impractical and unsafe, due to increased production of pollutants.

Proper maintenance of fuel burners and heat transfer surfaces also is required to maintain high boiler efficiencies. Fuel burning equipment allowed to become dirty and out of adjustment becomes increasingly inefficient with continued usage. Likewise, both fire-side and water-side heat transfer surfaces become less and less effective if allowed to become fouled by products of combustion, scaling, and other impurities. All heat not properly transferred is discharged through the stack. Boilers that are regularly checked, cleaned, and adjusted can have efficiencies 3 tO 5% higher than poorly maintained units.

The primary purpose of the Remote Boiler Monitoring and Supervision program is to aid in the maintenance of facility boilers. The savings are generated from a reduction of boiler-operator labor hours. A small savings in energy is also possible, depending on how well maintained the boilers were previous to installation of the EMCS. The reduction of boiler operator labor hours is governed by criteria which varies depending on local codes regulations. These should be investigated before investing in EMCS Boiler Monitoring.

The EMCS points required for implementation of this program are included in those listed for Boiler Optimization, with the possible addition of a stack temperature monitoring point. The two programs operate in conjunction with one another.

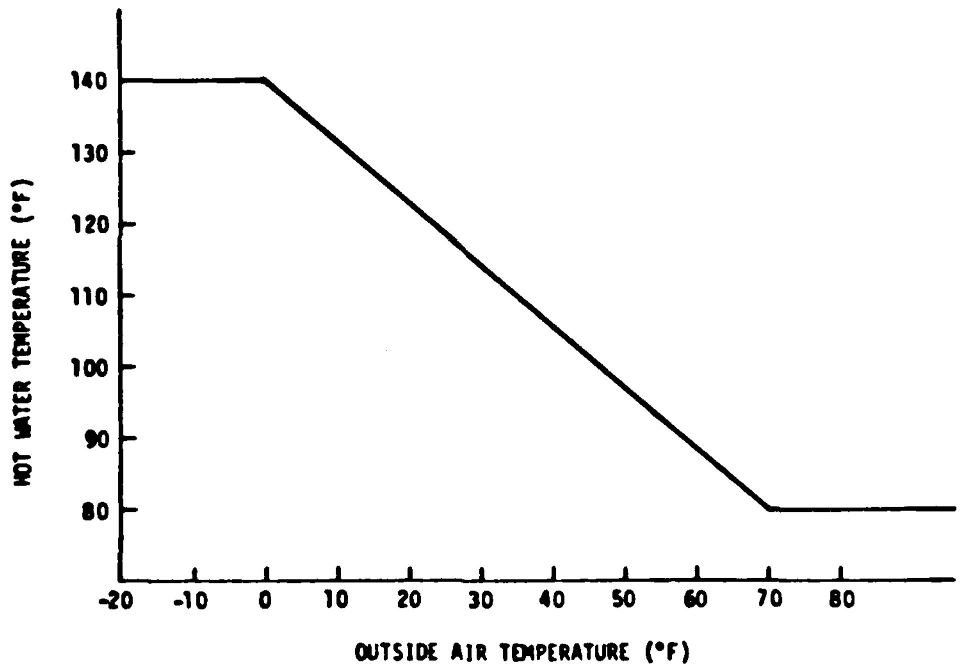


HEATING EFFECT OF FLUE GAS COMPOSITION AND TEMPERATURE ON BOILER EFFICIENCY

Figure 2-35

HOT WATER OUTSIDE AIR RESET

Hot water heating systems, whether the hot water is supplied by a boiler or a converter, are designed to supply the heating requirements for the system at outdoor design temperatures. Frequently, depending on the specific system design, the hot water supply temperature can be reduced based on the heating requirements for the facility. For most facilities, a reduction in heating requirements is directly related to an increase in outdoor ambient temperature. Where applicable, the temperature controller for the hot water supply is reset by the EMCS on a predetermined schedule as a function of outdoor temperature.



TYPICAL HOT WATER OUTSIDE AIR RESET SCHEDULE

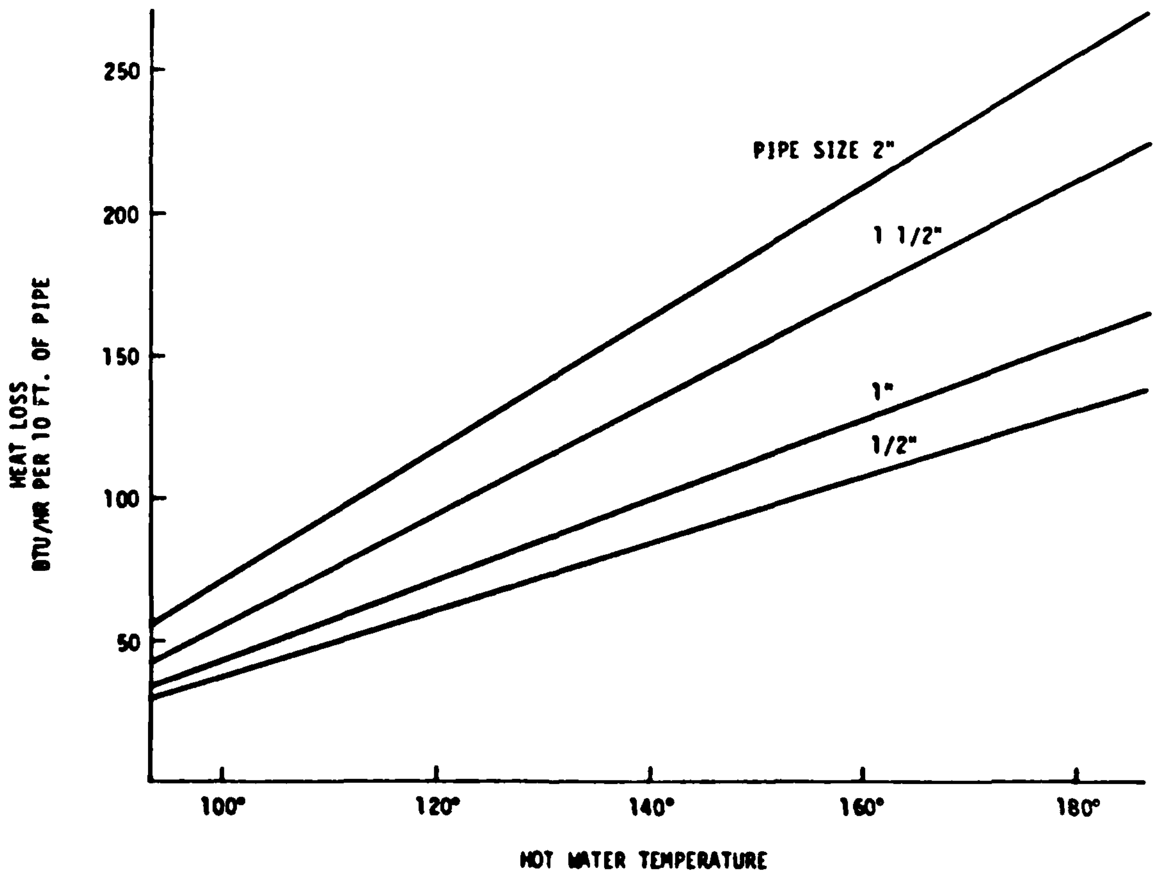
Figure 2-36

An example of a hot water outside air reset schedule is:

OA	HW
0°F	140°F
70°F	80°F

Below 0° outside air temperature the hot water is at 140°. Above 70° outside air temperature the hot water is at 80°. Between 0°F and 70°F the hot water temperature varies linearly. That is, at 35°F the hot water will be reset at 110°. (See Figure 2-36) Linear reset schedules, such as the example, are most common, although a different type schedule may be encountered at some facilities.

Energy savings is achieved by the Hot Water Outside Air Reset due primarily to a reduction in heat losses from pipes and heating system equipment. Figure 2-37 illustrates the effect of the water temperature on heat loss from indoor piping. The graph is based on pipes with 1" insulation. Note the greater rate of heat loss at higher water temperatures. The hot water reset also meets heating demands in uncontrolled hot water radiator zones more efficiently.



EFFECT OF HOT WATER TEMPERATURE ON HEAT LOSS FROM PIPES

Figure 2-37

The EMCS points which are required to implement this program are

Monitoring-

(1) Hot water supply temperature sensor, one per boiler or converter.

(2) Outside dry bulb temperature sensor, one per site.

Control-

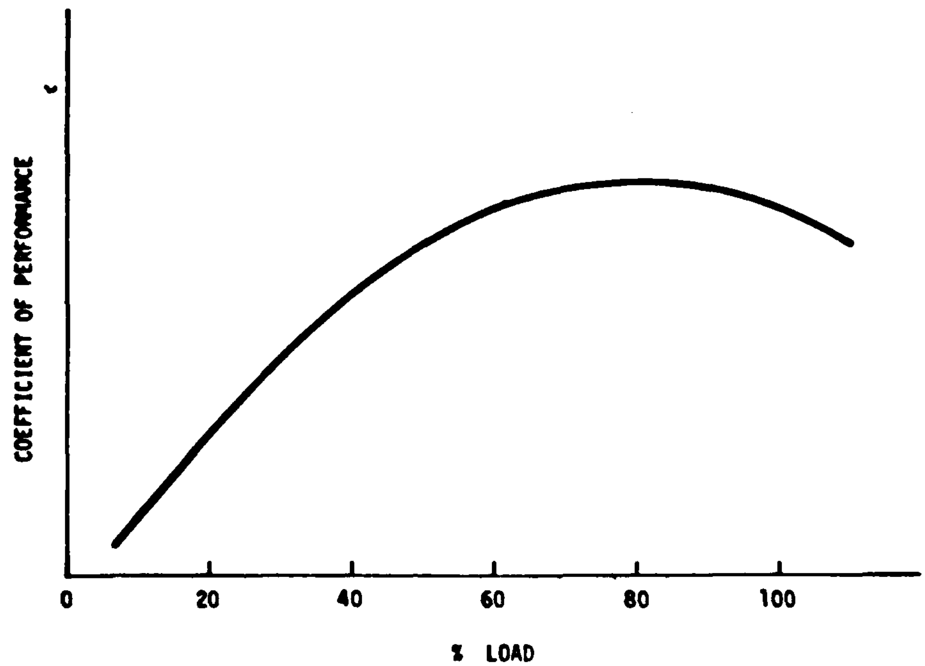
(1) Hot water supply temperature control point adjustment, one per boiler or converter.

At new EMCS installation, it may be necessary to adjust the reset schedule during the first heating season.

CHILLER OPTIMIZATION

The Chiller Optimization program works on the same principal as the Boiler Optimization program. A chiller is designed to operate most efficiently at a particular load condition, and efficiency drops off at loads significantly higher or lower than this. See the typical chiller load profile in Figure 2-38. In order to save energy, it is desirable to select the optimum combination of chillers needed at various partial load conditions. The chiller combination selection process should assume that the chillers that are in operation are running within their most efficient ranges.

The Chiller Optimization program is applied to chilled water plants with multiple chillers. Based on chiller operating data and the energy input requirements obtained from the manufacturer for each chiller, the program selects the chiller or chillers that meet the load with a minimum of energy consumption. When a chiller or chillers are started, chiller capacity is limited (prevented from going full load) for a predetermined period to allow the system to stabilize in order to determine the actual cooling load. Chillers may be started automatically by the EMCS or manually by the chiller operator depending on site requirements.



CHILLER EFFICIENCY VS. LOAD

Figure 2-38

Data gathered from this program may also be used for maintenance management of the chiller plant. Comparison of equipment characteristics to the actual operating chiller characteristics makes it possible to determine when heat transfer surfaces need cleaning, and thus help maintain high efficiency.

EMCS points which may be included, although all are not required in every case, to implement the Chiller Optimization program are

Monitoring-

(1) Chiller status, auxiliary contacts, one per chiller.
(2) Chilled water supply temperature sensor, one per chiller.
(3) Chilled water return temperature sensor, one per chiller.
(4) Chilled water flow sensor, one per each chiller with variable flow.
(5) Leaving condenser water temperature sensor, one per chiller.

(6) Condenser water flow sensor, one per chiller, for variable flow condenser system only.

(7) Instantaneous KW to chiller, one per chiller.

(8) Instantaneous KW to chilled water pump, one per CW pump, if variable.

(9) Instantaneous KW to condenser water pump, one per condensate water pump, if variable.

(10) Instantaneous KW to cooling tower fan, one per cooling tower fan, if variable.

(11) Common chilled water supply temperature sensor, one per chilled water plant.

(12) Common chilled water return temperature sensor, one per chilled water plant.

(13) Total chilled water flow sensor, one per chilled water plant.

(14) Chilled water pump status, differential pressure switch or flow switch, one per chilled water pump.

(15) Condenser water pump status, differential pressure switch or flow switch, one per condenser water pump.

(16) Cooling tower fan status, differential pressure switch, zero speed switch, or flow switch, one per cooling tower fan.

Control-

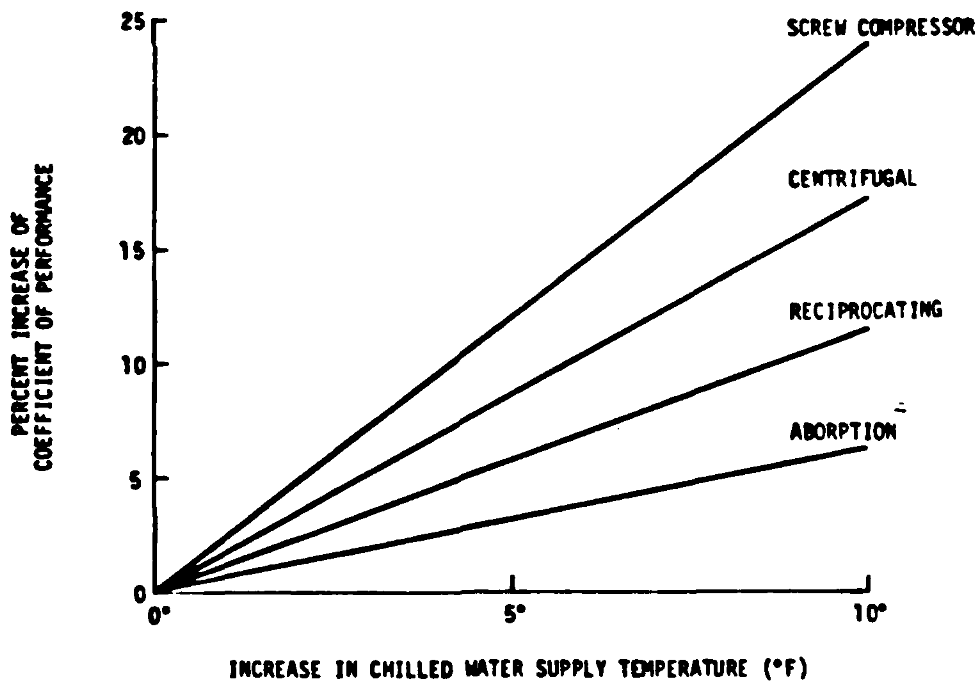
(1) Start/stop control signal to interposing relays or start/stop signal to chiller operator for manual control, one for each chiller, chilled water pump, condensate water pump, cooling tower fan, as required.

CHILLER WATER TEMPERATURE RESET

The energy required to generate chilled water in a reciprocating or centrifugal refrigeration machine is a function of a number of parameters including the temperature of the chilled water leaving the machine. Less refrigerant needs to be compressed by the compressor at higher chilled water temperatures resulting in lower energy input per ton of refrigeration. Normally, chillers are controlled to maintain a constant chilled water supply temperature of 45°F. Because chiller capacities are selected for peak design times, in the absence of strict humidity control requirements, chilled water temperatures can be elevated during most operating hours without any loss of human comfort.

The Chiller Water Temperature Reset program resets the chilled water temperature controller to the highest temperature which will maintain required space temperature and humidity conditions. This is determined by monitoring space temperatures or more accurately by monitoring positions of the chilled water valves on various cooling systems. The desired state has been attained when one valve is in the maximum open position.

The energy which can be saved from implementation of this program varies with climate and building conditions. Improvement in chiller efficiency is about 1.5% for each 1°F average increase in chilled water temperature as displayed in Figure 2-39 for the different types of chillers.



EFFECT OF CHW TEMPERATURE ON COP

Figure 2-39

EMCS points required to implement the Chilled Water Temperature Reset program are

Monitoring-

(1) Chilled water valve position, analog position indicator, or fully open indicator on valve stem, one per air conditioning chilled water valve.

(2) Space dry bulb temperature sensor, one per zone.

(3) Chilled water supply temperature sensor.

(4) Space relative humidity sensor, one per zone where required.

Control-

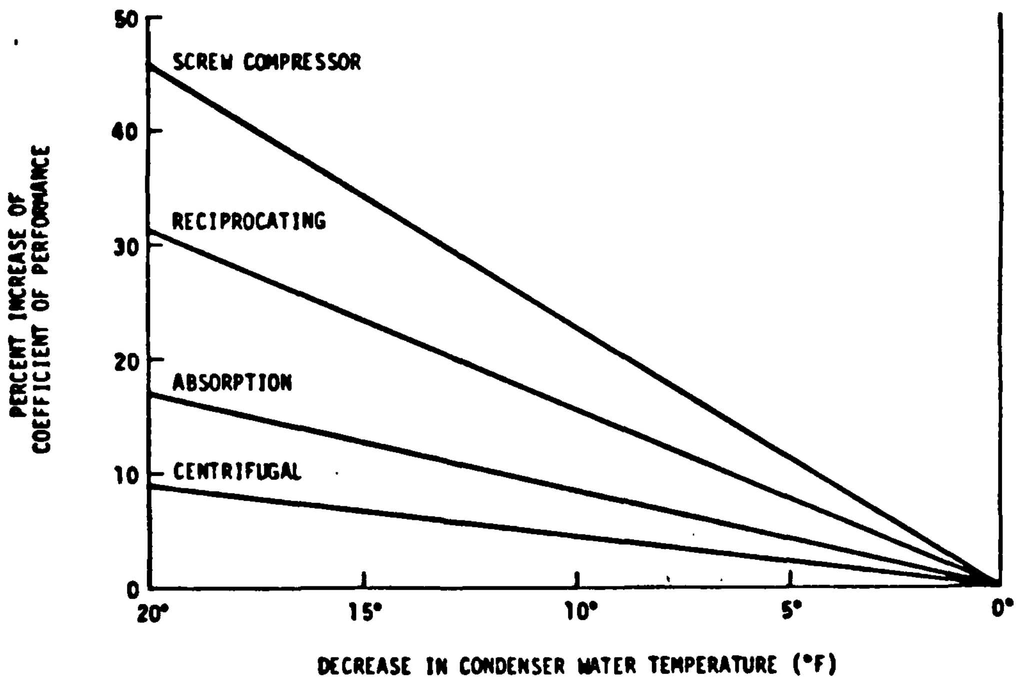
(1) Chilled water supply temperature control point adjustment, one per chiller.

CONDENSER WATER TEMPERATURE RESET

Another parameter affecting the energy input to a refrigeration system is the temperature of the condenser water entering the machine. Conventionally, heat rejection equipment is designed to produce a specified condenser water temperature, usually 85°, at peak wet bulb temperatures. In many instances, automatic controls are provided to maintain that temperature at conditions other than peak design. To optimize the performance of the condenser water system, however, this system can be reset when outdoor wet bulb temperatures will produce lower condenser water temperatures. The lower condenser water temperature subcools the liquid refrigerant in the condenser, below the required saturation temperature. As a result, the refrigerating effect (the amount of heat each pound of refrigerant can absorb) is increased and the compressor has less work to do.

A cooling tower dissipates heat from the chiller primarily because of the latent heat carried off by evaporating water. The condenser water cannot be cooled below outside air wet bulb temperature because no further evaporation will take place at that point. This places a lower limit on the condenser water temperature. A margin of several degrees is necessary for efficient evaporation. Cooling the condenser water down to this optimum value may require running the cooling tower fans more, but this consumes far less energy than running the chiller compressor.

The Condenser Water Temperature Reset program can save energy when applied to water cooled chillers. The program determines the optimum condenser water temperature based on the outside wet bulb temperature, which is calculated from measurement of outdoor dry bulb temperature and outdoor relative humidity. Manufacturer's requirements are also considered in establishing an acceptable condenser water temperature range. Savings from implementation of the program are in the range of 1% efficiency increase per 1°F decrease in condenser water temperature. The graph in Figure 2-40 compares the effect of condenser water temperature on COP for different types of chillers.



EFFECT OF CONDENSER WATER TEMPERATURE ON COP

Figure 2-40

EMCS points which are required to implement the Condenser Water Reset program are

Monitoring-

(1) Condenser water supply temperature sensor, one per condenser.

(2) Outside air dry bulb temperature sensor, one per site.

(3) Outside air relative humidity sensor, one per site.

Control-

(1) Condenser water supply temperature control point adjustment, one per condenser.

CHILLER DEMAND LIMIT

Chillers represent a large portion of demand for a facility, and therefore provide a large potential for demand limiting. The Chiller Demand Limit program is applicable to large centrifugal water chillers, which should not be completely shutdown for demand control. Starting and stopping of the large compressor motors is hard on the machinery. Generally, the off-time for these chillers is limited by a safety delay timer, thus limiting the potential for EMCS start/stop control.

Centrifugal water chillers are normally factory equipped with an adjustable control system which limits the maximum available cooling capacity; thus, the power the machine can use. The method of accomplishing this function varies with the manufacturer of the chiller. An interface between the FID and the chiller controls allows the EMCS to reduce the maximum available cooling capacity in several fixed steps in a demand limiting situation, thereby reducing the electric demand without completely shutting down the chiller.

To accomplish this task, the EMCS determines the chiller percent capacity by monitoring the chiller current input. When the chiller is selected for demand limiting, a single step signal is transmitted, reducing the chiller limit adjustment by a fixed amount. The chiller demand limit adjustment is performed by shunting out taps of transformers in the control circuit or by resetting the control air pressure to the chiller compressor vane operator. As further need arises, additional stop signals are transmitted until the demand limiting situation is corrected.

The chiller manufacturer's recommended minimum cooling capacity limit is incorporated into the program logic. Incorrect control can cause the refrigeration machine to operate in a surge condition, potentially causing it considerable damage. In general, surges occur in chillers at loads less than 20% of the rated capacity.

EMCS points which are required to implement the Chiller Demand Limit program are

Monitoring-

(1) Chiller current monitor, one per chiller.

Control-

(1) Step control signal, one per step per chiller.

(2) Or, analog control signal, one per chiller or as required by controls interface.

APPLICATIONS SOFTWARE DATA

The implementation of any of the above described applications programs requires the EMCS be provided with data which defines how those programs should control a particular HVAC system. For example, controlling an air handler with the scheduled start/stop program required definition of what start and stop times are desired for each different day type. These decisions must be made by the personnel who are responsible for HVAC system operation. In an existing EMCS, the EMCS operator enters the data into the EMCS. In an EMCS under construction, the EMCS contractor is required to enter the data into the system, but the base operating personnel must decide what that data is and provide it to the contractor. Normally the contractor will provide forms which are filled out and returned to him for entry into the system. The exact format and quantity of the data varies widely depending on the particular EMCS being installed. The Tri-Service EMCS guide specifications generally list the data required to run each application program. An example of the data required by the guide specification for the optimum start-stop program is included in Figure 2-41.

Excerpt from CEGS 13947 (October 1982)

14.16 Optimum Start-Stop Program: Provide software to start and stop equipment on a sliding schedule based on indoor and outdoor air conditions. The program shall automatically evaluate the thermal inertia of the structure, the capacity of the HVAC system to either increase or reduce space temperatures, indoor and OA conditions using the prediction software to determine the minimum time of HVAC system operation needed to satisfy the space environmental requirements at the start of the occupied cycle, and determines the earliest time for stopping equipment at the day's end. The program shall monitor the controlled equipment status to verify that the start or stop command has been carried out, and provide the operator with an alarm when the equipment does not start or stop, fails, or is localled started or stopped. The optimum start-stop program shall operate in conjunction and be coordinated with the scheduled start-stop, day-night setback, and ventilation-recirculation programs.

14.16.1 Program Inputs:

a. Day of week.
b. Time of day.
c. Summer or winter operation.
d. Equipment schedules.
e. Equipment status.
f. Building occupancy schedule.
g. Space temperature(s).
h. Building thermal inertia coefficient.
i. HVAC system cooling capacity.
j. HVAC system heating capacity.
k. OA temperature.
l. OA relative humidity.
m. Chilled water supply temperature.
n. Hot water or steam temperature.
o. Required space temperature at occupancy.
p. Equipment constraints.

14.16.2 Program Outputs:

a. Start signal.
b. Stop signal.

Figure 2-41

CHAPTER 3

SYSTEM OPERATION

SECTION 1. TREND LOGS AND REPORTS

Trend logs and reports are useful in maintaining energy efficient operation of the equipment under supervision of the EMCS and as maintenance management tools. Samples are included in Appendix B. Although the report titles may differ, standard reports which are available from most EMCS systems are as follows:

The Electrical Power Utilization Summary (page B-2) provides a record of electrical energy consumption on a daily and monthly basis. The operator may select any meter, combination of meters, or all meters which are connected to the EMCS for output into the report. For each selected meter, the report will include the total daily consumption, the total monthly consumption, the demand interval peak for the month and day, time of occurrence, and the consumption over each demand interval.

The Energy Utilization Summary (page B-3) provides a record of total energy consumption for a point, a system, a building, an area, or the entire EMCS installation, as selected by the EMCS operator. For each item, the report will include the beginning and ending dates and times, the total energy usage for the current and previous day, the total energy usage for the current and previous month, the maximum rate of consumption for the current and previous day, the maximum rate of consumption for the current and previous month, the outside air temperature, and the outside air relative humidity or dewpoint. The energy utilization is calculated by the EMCS based on equipment parameters such as motor rated kilowatts, measured data such as fuel flow, and equipment run-time. The data generally is displayed in BTU units.

The Alarm Summary (page B-4) lists all outstanding alarms by class.

The Lockout Summary (page B-5) lists all points which are currently disabled.

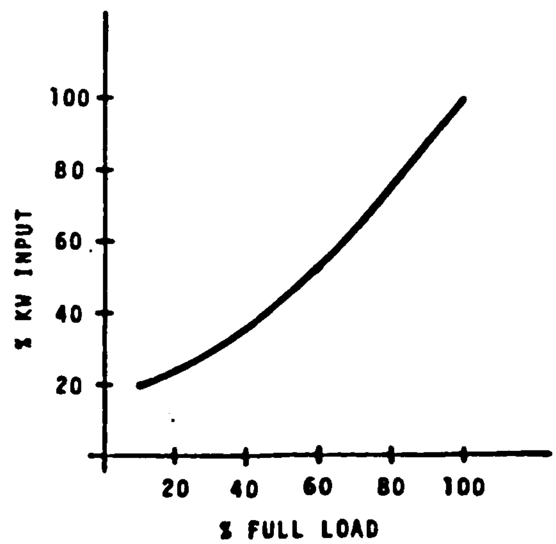
The Analog Limit Summary (page B-6) lists a point's analog value, units, high and low limits, and limit differentials for all analog points, all analog points within a building, or all analog points for a system, as selected by the operator.

Run-Time Reports (page B-7) list the accumulated run-time of individual pieces of equipment, that is, the total hours and minutes that an item has been "on" during a stated period of time. The operator is able to select subsets of equipment for a particular report, such as an individual piece of equipment, by equipment type (all air handlers), by equipment size (all motors over 20 hp), or equipment by physical grouping. If desired, the totalized run-time can be automatically reset to zero upon generation of a report. This report is particularly useful as a tool for maintenance management. Routine maintenance tasks can be scheduled based on total run-time. In fact, the EMCS can provide reports on equipment which has reached a target run-time specified by a maintenance schedule. (See page B-29). Run-time can also be used to evaluate the life expectancy of equipment components.

Cooling Tower Profiles (page B-8) provide data on cooling tower operation. The report lists the total daily and monthly on-time for each fan, the number of on and off transitions for each fan, the maximum and minimum daily condenser water temperature at the time the tower was turned on, and the maximum and minimum daily condenser water temperatures for the current month.

The Electrical Peak Demand Prediction Report (page B-9), which is based on the demand limiting program, includes the demand peak target, the actual peak and predicted peak for each demand interval for that day, and the predicted demand for the next demand interval. This report can be used to evaluate the demand limiting program and help determine strategy for changing the demand target or load shedding priorities.

The Chiller Utilization Summary (page B-10) summarizes chiller operations on a daily and monthly basis. It includes the daily electric consumption in KWH and the corresponding effective cooling in BTU/Hr for each of at least ten (10) discrete loading levels, the daily average of all the levels, the monthly average of these values for each level, and the total on-time for each level for the current month. This report is useful in developing chiller profiles and analyzing the effect of chilled water and condenser water reset strategies. An example of a graphed chiller profile showing the relationship of energy input to cooling load is shown in Figure 3-1.



KW INPUT VERSUS LOAD CAPACITY

Figure 3-1

The Optimum Start-Stop Report (page B-11) lists all systems and buildings not achieving occupancy temperature within twenty (20) minutes of the designated time. The report can help the operator determine if optimum start-stop program parameters should be adjusted.

The Out-of-Service Report (page B-12) lists the devices or points which are out of service for each item of central hardware and each data transmission link, FID, MUX, or IMUX.

All Points Summary (pages B-13 to B-15) lists the current status of all the points in the EMCS.

The EMCS is capable of generating a wide variety of logs and reports in addition to the above standard reports. Any statistical and variable data values or sets of parameters defined in the data base, calculated using the data base, or stored as historical data may be printed in a report. The operator or programmer may assign the parameters to be used in a custom report and designate the output format. The operator also has the option of specifying reports that are to be automatically displayed. The operator designates the time the initial report is to be generated, the interval of time between subsequent reports, and the output device on which they are to be printed or displayed. Samples of miscellaneous reports are shown on pages B-16 to B-24.

Log trends are a type of report which list a sampling of a defined parameter or parameters at a selected time interval, such as every fifteen (15) minutes, for a designated period of time. The kinds of data for which a log trend is useful are power consumption, power demand, and temperatures. Similarly, equipment profiles may be reported as a correlation of two variables. For instance, the incremental fuel consumption of a boiler versus the average outside air temperature over a given time interval can be recorded. The log trends can be graphed for easy visual interpretation of the data. See the samples pages B-25 to B-28.

In addition to run-time reports, other report formats can be developed for use in maintenance management. Maintenance work orders, such as the one on page B-29, can be automatically generated based on equipment run-time totals. Pages B-30 through B-32 are examples of reports of maintenance shop inventory information. Some facilities use the EMCS to keep track of all repairs and maintenance to facility equipment.

It is important to understand that some reports are available on demand while others require that data to be used in them be defined and stored by the EMCS prior to output of the report. Reports available on operator command use the current status or value of points in the system. Reports which include historical data (such as number of hours of air handling unit operation) can only be obtained if at some previous point in time the EMCS operator has commanded the EMCS to store and accumulate the data necessary for that report. Figure 3-2 lists the reports discussed in this Section according to type.

It is recommended that in addition to regular daily and monthly generation of system performance reports the operator keep a written log of actions taken during a work shift. An existing EMCS installation generally will have a procedure for documenting daily occurrences. Items that should be entered in the log, although not all inclusive, are:

1. Incoming telephone calls from occupants of buildings under control of the EMCS. The time of the call and the nature of the request or complaint should be recorded.

2. Modification of program or system parameters, such as revised temperature setpoints or occupancy schedules.

3. Routine maintenance on MCR equipment such as a change of the ribbon on a printer or a call to the service contractor to clean the heads on the disk drive.

4. Date, time, and service done during a service call.

5. EMCS error messages which occur.

REPORTS AVAILABLE ON DEMAND

Report	Example Page No.
Alarm Summary	B-4
Lockout Summary	B-5
Analog Limit Summary	B-6
Out-of-Service Report	B-12
All Points Summary	B-13

REPORTS REQUIRING PREVIOUS DEFINITION FOR EMCS DATA RECORDING

Report	Example Page No.
Electrical Power Utilization Summary	B-2
Energy Utilization Summary	B-3
Run Time Reports	B-7
Cooling Tower Profiles	B-8
Electrical Peak Demand Prediction Program	B-9
Chiller Utilization Summary	B-10
Optimum Start-Stop Report	B-11

Figure 3-2

SECTION 2. ALARMS

As well as automatically controlling HVAC equipment for minimum energy use, the EMCS monitors the equipment to detect any malfunctions. For example, high chilled water temperature may be indication of a chiller malfunction. The malfunctions are indicated by alarm messages that are displayed on the operator console or alarm printer. The message identifies the alarm condition, the time of occurrence, the alarm device or sensor type, the current value or status of the measured variable, and in the case of an analog point, the value of the alarm limit which was exceeded. Some EMCS operator consoles also indicate an alarm with an audible beeping tone or a blinking area on the screen. The operator can call up secondary messages which provide further information, such as telephone numbers of people who should be notified of the alarm condition. The alarm messages may be edited by the EMCS operator. The secondary alarm message shown in Figure 3-3 provides the operator with a scheme for diagnosing the cause of an alarm.

SUPPLEMENTARY ALARM SUMMARY REQUESTED BY: 0 0 4/24/1980
19:27:20

1 CHECK BOILER FUNCTION
2 CHECK COOLING COIL FUNCTION
3 SUPPLY FAN NOT OPERABLE, CHECK H-O-A SWITCH
4 CHECK AHU-1 COLD DUCT TEMP AND CHILLER FLOW
5 CHECK CONDENSER PUMP
6 CHECK COOLING TOWER FAN
7 CHECK CHILLER STATUS
8 CHECK CHILLER WATER SUPPLY PUMP
9 CHECK ENTHALPY SWITCHOVER

Figure 3-3

Alarms fall in three classes, as designated during data base generation prior to EMCS start-up. Class 1 alarms are printed at the time they occur and again when the condition returns to normal. Class 2 alarms are printed and indicated with an audible alarm at the time they occur and are printed when the condition returns to normal. Class 3 alarms are printed and indicated with an audible alarm both at the time of occurrence and when conditions return to normal. The audible alarms are terminated when the operator acknowledges the alarm or return to normal condition, normally by pushing a button on the console. All the alarms are printed on the alarm printer; Class 2 and Class 3 alarms are also displayed on the operator's console.

Alarms may also be classified as either digital alarms or analog alarms. Digital alarms are a result of a signal from a digital monitoring point, such as a tripped differential pressure switch which is monitoring the status of a supply air fan. The differential pressure switch senses the pressure upstream and downstream of a fan. When the difference between the pressures is not above a minimum value an electric contact closes and signals the FID and central computer, indicating that the fan is not operating. In this example, the alarm point would be interlocked with the start/stop control software so that the alarm is printed only if the fan is scheduled to be on at that time.

Analog sensor readings are compared to predefined high and low limits, resulting in an analog alarm condition if the value falls outside the established operating range. High and low limits are assigned to each analog point in a system. Each high and low limit has an associated unique limit differential, specifying the amount by which a variable must return into the proper operating range before being displayed as returned to normal. The operator can enter or change all alarm limits and differentials in units of the measured variable from the operator console. Analog points may have more than one set of alarm limits, which automatically change based on time scheduled operations. For example, the high and low limits for a space temperature in the heating mode might be 70°F and 65°F during occupied periods, and 90°F and 50°F during unoccupied periods. In control point adjustment applications, the high and low limits are defined based on a deviation from the setpoint. For example, the chilled water supply temperature will have "sliding" limits when the chiller water reset applications program is applied to the chiller. If the deviation from setpoint is ±3°F and the setpoint established by the program is 48°F then a measured value of 44°F will cause an alarm condition.

In addition to alarms associated with field monitoring points, alarms may be generated as a result of problems in the EMCS hardware. Such alarm conditions are a point not responding to a command, point change of state without command, a field panel not responding, data transmission high error rate, real timeclock error, intrusion alarm, and FID failure.

Associated with some alarms is a correlated alarm report as shown in Figure 3-4, which can be called up by the operator when the alarm condition

CORRELATED ALARM REPORT
BLDG-12-CV-1-HWS TEMP IN ALARM
3/15/83   9:07:18

LOW AT 105.9°F   SETPOINT = 114.7
LIMITS: LO = 111.7°   HI = 117.7°

USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT STATUS/VALUE	ENG UNITS	ALARM STATUS
BLDG 12 CONV1 PUMP	PUMP	ON		NRML
BLDG 12 CONV1 VALVE	VALVE POS	55	% OPEN	NRML
BLDG 12 BLR STEAM	PRESSURE	5.3	PSIG	NRML
BLDG 12 BLR STEAM	TEMP.	227	°F	NRML
BLDG 12 BLR	STATUS	ON		NRML

<u>Figure 3-4</u>

occurs. The purpose of the report is to display the current status of each parameter which is dependent on the alarmed point. This information can help the operator diagnose the possible cause of the alarm condition and determine the proper steps to be taken in response.

Diagnosing the cause of an alarm and determining the corrective actions which are necessary is not a cut and dried procedure. The EMCS operator needs to make judgment decisions that will become easier with experience. No concrete guidelines are available, but some general comments are in order.

Some alarms recur frequently, and may even become annoying to the operator. This happens most often with temperature points which are out of range. The first thing to look for is a malfunction somewhere in the HVAC equipment. For example, consider a space temperature sensor which repeatedly exceeds the high alarm limit. The temperature is only slightly out of range and returns to normal after an hour or two. If many other space temperatures in the same building are over the high alarm limit then the problem probably lies with the chiller or chilled water distribution systems.

If the problem is at the air handler it could be a dirty filter which would cut down the air flow and therefore, the cooling capacity of the unit. If the system also has an EMCS differential pressure sensor across the filter and it is also in an alarm condition then there is a good chance that a dirty filter is the cause of the temperature alarm. In most cases, however, there will be no filter alarm point. Another possible problem is a dirty cooling coil which will lower the heat transfer rate of the coil, and therefore the cooling capacity of the unit. The outside air damper linkages or motors may be broken resulting in restricted air flow or excess outside air. These are maintenance problems that require field inspection of the air handling unit to pinpoint the cause of the alarm.

Many malfunctions in the local control loop could cause the hypothetical temperature alarm. The room thermostat could be malfunctioning, out of calibration, or simply set at a temperature above the EMCS high alarm limit for the space temperature. There could be an air leak in the local pneumatic control system so that control devices receive low pressure signals. The cooling coil control valve could be restricted from opening to its fully open position or have some other problem. Another item to consider is a malfunctioning EMCS sensor or one which needs calibrating. These control system malfunctions would also require a field inspection and repair to alleviate the high space temperature.

If field checkout eliminates the possibility of equipment malfunction, then the problem may be that the design capacity of the equipment components cannot carry the space cooling load. This will occur at design conditions if any component of the system was underdesigned. Insufficient capacity may also be a result of an increase in internal loads such as the introduction of heat producing electronic equipment in the space being served. The problem can only be solved by redesign and replacement of equipment, and should be left in the hands of the EMCS supervisor or facility engineer.

In some instances of a frequently recurring analog alarm the limits may be set unreasonably close. The operator may want to increase the tolerance of the alarm limits, but <u>only</u> after all other possible causes have been investigated.

Critical alarms are those which signal a condition which is potentially dangerous to people or equipment. Boiler alarms are critical to human safety. Large boilers will have EMCS points for monitoring flame failure, low water level, high water temperature, or high steam pressure. Some of these points and others may be included in the local safeties of the boiler, and not duplicated by EMCS points. In this case a single EMCS "boiler safeties" digital point may be wired into the local controls to indicate when one of the safeties has been tripped. In the event of a boiler safeties alarm, the operator should verify that the local safeties have disabled the boiler by checking the status of the boiler. If not, the boiler should be disabled at the operator's console if possible, or maintenance personnel should be sent immediately to shut down the boiler.

Some chiller alarms are critical to equipment safety. Although malfunction of a chiller would rarely pose a threat to human safety, damage to the heat exchangers or compressors can be very expensive to repair. Also the possibility of having a chiller out of service for several days while being repaired could be a large problem at some facilities.

A high or low condenser water temperature can warp condenser plates. As a result of high condenser water temperature or low condenser water flow rate, the local safeties should disable the chiller due to a high condenser pressure safety. If the safety fails to turn off the chiller, however, the compressor motor could burn out. Low condenser water temperature may also cause a centrifugal chiller to surge, resulting in excess wear on the compressor.

In an absorption chiller, low condenser water temperature may result in crystallization of the absorbing solution. The lithium bromide salt crystallizes out of the water onto the inside surfaces of the absorption machine. Operation of the chiller can be resumed only after the concentrated solution temperature is raised above its saturation point, the temperature at which the salt will dissolve.

The danger of low chilled water temperature is the possibility of water freezing in the evaporator and bursting evaporator tubes. This can be the result of low chilled water flow rate. The chiller should shut down from local safety interlocks in the event of pump failure, but if it doesn't the EMCS operator needs to do so from the operator console. High return chilled water temperature can heat the refrigerant in the chiller to the point where the resultant increased pressure will pop the relief valve or rupture disk. The chiller will lose refrigerant and need to be recharged. Such a condition could happen as a result of the changeover of a two-pipe fan coil system from heating to cooling mode.

Other critical alarms are associated with the nature of the space being conditioned. Computer rooms require fairly stable temperatures and low humidity for dependable operation of the computer equipment. The pressure relationship between laboratories, clean rooms, or hospital rooms and adjoining rooms is an important health factor. Continuous operation of the air distribution systems thus becomes critical in these applications. Repair of these systems should have top priority in the maintenance schedules.

SECTION 3. OPTIMIZATION OF ENERGY SAVINGS

Considerable energy can be saved by the EMCS under control of the applications software. The EMCS personnel can effect additional savings by doing what is affectionately known as "tweaking" the system. EMCS operators can fine-tune the energy saving strategies by adjusting schedules, enabling or disabling applications programs based on time of day or season. Log trends, reports, and equipment profiles are invaluable tools for assisting the EMCS operator in developing these additional strategies. Many times the experience of trial and error is the only way to judge the combination of program strategies that will achieve the best results. Good record keeping is vital for developing historical data that can be used to analyze energy savings.

Let's look at several examples of ways savings can be maximized. Bear in mind that these are only examples. Some may or may not be applicable at your EMCS facility. There are certainly many other ways system operation can minimize energy consumption.

Demand Limiting

The Demand Limiting EMCS program is especially sensitive to conditions at a particular facility. Probably more than any other program, it requires adjustment to suit the local conditions during the initial start up period of an EMCS. Several parameters must be adjusted by the operator as experience is gained in the operation of the program and its affect on the systems it controls. The priority assigned to loads initially often must be changed to gain more effective demand limiting while minimizing inconvenience to building occupants. Some loads will be found not suitable for load shedding while others not initially controlled by the Demand Limiting program may be added.

In addition to adjusting relative priorities of loads, the demand target used by the Demand Limiting program must be adjusted by experience. If the Demand target is set to low, loads will be shut off for extended priods of time resulting in discomfort and complaints from building occupants. On the other hand, if the demand target is set too high, the program will not be effective in reducing electrical demand charges from the supplying utility. The determination of the "best" demand target setting is a trial and error process arrived at over a period of months by the EMCS operator.

In addition to adjusting the automatic control parameters of the Demand Limiting program, situations may arise where the EMCS predicts a peak above its target even though all EMCS controlled loads have been shed. When this occurs, an alarm will be provided to the operator. The operator may then manually shed loads not under control of the Demand Limiting Program or take other manual actions such as calling maintenance personnel to start emergency generators. The EMCS operator may also call large electrical users (such as industrial and testing buildings) and advise them a peak is approaching and they should shut down or delay operations which could reduce the peak. A prearranged manual demand limiting procedure along these lines should be prepared for the base, and all parties involved should be aware of their responsibilities in such a situation.

Duty cycling vs. Chiller water temperature reset.

Recall from the discussion of the Duty Cycling EMCS program, that duty cycling of fans is possible due to the fact that full heating and cooling capacity is not required year-round. The chiller capacity and cooling coil heat transfer capacity are based on cooling design conditions. When weather and internal load conditions permit, the Chiller Water Temperature Reset program raises the supply water temperature setpoint improving chiller efficiency. The higher chilled water temperature results in lower cooling capacity of the cooling coils. Therefore, to maintain the space temperature within acceptable limits, a longer fan on-time per cycle interval is required.

Let's look at a hypothetical example of a chiller serving seven (7) air handlers. To determine the reciprocal effects of duty cycling the fans and resetting chilled water supply temperature, the operator prints a daily summary of fan operation and chiller operation. Figures 3-5 and 3-6 show these reports for May 28 when both the Duty Cycling and Chiller Water Temperature Reset programs were in effect. Existing reports in an EMCS installation may or may not include all the information shown in these simulated reports. The fan size in horsepower or kilowatt draw may not be included in the EMCS data base. If not, it can be obtained from mechanical plans or from the motors themselves. If the computer is not set up to calculate fan energy consumption from run-time information, it can be programmed to do so or it may be calculated by hand.

The calculation used to derive energy consumption for the example is as follows:

$$KWH = \frac{HP \times .8 \times .746\ KW/HP \times MIN}{60\ MIN/HR}$$

where,

HP = motor horsepower

.8 = load factor to account for only partial load on motor

.746 KW/HP = energy conversion factor

MIN = minutes of run-time for the day

The total energy consumed for both the fans and chiller for May 28 is

107.2 KWH + 252 KWH = 359 KWH

On a day with similar weather and occupancy schedules, the EMCS operator

DAILY AHU FAN ENERGY CONSUMPTION
BUILDING 23
5/30/83

AHU NO.	FAN SIZE HP	RUN-TIME MIN.	ENERGY KWH
1	3	454	13.5
2	2	380	7.6
3	7½	396	29.5
4	1	429	4.3
5A	5	377	18.7
5B	5	377	18.7
6	3	410	12.2

TOTAL ENERGY CONSUMPTION TODAY = 104.5 KWH

Figure 3-7

CHILLER 23-1 PROFILE

5/30/83

CHILLED WATER: SUPPLY TEMP 46.1 DEG F RETURN TEMP 51.8 DEG F FLOW 200 GPM
CONDENSER WATER: SUPPLY TEMP 74.9 DEG F RETURN TEMP 80.2 DEG F FLOW 270 GPM
ENERGY FLOW: CHILLER AND AUXILIARIES 40 KW
TOTALIZED ENERGY TO DATE:
DAY = 294 KWH
WEEK = 2,114 KWH
COST PER UNIT ENERGY: EL = $.04/KWH
TOTAL COST OF ENERGY TO DATE:
TODAY = $11.76 WEEK = $84.56
LOAD RATE: INSTANTANEOUS = .36 MBTU/HR AVG. TODAY = .50 MBTU/HR
TOTALIZED BTU LOAD: TODAY 2.72 MBTU WEEK: 20.78 MBTU
COEFFICIENT OF PERFORMANCE:
INSTANTANEOUS = 2.64 DAY = 2.71
WEEK = 2.80 SEASON = 3.0
COST OF BTU: TODAY = $4.32/MBTU WEEK: $4.07/MBTU

NOTE: MBTU = MILLION BTU

Figure 3-8

disables the Chiller Water Temperature Reset program, and again prints out the reports. See Figures 3-7 and 3-8 for May 30 chiller and air handler operation. The operator compares the total energy consumed for the fans and the chiller, to determine the net effect of the chiller reset program. In this example, the total energy consumption without chiller water reset is 398.5 kwh (104.5 + 294), which indicates that for this equipment with the present weather conditions chiller water reset does not impose too high a penalty on duty cycling savings.

In a similar fashion chilled water reset can effect the energy consumption of a VAV system's fans. The VAV fan motors draw more electric power when they are required to deliver greater cfm. Although a VAV system is not duty cycled, greater cfm will be required to meet a cooling load with higher chilled water temperature.

Economizer control on double duct units.

EMCS operators should be aware of the danger of economizer control on double duct (and some types of multizone) units. During the winter when interior zones require cooling the economizer will bring in outside air for cooling. The savings of cooling energy may be offset by additional heating energy required in the hot deck to compensate for the low outside air temperature. Where implemented, the Hot Deck/Cold Deck Temperature Reset program is designed to eliminate unnecessary mixing of hot air and cold air streams. However, if the double duct system does not have the adequate EMCS monitoring points, or if the EMCS software is incapable of overriding the economizer (dry bulb or enthalpy) control based on the hot/cold deck reset strategy, then heating energy can be wasted. The problem is worse during severely cold weather than during mild weather. If dry bulb or enthalpy economizer control is applied to any double duct system, the operator needs to analyze the situation and disable the economizer control during the appropriate times. This is also true of some types of multizone systems.

Optimizing hot/cold deck reset

Another way to save additional energy in multizone and double duct systems is to disengage the heating coil or the cooling coil when conditions permit. During the hottest part of the year when all zones have a net cooling load the hot water flow through the heating coil can be valved off. The hot deck will then serve as a bypass deck. The local temperature control will mix cold deck air with mixed air in the proper ratio for each zone. The reverse may be possible during the winter heating season. The operator may determine the potential of these strategies by generating log trends of the damper motor positions.

Minimizing warm-up/cool-down periods.

The Optimum Start/Stop program predicts the time that a system needs to come on in the morning to achieve the space temperature setpoint by occupancy time. The EMCS computer software is capable of making predictions based on past analog values. In the case of the Optimum Start/Stop program, start and stop times are based on past indoor and outdoor temperatures. When a large change in weather conditions or building structure occurs, it sometimes takes the program several days to "catch up" and start systems at the appropriate times. Whenever conditions change suddenly, such as the first cold snap in the fall, or when systems switchover from cooling to heating mode (or vice versa) the status of start-stop times and corresponding temperatures at occupancy time should be checked. The operator should make the necessary adjustments to the Optimum Start/Stop program parameters. Exactly how this is achieved depends on the software strategy of the particular EMCS vendor.

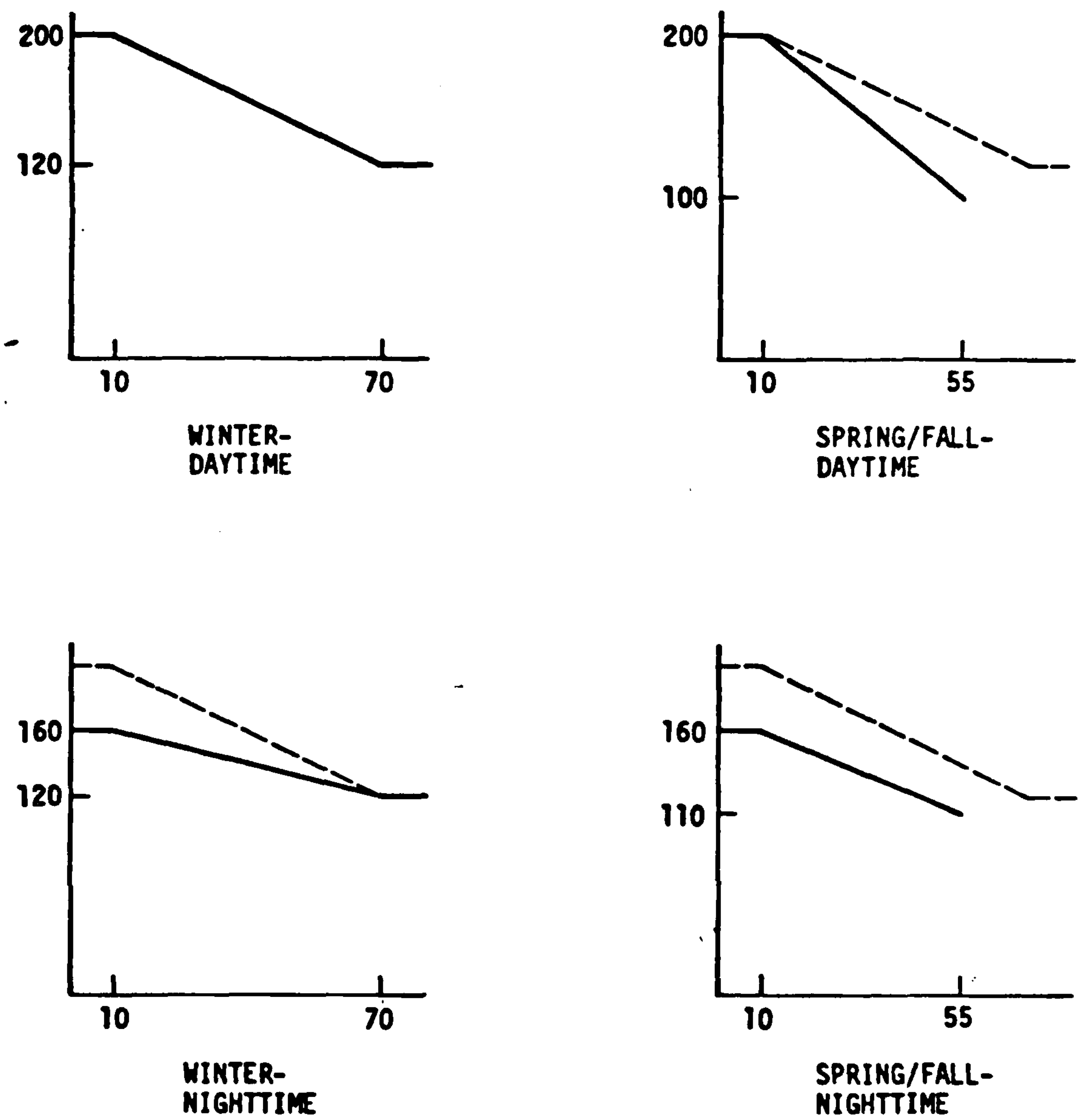
Night flushing.

During the cooling season, early morning outdoor air temperature is often lower than the space temperature within a building. As with the Economizer and Enthalpy programs cool outdoor air can provide efficient free cooling. Night flushing can be applied to any system which has EMCS points allowing damper control. This strategy is not a standard applications program, but can be implemented by the EMCS operator. For several hours during the coolest part of the night open the outdoor air dampers 100% and start the fans and operate until the space temperatures equal the outside air temperature. By bringing in cool air at night when very little internal heat is generated, the structure of the building can be cooled down so that it acts as a "heat sink" for the heat generated within the building during the day. A precooled building allows morning start-up to be delayed and also reduces the load placed upon a cooling system in preparation for morning occupancy. At one military facility use of this strategy during fall and spring has made it possible to delay starting chillers and associated pumps until well into the afternoon.

A flexible hot water outside air reset schedule.

Generally, a linear hot water outside air reset schedule for a hot water heating system is established and left alone. Additional energy can be saved by varying the schedule by time of day and season. Figure 3-9 displays variations from a base reset schedule established for winter heating. The schedules are only representative examples, and are not necessarily suitable for any application. During spring and fall, milder outside air temperatures allow heat to be stored up in the structure of the building. This stored heat offsets some of the heating load at the higher end of the outdoor air temperature scale; therefore, the low end of the hot water temperature can be decreased during spring and fall.

Another variation in hot water reset schedule may be possible during unoccupied periods. Lower unoccupied space temperature setpoints place less heating demand on the HVAC system. The lower required heating capacity can be met at lower hot water temperatures; therefore, the high end of the hot water temperature can be decreased during unoccupied



NOTES: DASHED LINE IS BASE WINTER/DAYTIME SCHEDULE. VERTICAL AXES ARE HOT WATER TEMPERATURES (°F). HORIZONTAL AXES ARE OUTSIDE AIR TEMPERATURES (°F).

VARYING HOT WATER RESET SCHEDULES

Figure 3-9

periods. Two cautions about this strategy: (1) The lower heating demand may be completely offset by the lack of internal heat gains during unoccupied periods (2) For fan systems which come on only when heat is required during unoccupied periods, the savings from lower hot water temperatures may be offset by longer run times.

During morning warmup it is probably more efficient to supply hot water at the maximum setpoint than at a temperature set by the reset schedule. This will shorten the time required for warmup prior to occupancy.

Additional savings can be achieved by shutting down the central heating system when outside temperatures permit. On the occasion of an unseasonably warm day the EMCS operator can shut down the hot water pumps from the operator console. They can remain disabled until scheduled to shut down under the Scheduled Start/Stop program or until a low space temperature alarm occurs. Boilers with the pumps will respond according to local control strategy, but they should not be shut down independently by the operator.

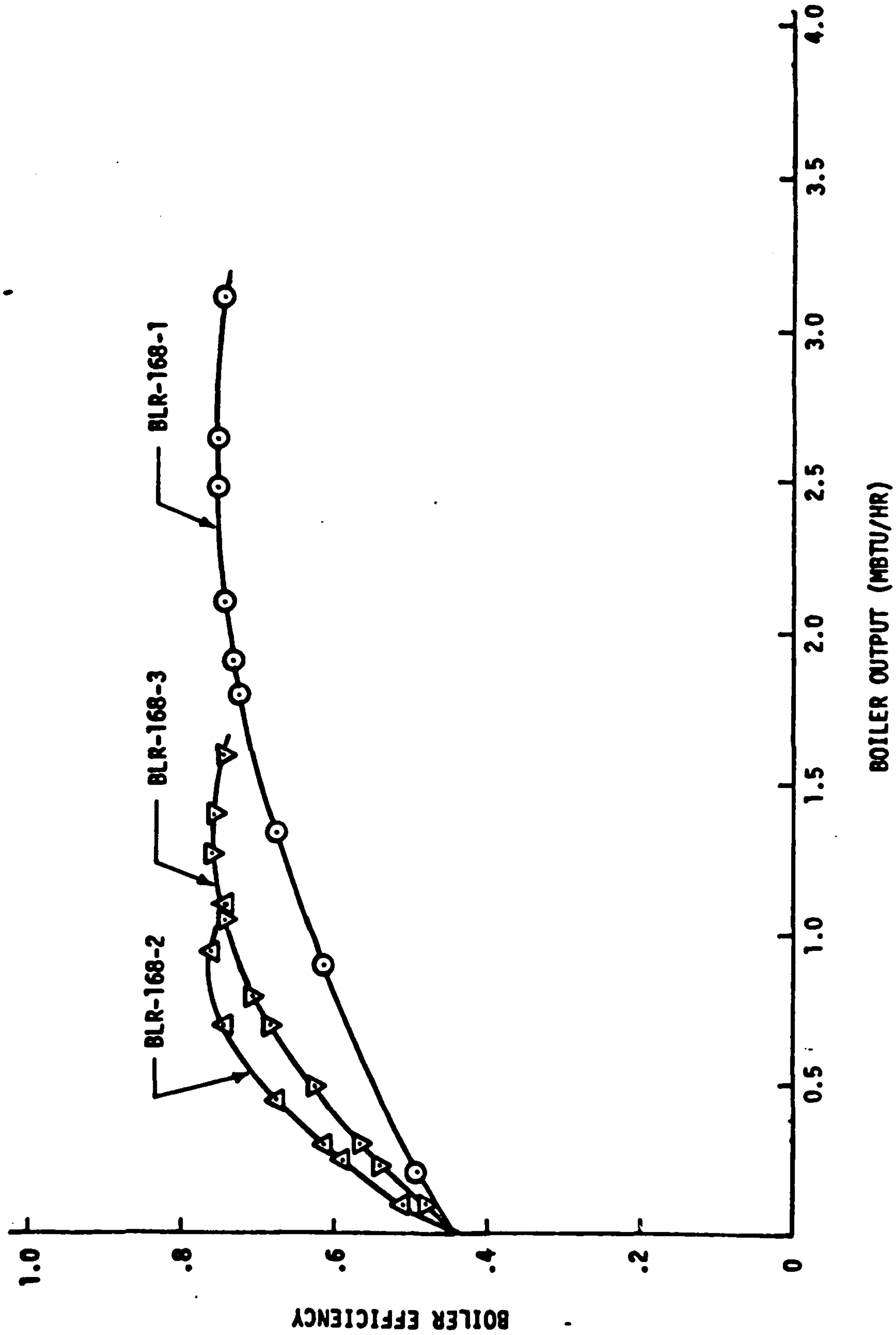
Boiler optimization.

The boiler optimization and monitoring and supervision programs will provide operating information about the central boilers. The EMCS operator must analyze this information and take the proper actions to achieve any energy savings. A sample boiler profile report is shown in Figure 3-10. The report indicates the instantaneous energy output of the boiler and the instantaneous boiler efficiency. These values can be plotted on graph paper from boiler profiles chosen over a range of heating loads. An example of such a graph is shown in Figure 3-11. Hypothetical boiler BLR-168-1 along with two smaller boilers which serve the same building are shown on the same graph.

BOILER PROFILE
BLR-168-1
11/15/83   10:03:57

BOILER STATUS:	ON
BOILER OUTPUT STEAM PRESSURE:	12.3 psig
STEAM TEMPERATURE:	265.1 °F
STEAM OUTPUT:	1395 LB/HR
BOILER OUTPUT:	1.34 MBTU/HR
FUEL INPUT:	14.2 GAL/HR
ENERGY INPUT:	1.97 MBTU/HR
INSTANTANEOUS EFFICIENCY:	68%
FEEDWATER TEMPERATURE:	187.6°F
OUTSIDE TEMPERATURE:	41.7°F
SEASONAL EFFICIENCY:	69%

Figure 3-10



BOILER EFFICIENCY PROFILES
BUILDING 168

Figure 3-11

By definition, efficiency is the ratio of energy output to energy input; therefore, the higher the efficiency, the more heat is delivered per single gallon of fuel. With the aid of the graph, the operator can choose which boiler will consume the least fuel at a given heating demand. An operating schedule can be developed for easy reference. For the example under consideration the schedule in Figure 3-12 would be appropriate.

Heating Demand (MBTU/HR)	Most Efficient Boiler(s)
.0 - 1.07	BLR-168-2
1.07 - 1.65	BLR-168-3
1.65 - 3.10	BLR-168-1
3.10 - 4.00	BLR-168-1 and BLR-168-2

BOILER SCHEDULE
Figure 3-12

The EMCS operator may also want to generate a log trend of heating demand versus outside air temperature. If a good correlation exists, then the boiler operating schedule can be based on outside temperature rather than heating demand. Of course, a schedule based on ambient temperature will be different for daytime/nighttime and occupied/unoccupied periods due to solar and internal heat gains.

APPENDIX A. GLOSSARY

Apalog:

Representative of a physical parameter by a proportional signal. In an EMCS it is in the form of a electric signal; the magnitude of the current is representative of the value of the parameter.

Architecture:

The general organization structure of hardware and software.

BASIC:

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

Bootstrap:

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

British Thermal Unit (BTU)

The quantity of heat required to raise the temperature of one (1) pound of water by 1°F. An English unit of measure of heat or energy.

Building envelope:

All external surfaces which are subject to climatic impact, for example, walls, windows, roof, floor, etc.

Bus:

A circuit within a computer over which data or instructions are transmitted.

Central Communication Controller (CCC):

A computer that performs data gathering and dissemination from and to the FIDs, as well as providing limited back-up to the CCU.

Central Processing Unit (CPU):

The portion of a computer that performs the interpretation and execution of instructions. It does not include memory or I/O.

Central Control Unit (CCU):

A process control digital computer that includes a CPU, central memory, and I/O bus.

Coefficient of performance:

Ratio of the quantity of refrigeration produced to energy required to operate equipment.

Communication Link Termination (CLT):

The communications interface between field equipment and MCR equipment.

Control Point Adjustment (CPA):

The procedure of changing the operating point of a local loop controller from a remote location.

Control Sequence:

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

Damper:

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

Data Base:

An organized and structured collection of data stored in computer memory from which specialized data may be extracted, organized, and manipulated by a program.

Data Environment (DE):

The sensors and control devices connected to a single FID/MUX/IMUX from the equipment and systems sampled or controlled.

Data Transmission Media (DTM):

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

Deck:

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

Demand:

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

Demultiplexer:

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

Digital:

Representative of an either-or physical state, that is, on or off, open or closed, etc. In an EMCS discrete physical states are represented by a current or no current.

Direct Digital Control (DDC):

Sensing and control of processes directly with digital control electronics.

Enthalpy:

For the purpose of air conditioning, enthalpy is the total heat content of air usually in units of BTU/LB. It is the sum of sensible and latent heat.

Facility Engineer:

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

Failover Control Board:

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

Fall-Back Mode:

The preselected operating mode of a FID when communications cease with the MCR or the operating sequence of each local control loop when the FID to which it is connected ceases to function.

FORTRAN:

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

Hardware:

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

I/O:

Abbreviation for input/output, which refers to the data and means by which it is entered into and retrieved from computer memory.

Interactive:

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

Local Loop Control:

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

Master Control Room (MCR):

An area containing the CCU, CCC, operator's console, system terminal, storage devices, printers and other EMCS accessory devices.

Microcomputer:

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

Microprocessor:

A central processing unit fabricated as one integrated circuit.

MODEM:

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

PASCAL:

A "structured programming" high-level computer language.

Peripheral:

A device used for storing data, entering it into or retrieving it from a computer. Examples of such devices are a flexible disk system and a line printer.

Pneumatic:

Of, operated by, or filled with air or another gas. A pneumatic control system is energized with compressed air which is piped throughout a building.

Point:

Individually connected monitor or control devices (i.e., relay, temperature sensor).

Predictor/Corrector:

Applications software which mathematically predicts future values based on past and present values, and subsequent correction.

Program:

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

Real Time:

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

Resistance Temperature
Detector (RTD):

A device where resistance changes linearly as a function of temperature.

Software:

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

Ton:

A measure of cooling capacity equivalent to 12,000 Btu/hr, the rate of heat absorption as one ton of ice melts over a 24 hour period.

Zone:

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

APPENDIX B.

SAMPLE LOG TRENDS AND REPORTS

ELECTRICAL POWER UTILIZATION SUMMARY
REQUESTED BY: JBR 5/ 9/1983 23:19:10

METER NO. 1 ADMINISTRATION BLDG

DAY	KWH	PEAK KW	TIME
5/ 1/83	85,300	4221	7:13
5/ 2/83	257,400	10944	15:55
5/ 3/83	263,900	11056	15:32
5/ 4/83	261,600	10931	15:41
5/ 5/83	265,400	10872	15:46
5/ 6/83	252,200	11211	15:27
5/ 7/83	173,400	7814	12:51
5/ 8/83	88,700	4003	7:42

LAST MO. 6,752,400
THIS MO. 1,647,900

CONSUMPTION RECORD TODAY:

INTERVAL	KWH	PEAK KW
:03		
:33	5363	10753
1:03	5186	10388
1:33	4991	10376
2:03	4801	9583
.	.	.
.	.	.
.	.	.

ENERGY UTILIZATION SUMMARY

REQUESTED BY: JXD 12/20/83 14:12:08

OAT = 43.1°F

HOUSING

RH = 33%

	MAX MBTU/HR	ELEC	GAS	MBTU OIL	TOTAL
12/19/83	239	1501	85	1288	2874
12/20/83	215	834	62	702	1598
November	244	53848	1702	16618	72168
December	239	30571	1626	24743	56940

13:01 09/15/82 WED MASTER CONSOLE MCC 150.8 DEG F 24.0 KWH

ALARM SUMMARY PAGE 001

	USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT STATUS/VALUE	ENG. UNITS	ALARM STATUS
CLASS 1	MAIN BLDG W.	SMOKE ZONE	SMOKE		**ALM**
CLASS 2	CHPUMP	CHW PUMP	ON		**ALM**
	MAIN BLDG COOLING 01	CHILLER 1	ON		**ALM**
	MAIN BLDG COOLING 03	CHW PUMP	ON		**ALM**
	MAIN BLDG COOLING 07	CLG TOWER LO	ON		**ALM**
	MAIN BLDG COOLING 08	CLG TOWER HI	ON		**ALM**
	MAIN BLDG COOLING 09	COND PUMP	ON		**ALM**
CLASS 3	MAIN BLDG ZONE 1	SPACE TEMP	86.1	DEG F	**ALM**
	MAIN BLDG ZONE 3	SPACE TEMP	79.2	DEG F	**ALM**
	MAIN BLDG ZONE 4	SPACE TEMP	83.5	DEG F	**ALM**

LOCKOUT SUMMARY REQUESTED BY: 0 0 4/22/1980 17: 5:58

T	TEST PANEL	S	SUPPLY FAN 1
	1	SUPPLY FAN 1	LOCKED OUT
	14	WALL TEMP	LOCKED OUT
	15	ROOM TEMP	LOCKED OUT
	16	HIGH ZONE	LOCKED OUT
	17	LOW ZONE	LOCKED OUT

ANALOG LIMIT SUMMARY
CHILLER 79-2
10/18/83

POINT I.D.	ANALOG VALVE	UNITS	HIGH LIMIT	LOW LIMIT	SLIDING LIMITS
79-2-CWS	45.6	DEG F	--	--	±3
79-2-CHR	57.5	DEG F	60.0	50.0	--
79-2-ECW	71.3	DEG F	90.0	65.0	--
79-2-LCW	82.1	DEG F	100.0	65.0	--
79-2-KW	109.4	KW	170.0	10	--

CAMP LEJEUNE
HEAT/COOL SYSTEM RUN TIME REPORT
START DATE/TIME 1/25/82 8/14

LOAD	HOURS/MINUTES		LOAD	HOURS/MINUTES		LOAD	HOURS/MINUTES	
1	4	17	2	3	10	3	6	31
4	11	7	5	1	22	6	13	49
7	7	13	8	8	10	9	3	28
10	3	46	11	7	48	12	1	56
13	11	30	14	5	4	15	12	15
16	5	45	17	3	39	18	0	0
19	0	0	20	4	27	21	8	34
22	12	14	23	13	21	24	11	13
25	0	4	26	0	0	27	5	17
28	0	0	29	13	17	30	1	1
31	4	35	32	0	56	33	0	0
34	0	0	35	0	0	36	0	0
37	1	41	38	1	35	39	2	8
40	1	56	41	1	24	42	1	12
43	1	0	44	4	44	45	2	49
46	4	40	47	1	0	48	6	49
49	5	4	50	2	19	51	4	16
52	4	26	53	3	52	54	2	19
55	4	48	56	5	13	57	3	30
58	2	56	59	7	5	60	0	0
61	11	13	62	10	53	63	13	41
64	9	54	65	12	23	66	3	30
67	3	16	68	5	43	69	7	35
70	2	16	71	4	31	72	13	30
73	4	6	74	7	50	75	12	20
76	7	50	77	0	0	78	0	0
79	0	0	80	0	0	81	0	0
82	0	0	83	0	0	84	0	0
85	0	0	86	0	0	87	0	0
88	0	0	89	0	0	90	6	2
91	0	0	92	0	0	93	0	0
94	0	0	95	0	0			

TOTAL HEAT SYSTEM ON TIME 407 HRS 16 MIN

TOTAL COOL SYSTEM ON TIME 0 HRS 0 MIN

TOTAL ELASPED TIME 14 HRS 11 MIN

ENDING DATE/TIME 1/25/82 14/25

COOLING TOWER PROFILE
5/28/83

COOLING TOWERS:	DAILY TOTAL ON TIME	DAILY TOTAL ON-OFF TRANSITIONS	MONTH TO DATE TOTAL ON LINE
TOWER #1-FAN #1	9	1	45
#2	8	3	32
#3	5	18	25
#4	0	0	10
TOWER #2-FAN #1	0	0	20
#2	0	0	15
#3	0	0	0
#4	0	0	0
TOWER #3-FAN #1	9	1	18
#2	7	5	14
#3	4	16	8
#4	0	0	0

CONDENSER WATER COMMON:
DAILY: MAX TEMP 89.2 DEG F/1320 MIN TEMP 71.4 DEG F/0630
MONTH TO DATE: MAX TEMP 92.1 DEG F/05/22/1330 MIN TEMP 66.5 DEG F/05/02/0640

TASK?RE 1/15/80

POWER DEMAND REPORT FOR METER 1

PROG	MEASURED	PREDICTED	REDUCTION	LIMIT	TIME AND DATE	
0	1300 KW	1452 KW	249 KWH	1999 KW	00:21	01/15/80
0	1350 KW	1486 KW	250 KWH	1999 KW	00:51	01/15/80
0	1311 KW	1438 KW	249 KWH	1999 KW	01:21	01/15/80
0	1323 KW	1435 KW	249 KWH	1999 KW	01:51	01/15/80
0	1323 KW	1471 KW	250 KWH	1999 KW	02:21	01/15/80
0	1320 KW	1464 KW	249 KWH	1999 KW	02:51	01/15/80
0	1338 KW	1471 KW	249 KWH	1999 KW	03:21	01/15/80
0	1323 KW	1446 KW	250 KWH	1999 KW	03:51	01/15/80
MAX= 1381 KW , SHED= 17,006 KWH , TOTAL=115,574 KWH						
0	1323 KW	1450 KW	249 KWH	1999 KW	04:21	01/15/80
0	1299 KW	1435 KW	249 KWH	1999 KW	04:51	01/15/80
0	1342 KW	1491 KW	250 KWH	1999 KW	05:21	01/15/80
0	1335 KW	1479 KW	249 KWH	1999 KW	05:51	01/15/80
MAX= 1381 KW ,SHED= 18,006 KWH , TOTAL=118,224 KWH						
0	1350 KW	1480 KW	249 KWH	1999 KW	06:21	01/15/80
0	1324 KW	1441 KW	250 KWH	1999 KW	06:51	01/15/80
1	1311 KW	1465 KW	42 KWH	1999 KW	07:21	01/15/80
1	1342 KW	1476 KW	54 KWH	1999 KW	07:51	01/15/80
1	1329 KW	1443 KW	68 KWH	1399 KW	08:21	01/15/80
MAX= 1381 KW , SHED= 18,672 KWH , TOTAL=121,552 KWH						

CHILLER UTILIZATION SUMMARY

WEEK ENDING 05/02/80

LOAD LEVEL IN KWH	1 0-1500	2 1500-3000	3 3000-4500	4 4500-6000	5 6000-7500	6 7500-9000	7 9000-10500	8 10500-12000	9 12000-13500	10 13500-15000	TOTAL 0-15000
DAILY RUN TIME AVE. IN HOURS											
MON	0	0	2	4	3	0	0	0	0	0	9
TUES	0	2	2	2	3	0	0	0	0	0	9
WED	0	0	2	3	4	0	0	0	0	0	9
THUR	0	0	2	4	3	0	0	0	0	0	9
FRI	0	0	1	4	4	0	0	0	0	0	9
SAT	1	2	0	0	0	0	0	0	0	0	3
SUN	0	0	0	0	0	0	0	0	0	0	0
CURR MONTH TOTAL TIME	15	45	50	55	57	0	0	0	0	0	222
KWH TO DATE	15000	90000	175000	275000	399000	0	0	0	0	0	954000
MBTU TO DATE	51.2	307.2	597.3	938.7	1361.9	0	0	0	0	0	3256.4
COEF. OF PERFORM.											
WEEK TO DATE	3.0	3.2	3.3	3.3	3.1	0	0	0	0	0	3.25
MONTH TO DATE	3.1	3.2	3.3	3.2	3.1	0	0	0	0	0	3.25

OPTIMUM START TIME SUMMARY 11/ 2/1901 15:22:56

SF1 SUPPLY FAN 1 CURRENT STATUS CLOSED

```
CURRENT OPERATIONAL VALUES
MODE        HEATING
OCCUPANCY SCHEDULE (TIME AND DOW):  7: 0      1-------78
OUTSIDE AIR TEMP SENSOR       TC    ,ATMP,ATB      65.0 DEG.
INSIDE AIR TEMP SENSOR        TC    ,ATMP,ATA      64.0 DEG.
ZONE AIR TEMP SENSOR          TC    ,ATMP,ATC      64.0 DEG.
NO ADJUSTMENT TEMP                   75.0   DEGF
MAX OUTSIDE AIR TEMP                100.0   DEGF
OCCUPANCY TEMP REACHED WITHIN 20 MINS     NO
```

OUT-OF-SERVICE REPORT 8/14/84 3:14:10

FID # 4 CLOSED

MUX # 3 CLOSED MUX # 6 CLOSED MUX # 7 CLOSED

MUX # 8 CLOSED

********* THE END **********

ALL POINT LOG REPORT

USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT STATUS/VALUE	ENG UNITS	ALARM STATUS
ADM BLDG AHU SF	SUPPLY FAN	ON		NRML
ADM BLDG AHU RF	RETURN FAN	ON		NRML
ADM BLDG AHU MA	MIXED AIR	55.1	DEG F	NRML
ADM BLDG AHU SA	SUPPLY AIR	63.5	DEG F	**ALM**
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

11:01 09/15/82 WED   MASTER CONSOLE   MCC 34.8 DEG F 24.0 KWH

ALL POINT LOG (ASTERISKS INDICATE POINTS AT PRIORITY 3)   PAGE 1 00

HOST CNTL	USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT STATUS/VALUE	ENG. UNITS	ALARM STATUS
*	LAW BLDG AIR HANDLER 00	SUPPLY FAN	ON		NRML
*	LAW BLDG AIR HANDLER 01	MIXED AIR	80.30	DEG F	NRML
*	LAW BLDG AIR HANDLER 02	COLD DECK	55.30	DEG F	NRML
	LAW BLDG AIR HANDLER 03	FILTER	CLEAN		NRML
	LAW BLDG AIR HANDLER 04	FREEZE STAT	NORMAL		NRML
*	LAW BLDG COOLING 00	CHWR TEMP	57.50	DEG F	NRML
*	LAW BLDG COOLING 01	CHWS TEMP	44.40	DEG F	NRML
	LAW BLDG COOLING 02	CHW PUMP 2	OFF		NRML
*	LAW BLDG HEATING 00	HWS TEMP	104.4	DEG F	NRML
*	LAW BLDG HEATING 01	HWR TEMP	90.20	DEG F	NRML
*	LAW BLDG HEATING 02	GAS FLOW	23.20	CFM	
	LAW BLDG SECURITY 00	LIBRARY	SECURE		NRML
	LAW BLDG SECURITY 01	RECORDS	SECURE		NRML
	LAW BLDG SECURITY 02	AUDIO VISUAL	SECURE		NRML

END OF REPORT

ANALOG VALUES

TIME/DATE 4: 0 7/29/81

PT ID	VALUE	UNIT	STAT	PT ID	VALUE	UNIT	STAT	PT ID	VALUE	UNIT	STAT	PT ID	VALUE	UNIT	STAT
T001	76.55	DEG F	ON	T002	73.92	DEG F	ON	T003	73.11	DEG F		T004	78.85	DEG F	ON
T005	87.26	DEG F	ON	T006	76.69	DEG F		T007	76.90	DEG F	ON	T008	76.42	DEG F	ON
T009	75.24	DEG F	ON	T010	78.20	DEG F	ON	T011	76.42	DEG F		T012	80.43	DEG F	
T013	77.84	DEG F	ON	T014	78.05	DEG F	ON	T015	77.48	DEG F		T016	75.31	DEG F	ON
T017	74.13	DEG F	ON	T018	76.00	DEG F		T019	74.89	DEG F		T020	65.27	DEG F	ON
T021	77.26	DEG F		T022	75.93	DEG F	ON	T023	80.36	DEG F	ON	T024	67.54	DEG F	ON
T025	74.62	DEG F	ON	T026	72.51	DEG F		T027	74.13	DEG F	ON	T028	76.83	DEG F	
T029	74.82	DEG F		T030	77.12	DEG F		T031	75.52	DEG F	ON	T032	76.42	DEG F	ON
T035	37.37	DEG F		T036	37.61	DEG F		T037	76.97	DEG F		T038	82.07	DEG F	ON
T039	74.41	DEG F		T040	84.39	DEG F	ON	T041	77.48	DEG F		T042	74.48	DEG F	
T043	74.68	DEG F	ON	T044	77.62	DEG F	ON	T045	81.25	DEG F	ON	T046	75.31	DEG F	
T047	76.97	DEG F		T048	74.68	DEG F	ON	T049	74.96	DEG F		T050	85.15	DEG F	ON
T051	75.24	DEG F	ON	T052	75.45	DEG F	ON	T053	76.00	DEG F	ON	T054	83.79	DEG F	ON
T055	77.12	DEG F	ON	T056	74.96	DEG F	ON	T057	80.58	DEG F		T058	80.50	DEG F	
T059	78.70	DEG F	ON	T060	83.34	DEG F		T061	72.51	DEG F		T062	74.75	DEG F	
T063	78.41	DEG F	ON	T064	74.75	DEG F		T065	74.89	DEG F	ON	T066	74.89	DEG F	ON
T067	75.52	DEG F	ON	T068	76.35	DEG F		T069	74.89	DEG F	ON	T070	77.19	DEG F	
T071	80.58	DEG F	ON	T072	76.55	DEG F		T073	75.52	DEG F	ON	T074	76.69	DEG F	ON
4: 0	WARNING RSTR CAPACITY = 68 KW														
T075	77.55	DEG F		T076	77.26	DEG F		T080	85.60	DEG F		T081	82.89	DEG F	
T090	81.10	DEG F		T091	900.00	DEG F		T092	900.00	DEG F		T101	70.14	DEG F	
T102	900.00	DEG F		T103	900.00	DEG F		T104	5.86	DEG F		T105	5.86	DEG F	
T106	5.86	DEG F		T110	39.32	DEG F		T111	39.27	DEG F		T112	6.01	DEG F	
T113	5.86	DEG F		P001	900.00	PSIG		P002	900.00	PSIG		P003	900.00	PSIG	
P004	900.00	PSIG		P020	50.00	PSIG		P021	53.03	PSIG		P028	900.00	PSIG	
P029	5.33	PSIG		P030	6.05	PSIG		P031	900.00	PSIG		P032	900.00	PSIG	
L001	900.00	INCH		L002	900.00	INCH		L003	900.00	INCH		L004	18.00	INCH	
L005	18.00	INCH		L006	18.00	INCH		L010	32.42	INCH		L011	11.65	INCH	
L012	999.99	INCH		L013	999.99	INCH		L014	7.48	INCH		L015	7.62	INCH	
L016	900.00	INCH		L017	900.00	INCH									

13:09 09/15/82 WED   MASTER CONSOLE   MCC 150.8 DEG F 24.0 KWH

OPERATOR ACCESS REPORT   PAGE 1

NAME	INITIALS	PRIORITY
CARTER	WJC	4
DRAPER	DD	4
HANSEN	FAH	4
HOVEY	KMH	4
HUGHES	JH	4
HYCNAR	JMH	4
LEBLANC	RJL	4
MOCERI	DJM	4
O	OPR	1
ORION	ORI	4
P	MCC	4
SCHULTZ	WS	4
SELDON	WHS	4
SHEEHAN	PMS	4
ZIVNEY	RCZ	4

END OF REPORT

BOILER PROFILE
BLR-168-1
11/15/83   10:03:57

BOILER STATUS:	ON
BOILER OUTPUT STEAM PRESSURE:	12.3 psig
STEAM TEMPERATURE:	265.1 °F
STEAM OUTPUT:	1395 LB/HR
BOILER OUTPUT:	1.34 MBTU/HR
FUEL INPUT:	14.2 GAL/HR
ENERGY INPUT:	1.97 MBTU/HR
INSTANTANEOUS EFFICIENCY:	68%
FEEDWATER TEMPERATURE:	187.6°F
OUTSIDE TEMPERATURE:	41.7°F
SEASONAL EFFICIENCY:	69%

CHILLER 23-1 PROFILE

9/22/83

CHILLED WATER:	SUPPLY TEMP 68.7 DEG F RETURN TEMP 72.2 DEG F FLOW 200 GPM
CONDENSER WATER:	SUPPLY TEMP 85.4 DEG F RETURN TEMP 85.4 DEG F FLOW 270 GPM
ENERGY FLOW:	CHILLER AND AUXILIARIES 0 KW
TOTALIZED ENERGY TO DATE:	
	DAY = 102 KWH
	WEEK = 414 KWH
COST PER UNIT ENERGY:	EL = $.04/KWH
TOTAL COST OF ENERGY TO DATE:	
	TODAY = $4.08 WEEK = $16.56
LOAD RATE:	INSTANTANEOUS = 0.0 MBTU/HR AVG. TODAY = .45 MBTU/HR
TOTALIZED BTU LOAD:	TODAY .985 MBTU WEEK: 4.10 MBTU
COEFFICIENT OF PERFORMANCE:	
	INSTANTANEOUS = 0.0 DAY = 2.83
	WEEK = 2.90 SEASON = 3.2
COST OF BTU:	TODAY = $4.14/MBTU WEEK: $4.04/MBTU

NOTE: MBTU = MILLION BTU

DAILY AHU FAN ENERGY CONSUMPTION
BUILDING 23
5/28/83

AHU NO.	FAN SIZE HP	RUN-TIME MIN.	ENERGY KWH
1	3	465	13.9
2	2	392	7.8
3	7½	404	30.1
4	1	433	4.3
5A	5	387	19.2
5B	5	387	19.2
6	3	425	12.7

TOTAL ENERGY CONSUMPTION TODAY = 107.2 KWH

12:59 09/15/82 WED   MASTER CONSOLE   MCC 150.8 DEG F 24.0 KWH

TOTALIZATION REPORT   PAGE 001

USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT TOTAL VALUE	ENG. UNITS
CHPUMP	CHW PUMP	10691.8	HOURS
DAY		-1296.	HOURS
EDIFICE FEDERAL SYST VENT 1	VENT. ALIM.	0.0000	HOURS
EDIFICE FEDERAL SYST VENT 2	VENT. RETOUR	0.0000	HOURS
HPUMP	PUMP	20094.4	HOURS
KWH ADMIN BUILDING	KWH METER	466113.2	KHW
KWH HARRISON ST	KHW METER	224698.2	KHW
KWH LAW BUILDING	KWH METER	299596.5	KHW
KWH RESEARCH BLDG	KHW METER	224698.2	KHW
KWH TOTAL	KWH USEAGE	637729.3	KWH
KWH TOTAL DOLLARS	DOLLARS	29477.3	DOLLAR
KWH TOWER 1	KWH METER	466113.2	KHW
KWH TOWER 5	KWH METER	299596.6	KHW
KWH TRIBUNE DOLLARS	DOLLARS	29477.3	DOLLAR
KWH TRIBUNE TOTAL	KWH USEAGE	637729.3	KWH
LAW BLDG AIR HANDLER 00	SUPPLY FAN	5068.	HOURS
LAW BLDG COOLING 02	CHW PUMP 2	0.0000	HOURS
LAW BLDG HEATING 02	GAS FLOW	7054832.5	CUFT
LITE1	OFFICE LITE1	7662.	HOURS
LITE2	NIGHT LIGHTS	400.2	HOURS
LITE3	OFFICE LITE3	9230.	HOURS
MAIN BLDG ADMIN AREA 02	OFFICE LITE1	7662.	HOURS
MAIN BLDG ADMIN AREA 03	NIGHT LIGHTS	400.2	HOURS
MAIN BLDG ADMIN AREA 04	OFFICE LITE3	9230.	HOURS
MAIN BLDG AHU 1 00	SUPPLY FAN	7892.	HOURS
MAIN BLDG AHU 1 02	RETURN FAN	4470.	HOURS
MAIN BLDG COOLING 01	CHILLER 1	12932.0	HOURS
MAIN BLDG COOLING 03	CHW PUMP	10691.8	HOURS
MAIN BLDG COOLING 07	CLG TOWER LO	13292.3	HOURS
MAIN BLDG COOLING 08	CLG TOWER HI	12942.2	HOURS
MAIN BLDG COOLING 09	COND PUMP	5255.	HOURS
MAIN BLDG HEATING 01	PUMP	20094.4	HOURS
OCCUPIED		17764.2	HOURS
RESEARCH BLDG AIR HANDLER 0	SUPPLY FAN	5068.	HOURS
RF1	RETURN FAN	4470.	HOURS
SF1	SUPPLY FAN	7892.	HOURS

END OF REPORT

BUILDING 402 ENERGY AUDIT FOR WEEK ENDING MARCH 6, 1984

KWH OF ELECTRICITY

DATE	2/29	3/1	3/2	3/3	3/4	3/5	3/6	WEEK TOTAL
BUDGET/DAY	333	333	333	333	333	333	20	2000
CORRECTED BUDGET/ DAY	300	300	300	250	250	300	30	1730
ACTUAL/DAY USED	315	330	350	360	280	350	20	1945
BUDGET DEVIATION (BUDGET MINUS ACTUAL)	18	3	-17	33	53	-17	0	73
PERFORMANCE RATIO (ACTUAL/CORRECTED BUDGET)	1.05	1.10	1.45	1.20	1.12	1.33	0.68	1.19
DAILY TEMP RANGE HI/LO	40/16	43/18	53/25	60/32	51/18	38/10	32/8	
ACTUAL DEGREE DAYS	6	8	10	8	6	5	3	46
BUDGET DEGREE DAYS	8	9	10	10	10	9	8	60

CAMP LEJEUNE
MARINE CORPS BASE / BASE HOUSING
MEGA BTU DATA

FY 82

MONTH	AREA	** ELECTRICITY	ENERGY TYPES COAL	GAS	** OIL	AREA TOTAL MBTU	MONTH TOTAL MBTU	DEGREE DAYS HEAT	COOL
OCTOBER	MCBASE	133655.00	48852.00	1161.00	83065.00	266733.00			
OCTOBER	HOUSIN	56376.00	0.00	1362.00	15217.00	72957.00			
ENERGY TOTAL BY TYPE		190031.00	48852.00	2523.00	98284.00		339690.00	132.50	49.00
NOVEMBER	MCBASE	132066.37	84782.00	1467.00	102755.00	322070.37			
NOVEMBER	HOUSIN	53047.19	0.00	1702.00	16618.00	72167.19			
ENERGY TOTAL BY TYPE		186713.56	84782.00	3169.00	119373.00		394237.56	341.50	6.00
DECEMBER	MCBASE	137460.00	110707.00	2572.00	154622.00	405361.00			
DECEMBER	HOUSIN	61143.00	0.00	3252.00	49487.00	113882.00			
ENERGY TOTAL BY TYPE		198603.00	110707.00	5824.00	204109.00		519243.00	610.00	3.00

YEAR TO DATE TOTAL MBTU	TOTAL SQ FT	** MBTU/SQ FT FY 75	COAL FY 85	** ACTUAL FY 82	DEVIATION FROM FY 75	** DEGREE DAYS HEAT FY 75	HEAT FY 82	COOL FY 75	** COOL FY 82
1253170.56	18960844.00	.073060	.058450	.066093	9.54 %	1059.00	1084.00	71.00	58.00

SUPPLEMENTARY ALARM SUMMARY REQUESTED BY: 0 0 4/24/1980 19:27:20

1 CHECK BOILER FUNCTION
2 CHECK COOLING COIL FUNCTION
3 SUPPLY FAN NOT OPERABLE, CHECK H-O-A SWITCH
4 CHECK AHU-1 COLD DUCT TEMP AND CHILLER FLOW
5 CHECK CONDENSER PUMP
6 CHECK COOLING TOWER FAN
7 CHECK CHILLER STATUS
8 CHECK CHILLER WATER SUPPLY PUMP
9 CHECK ENTHALPY SWITCHOVER

CORRELATED ALARM REPORT
BLDG-12-CV-1-HWS TEMP IN ALARM
3/15/83 9:07:18

LOW AT 105.9°F SETPOINT = 114.7
LIMITS: LO = 111.7° HI = 117.7°

USER/ENGLISH NAME	POINT DESCRIPTION	CURRENT STATUS/VALUE	ENG UNITS	ALARM STATUS
BLDG 12 CONV1 PUMP	PUMP	ON		NRML
BLDG 12 CONV1 VALVE	VALVE POS.	55	% OPEN	NRML
BLDG 12 BLR STEAM	PRESSURE	5.3	PSIG	NRML
BLDG 12 BLR STEAM	TEMP.	227	°F	NRML
BLDG 12 BLR	STATUS	ON		NRML

CAMP LEJEUNE
POWER DEMAND CONTROL
DAILY SUMMARY REPORT
12/31/78

PERIOD ENDING	USAGE KWH	H I	AVERAGE DEMAND-KW	H I
0: 1				
0:16	2721		10884.0	
0:31	2656		10624.0	
0:46	2624		10496.0	
1: 1	2559		10236.0	
1:16	2494		9976.0	
1:31	2494		9976.0	
1:46	2429		9716.0	
2: 1	2397		9588.0	
2:16	2397		9588.0	
2:31	2397		9588.0	
2:46	2365		9460.0	
3: 1	2365		9460.0	
3:16	2300		9200.0	
3:31	2300		9200.0	
3:46	2300		9200.0	
4: 1	2300		9200.0	
4:16	2300		9200.0	
4:31	2332		9328.0	
4:46	2300		9200.0	
5: 1	2267		9068.0	
5:16	2267		9068.0	
5:31	2300		9200.0	
5:46	2267		9037.9	
6: 1	2267		9068.0	
6:16	2332		9328.0	
6:31	2332		9328.0	
6:46	2397		9588.0	
7: 1	2397		9588.0	
7:16	2365		9460.0	
7:31	2365		9460.0	
7:46	2397		9620.1	
8: 1	2397		9588.0	
8:16	2494		9976.0	
8:31	2559		10236.0	
8:46	2591		10364.0	
9: 1	2624		10496.0	
9:16	2721		10884.0	
9:31	2753		11012.0	
9:46	2818		11272.0	
10: 1	2851		11404.0	
10:16	2915		11660.0	
10:31	2948		11792.0	
10:46	2980		11920.0	
11: 1	2980		11920.0	
11:16	2980		11920.0	
11:31	3013		12052.0	
11:46	3045		12180.0	
12: 1	3045		12139.5	
12:16	3077		12308.0	

DAILY SUMMARY REPORT
12/31/78

PERIOD ENDING	USAGE KWH	H I	AVERAGE DEMAND-KW	H I
12:16				
12:31	3077		12308.0	
12:46	3045		12180.0	
13: 1	3110		12440.0	
13:16	3077		12308.0	
13:31	3077		12308.0	
13:46	3077		12308.0	
14: 1	3013		12092.3	
14:16	3013		12052.0	
14:31	2980		11920.0	
14:46	2980		11920.0	
15: 1	2980		11920.0	
15:16	2980		11920.0	
15:31	3013		12052.0	
15:46	3045		12180.0	
16: 1	3110		12440.0	
16:16	3045		12180.0	
16:31	3077		12308.0	
16:46	3110		12440.0	
17: 1	3110		12440.0	
17:16	3207		12828.0	
17:31	3337		13348.0	
17:46	3434		13736.0	
18: 1	3434		13736.0	
18:16	3466	*	13864.0	*
18:31	3466	*	13864.0	*
18:46	3466	*	13864.0	*
19: 1	3434		13736.0	
19:16	3401		13604.0	
19:31	3337		13348.0	
19:46	3304		13216.0	
20: 1	3239		12956.0	
20:16	3239		12956.0	
20:31	3175		12700.0	
20:46	3175		12700.0	
21: 1	3077		12308.0	
21:16	3077		12308.0	
21:31	3077		12308.0	
21:46	2980		11920.0	
22: 1	2915		11660.0	
22:16	2883		11532.0	
22:31	2851		11404.0	
22:46	2786		11144.0	
23: 1	2721		10884.0	
23:16	2689		10756.0	
23:31	2624		10496.0	
23:46	2624		10496.0	
0: 1	2591		10364.0	
TOTAL	269702.			

NO LOADS SHED

CAMP LEJEUNE
DAILY OUTSIDE TEMPERATURE REPORT
1/25/82

PERIOD	TEMPERATURE
24:00 TO 1:00	42.54
1:00 TO 2:00	40.18
2:00 TO 3:00	39.07
3:00 TO 4:00	37.17
4:00 TO 5:00	34.40
5:00 TO 6:00	34.11
6:00 TO 7:00	33.46
7:00 TO 8:00	34.08
8:00 TO 9:00	37.36
9:00 TO 10:00	40.14
10:00 TO 11:00	41.14
11:00 TO 12:00	44.76
12:00 TO 13:00	46.56
13:00 TO 14:00	48.21
14:00 TO 15:00	****
15:00 TO 16:00	****
16:00 TO 17:00	****
17:00 TO 18:00	****
18:00 TO 19:00	****
19:00 TO 20:00	****
20:00 TO 21:00	****
21:00 TO 22:00	****
22:00 TO 23:00	****
23:00 TO 24:00	****

AVERAGE 39.57

AHU 23-1
SELECTED POINT DAILY TREND LOG
9/22/83

TIME	FAN STATUS	SPACE TEMPERATURE
1:00	ON	76.4
2:00	ON	70.8
3:00	ON	69.5
4:00	ON	68.3
5:00	ON	67.5
6:00	ON	66.6
7:00	ON	65.8
8:00	ON	65.6
9:00	OFF	66.3
10:00	OFF	67.9
11:00	OFF	68.8
12:00	OFF	70.1
13:00	OFF	72.4
14:00	OFF	75.6
15:00	ON	78.3
16:00	ON	77.5
17:00	OFF	77.6
18:00	OFF	78.2
19:00	OFF	78.5
20:00	OFF	77.9
21:00	OFF	77.8
22:00	OFF	77.5
23:00	OFF	77.1
24:00	OFF	76.6

FAN RUN-TIME = 578 MIN

```
10:53 09/15/82 WED     MASTER CONSOLE           MCC   34.8  DEG F   24.0 KWH

ADMINISTRATION BUILDING AIR HANDLER ONE HAS EXCEEDED 1000 HOURS RUNNING TIME

THE FOLLOWING SERVICE ITEMS SHOULD BE PERFORMED

       TASKS                                                      COMPLETED

   VISUAL CHECK
     CLEANLINESS OF HEATING/COOLING COILS
     DAMPER ACTUATORS
     VALVE ACTUATORS

   CLEAN
     HEATING/COOLING COILS
     HUMIDIFIER PAN AND OVERFLOW TUBE

   REPLACE
     FAN BELT              PART NO. FB430A
     FILTER ELEMENT        PART NO. FE112

   LUBE
     FAN BEARINGS          GRAPHITE NO.12
     MOTOR BEARINGS        GRAPHITE NO.12
     VALVE ACTUATORS       PART NO.PR03

   CALIBRATE
     MIXED AIR RECEIVER/CONTROLLER AT 55 DEGREES F
     HOT DECK RECEIVER/CONTROLLER AT 90 DEGREES F
     COLD DECK RECEIVER/CONTROLLER AT 50 DEGREES F
     HUMIDITY TRANSMITTER AT 50 PERCENT RH


MAINTENANCE SIGNATURE                                         DATE COMPLETED
RELATED COMMENTS
```

CAMP LEJEUNE
UTILITY MONITORING AND CONTROL SYSTEM
INVENTORY CONTROL REPORT

1/25/82 PAGE 8

MANU-FACTOR	MODEL NUM	SERIAL NUM	UMACS PURCHASED	DATE RECEIVED	WARRANTY DAYS	REPAIR REQUEST	DOC NUM	LAST REPAIR	PRIOR REPAIR	REPAIR COUNT	AWAIT REPAIR	WARRANTY DAYS
01	00022015601J	001501703066	NO	0017	0365		0000	0170	0000	01	NO	0060
01	00022015601J	001501704023	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022015601J	001501704024	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022015601J	001501704037	NO	0017	0365	7102	0003	7100	0000	01	NO	0060
01	00022015601J	001501704056	NO	0017	0365		0000	0177	0000	01	NO	0060
01	00022015601J	001004500001	NO	0017	0365	1161	0011	1232	0077	02	NO	0060
01	00022015601J	001004500021	NO	0017	0365	0106	0001	0130	0170	02	NO	0060
01	00022016201J	MCI A 1176	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	MCI B 1176	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	SHOP 177	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	SHOP 277	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	001004600043	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	001705000004	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
01	00022016201J	001705000027	YES	0106	0365	1161	0011	1232	0000	01	NO	0060
01	00022016201J	001705000030	YES	0106	0365	1161	0011	1232	0000	01	NO	0060
01	00022016201J	SHOPMCI 177	YES	0106	0365	1161	0011	1232	0000	01	NO	0060
01	00022016201J	SHOPMCI177A3	YES	0106	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031002	CHASSIS 1	NO	0017	0365	0120	0000	0126	0000	01	NO	0060
02	00SP42031002	CHASSIS 2	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031020	UTILITY 1	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031021	DECODER 1	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 1	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 2	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 3	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 4	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 5	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 6	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 7	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 8	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 9	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 10	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 11	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	00SP42031023	MODULE 12	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	0C1551AA5P07	000000TP001N	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	0C1551AA5P07	000000TP002N	NO	0017	0365	0000	0000	0000	0000	00	NO	0000
02	0C1551AA5P07	000000TP003N	NO	0017	0365	1071	0007	1216	0000	01	NO	0060
02	0C1551AA5P07	000000TP004N	NO	0017	0365	0000	0000	0000	0000	00	NO	0000

V19-15

CAMP LEJEUNE
BASE MAINTENANCE UTILITY DIVISION
PROPERTY CONTROL REPORT

1/25/02

ACCOUNT CODE	SHOP CODE	NATIONAL STOCK NUMBER	NOMENCLATURE	SERIAL NUMBER	QUANTITY	OWNER COMMENTS
203	03	341301C000010	DRILL	1460145	1	....
203	03	341301C000010	DRILL	BPC0004	1	....
203	03	341500C000003	MACHINE GRINDER	244265	1	....
203	83	341500C000003	MACHINE GRINDER	705135	1	....
203	03	343201C000001	WELDING MACHINE	12RT71521	1	....
203	03	3433009130016	KIT,WELD/CUTTING		1	....
203	03	344201C000001	HYDRAULIC PRESS	RC1010	1	....
203	83	3750001413279	MOWER LAWN	3319	1	....
203	83	3750001413279	MOWER LAWN	3320	1	....
203	83	3750001413279	MOWER LAWN	422652	1	....
203	83	3750001413279	MOWER LAWN	422673	1	....
203	83	3750001413279	MOWER LAWN	472462	1	....
203	03	3750001413279	MOWER LAWN	512706	1	....
203	03	3750001413279	MOWER LAWN	513793	1	....
203	83	3750001413279	MOWER LAWN	BPC0004	1	....
203	03	3750001413279	MOWER LAWN	BPC0006	1	....
203	83	375001C000006	MOWER RIDING	2074	1	....
203	83	375001C000006	MOWER RIDING	2290	1	....
203	83	375001C000006	MOWER RIDING	360609	1	....
203	83	375001C000006	MOWER RIDING	562600	1	....
203	03	375001C000006	MOWER RIDING	91072579	1	....
203	83	375001C000011	CUTTER WEED	7044007	1	....
203	83	375001C001026	GAS ENG EDGER	BPC0007	1	....
203	83	3720006407107	WHEELBARROW		2	....
203	83	392000C000045	HAND TRUCK	WT001	1	....
203	03	392000C000045	HAND TRUCK	WT002	1	....
203	83	392000C000050	TRUCK PALLET	376127	1	....
203	03	392000C000050	TRUCK PALLET	455652	1	....
203	83	392001C000010	TRUCK HAND	26706	1	....
203	03	395001C000004	HOIST CHAIN	RT79	1	....
203	83	4110002550760	DISPR W/O BOTTLE		0	....
203	03	411000C000074	REFRIGERATOR		7	....
203	03	4120009054232	AIR COND 24K BTU	217756	1	....
203	03	412000C000007	AIR COND 0K BTU	2H574670	1	....
203	03	412000C000007	AIR COND 0K BTU	2H574677	1	....
203	03	412000C000007	AIR COND 0K BTU	KB450730	1	....
203	03	412000C000064	AIR COND 12K BTU	1073313705	1	....

CAMP LEJEUNE
BASE MAINTENANCE UTILITY DIVISION
PROPERTY CONTROL REPORT

1/25/82

ACCOUNT CODE	SHOP CODE	NATIONAL STOCK NUMBER	NOMENCLATURE	SERIAL NUMBER	QUANTITY	OWNER COMMENTS
203	03	7910000000013	VACUUM CLEANER		2	....
203	03	PA 210291	WELDING MACHINE	6FW5066	1	....
203	03	PA 213606	THREADER, PIPE	301954	1	....
203	03	PA 213791	MACHINE WELDING	01WS03043	1	....
203	03	PA 214125	DETECTOR LEAK	463	1	....

TOTAL ITEMS = 233 TOTAL RECORDS = 116

SHOP	BRANCH
00	OFFICE/UMACS
01	STEAM
03	WATER
04	SEWAGE
05	COLD STORAGE

CAMP LEJEUNE
POOL 540 CHEMICAL CONTENTS REPORT
1/25/82

TIME ENDING	** ORP	AVERAGE PH	** DEG F	TIME ENDING	** ORP	AVERAGE PH	** DEG F	TIME ENDING	** ORP	AVERAGE PH	** DEG F	TIME ENDING	** ORP	AVERAGE PH	** DEG F
0/30	5.39	7.14	74.60	0/45	5.38	7.14	74.64	1/ 0	5.37	7.14	74.62	1/15	5.37	7.15	74.62
1/30	5.36	7.15	74.62	1/45	5.35	7.15	74.55	2/ 0	5.34	7.15	74.55	2/15	5.33	7.15	74.55
2/30	5.33	7.15	74.54	2/45	5.31	7.14	74.55	3/ 0	5.25	7.11	74.62	3/15	5.26	7.11	74.65
3/30	5.36	7.15	74.60	3/45	5.42	7.14	74.71	4/ 0	5.49	7.14	74.75	4/15	5.55	7.14	74.79
4/30	5.61	7.13	74.82	4/45	5.66	7.13	74.88	5/ 0	5.71	7.13	74.91	5/15	5.76	7.12	74.97
5/30	5.80	7.12	75.02	5/45	5.83	7.11	75.04	6/ 0	5.86	7.11	75.10	6/15	5.88	7.11	75.13
6/30	5.91	7.10	75.17	6/45	5.93	7.10	75.20	7/ 0	5.94	7.10	75.24	7/15	5.95	7.10	75.29
7/30	5.96	7.09	75.32	7/45	5.97	7.09	75.37	8/ 0	5.97	7.09	75.39	8/15	5.98	7.09	75.45
8/30	5.98	7.09	75.45	8/45	5.98	7.09	75.52	9/ 0	5.97	7.09	75.52	9/15	5.97	7.09	75.52
9/30	5.97	7.09	75.52	9/45	5.96	7.09	75.52	10/ 0	5.95	7.09	75.52	10/15	5.94	7.09	75.52
10/30	5.93	7.09	75.52	10/45	5.92	7.10	75.49	11/ 0	5.91	7.10	75.47	11/15	5.90	7.10	75.45
11/30	5.89	7.10	75.45	11/45	5.88	7.10	75.45	12/ 0	5.87	7.10	75.41	12/15	5.86	7.10	75.38
12/30	5.85	7.10	75.38	12/45	5.84	7.10	75.38	13/ 0	5.83	7.10	75.38	13/15	5.82	7.10	75.36
13/30	5.81	7.10	75.32	13/45	5.80	7.10	75.31	14/ 0	5.79	7.10	75.31	14/15	5.78	7.10	75.29

	ORP	PH	DEG F
DAILY AVERAGES **	5.73	7.11	75.12

SECURITY REPORT

TYPE		STATUS	TIME	DATE	NAME	PASSWORD
ON	1	4	14:29:16	8/28/82	HELLO	JOHN
ON	1	4	14:29:53	8/28/82	JOHN	JAP
ON	1	4	14:30:18	8/28/82	PARKER	JOHN
ON	1	0	14:30:47	8/28/82	HANSEN	FRED
OFF	1	0	14:49:20	8/28/82		
OFF	1	1	18:00:06	8/28/82		
OFF	1	1	18:00:04	8/29/82		
ON	1	2	08:47:30	8/30/82		
ON	1	0	09:22:34	8/30/82	HANSEN	FRED
OFF	1	0	09:23:41	8/30/82		
ON	1	4	10:34:05	8/30/82	ORION	ORINO
ON	1	2	10:34:30	8/30/82	ORION	
ON	1	0	10:34:46	8/30/82	ORION	ORION
OFF	1	0	18:00:04	8/30/82		
ON	1	0	10:57:49	8/31/82	HANSEN	FRED
ON	1	0	11:26:35	9/14/82	ORION	ORION
ON	1	0	12:03:33	9/14/82	ORION	ORION
ON	1	0	12:17:27	9/14/82	ORION	ORION
ON	1	0	12:27:25	9/14/82	ORION	ORION
OFF	1	0	12:29:04	9/14/82		
ON	1	0	13:02:12	9/14/82	ORION	ORION
OFF	1	0	13:17:38	9/14/82		
ON	1	0	13:36:59	9/14/82	ORION	ORION
OFF	1	0	13:39:08	9/14/82		
ON	1	0	14:55:16	9/14/82	ORION	ORION
ON	1	0	15:14:21	9/14/82	ORION	ORION
ON	1	0	15:39:27	9/14/82	ORION	ORION
ON	1	0	15:46:26	9/14/82	ORION	ORION
ON	1	0	16:00:58	9/14/82	ORION	ORION
OFF	1	0	16:27:56	9/14/82		
ON	1	0	16:52:03	9/14/82	P	T

END OF REPORT

DISTRIBUTION LIST

AF HQ LEEEU (Aimone), Wash., DC

AFB AFCS/DEO (Corbett), Scott AFB, IL; AFSC/DEE, Andrews AFB, Wash, DC; HQ AFLC/DEE (EMCS Mgr), Wright-Patterson AFB, OH; HQ ATC/DEM (Ling), Randolph AFB, TX; HQ PACAF/DEE (EMCS Mgr), Hickam AFB, HI; HQ SAC/DEE (Butters), Offutt AFB, NE; HQ SAC/DEER, Offutt AFB, NE; HQ SAC/DEM (Tonsi), Offutt AFB, NE; HQ SPACECOM/DE (Moytinia), Peterson AFB, CO; HQ TAC/DEE (Scercy), Langley AFB, VA; HQ TAC/DEM (White), Langley AFB, VA; MAC/DEE (West), Scott AFB, IL; MAC/DEM (Kosch), Scott AFB, IL

AFESC DEB (Stother), Tyndall AFB, FL

USAF-AAC DEE, Elmendorf AFB, AK

ARMY CORPS OF ENGINEERS DAEN-MPC-C (Wharry), Wash., DC; DAEN-MPE-E (Brake), Wash., DC; DAEN-MPE-E (McCarthy), Wash., DC; DAEN-MPO-U (Walton), Wash., DC

ARMY ENG DIV EUDED-TM (O'Malley).; HNDED-ME (Carlen), Huntsville, AL; HNDED-ME (DeShazo), Huntsville, AL; HNDED-ME (Herden), Hunstville, AL; HNDED-ME (Holland), Huntsville, AL; HNDED-ME (Wilcox), Huntsville, AL; HNDED-PM (Brown), Huntsville, AL; HNDED-PM (Ganus), Huntsville, AL; MRDED-TM (Beranek), Omaha, NE; MRDED-TM (Jones), Omaha, NE; NADCO-CM (Eng), New York, NY; NADEN-TM (Stuart), New York, NY; NPDEN-TE (Wottlin), Portland, OR; ORDED-T, (Norman), Cincinnati, OH; PODED-T (Nakasone), Ft. Shafter, HI; SADCO-CC (Mindel), Atlanta, GA; SADEN-TE (Smith), Atlanta, GA; SPDED-TG (Kishaba) San Francisco, CA; SWDED-M (Powell), Dallas, TX

ARMY ENGR DIST. CO, Tulsa, OK; MRKED-DM (Rabuse), Kansas City, MO; MRKED-M (McCollum), Kansas City, MO; MROCD-SM (Hall), Omaha, NE; MROCD-SM (O'Brien), Omaha, NE; MROED-DC (Sawick), Omaha, NE; NABCO-S (Meisel), Baltimore, MD; NABEN-D (Kelly), Baltimore, MD; NANCO-C (Spector), New York, NY; NANEN-DM (Kessenides), New York, NY; NAOEN-MA (Daughety), Norfolk, VA; NAOOP-C (Herndon), Norfolk, VA; NPSEN-DB (Eason), Seattle, WA; ORLED-D (Pfeifer), Louisville, KY; SAMCO-SI (Rawls) Mobile, AL; SAMEN-C (Anderson), Mobile, AL; SAMEN-CI (Tunnell), Mobile, AL; SASEN-DF (Plunkett), Savannah, GA; SASEN-MA (Grimes), Savannah, GA; SCD-SB (Stone), Savannah, GA; SPKCO-C (Del Porto), Sacramento, CA; SPKCO-C (Evans), Sacramento, CA; SPKED-M (Lowell), Sacramento, CA; SPKED-M (Stoner), Sacramento, CA; SPLCO-CS (Molina), Los Angeles, CA; SWFCD-ST (Ready), Ft. Worth, TX; SWFCD-ST (Wood), Ft. Worth, TX; SWFED-DM (Story), Ft. Worth, TX; SWFED-DM (Wike), Ft. Worth, TX

NAVFACENGCOM Code 03 Alexandria, VA; Code 03T (Essoglou) Alexandria, VA; Code 04 Alexandria VA; Code 04T2 (Knapp), Alexandria, VA; Code 04T2B (McGrath), Alexandria, VA; Code 04T7B (Stickley), Alexandria, VA; Code 05D1 (Bersson), Alexandria, VA; Code 09M54, Tech Lib, Alexandria, VA; Code 111 (Mitchum), Alexandria, VA; Code 1112E (Tayler), Alexandria, VA; Code 111B (Hanneman), Alexandria, VA

NAVFACENGCOM - CHES DIV. CO, Washington DC

NAVFACENGCOM - LANT DIV. Norfolk, VA

NAVFACENGCOM - NORTH DIV. CO

NAVFACENGCOM - PAC DIV. Commander, Pearl Harbor, HI

NAVFACENGCOM - SOUTH DIV. CO, Charleston SC

NAVFACENGCOM - WEST DIV. San Bruno, CA

NAVFACENGCOM CONTRACTS OICC, Kings Bay, GA

NAVSHIPYD PWO, Mare Is.

USAF AFRCE/CR (Walton), Dallas, TX; AFRCE/ER (Burns), Atlanta, GA; AFRCE/M-X (Stevens), Norton AFB, CA; AFRCE/WR (Lowry), San Francisco, CA

USAFE HQ DEE (EMCS Mgr), Ramstein AFB, Germany