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TECHNICAL NOTE

TITLE: UTILIZING THE OPTIMUM START/STOP CONTROL STRATEGY FOR HEATING NAVAL CIVIL ENGINEERING LABORATORY

AUTHOR: Ivan Sanchez

DATE: April 1983

SPONSOR: Chief of Naval Material

PROGRAM NO: SO371-01-221C

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

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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

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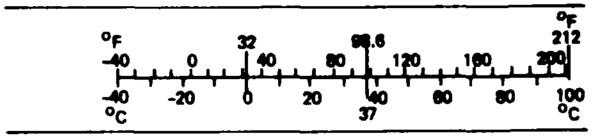
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

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



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

NCEL has successfully implemented a single-building controller that measures indoor and outdoor temperatures to determine optimum times to start and stop steam heat. Significant energy and dollar savings have been demonstrated. Operating experience with the controller and details on its hardware and software are presented in this report.

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1. EMCS 2. Energy conservation I. SO371-01-221C

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CONTENTS

INTRODUCTION

The concept of energizing equipment only when it is needed forms the basis for many energy conservation control strategies. Two of these strategies are: Scheduled Start/Stop and Optimum Start/Stop. Scheduled Start/Stop can be implemented with many different types of equipment and has the potential for saving all the energy that would have been used during the unoccupied time except for that needed to warm-up or cool-down the building prior to occupancy. Scheduled Start/Stop is based solely on time and the warm-up/cool-down time is determined using the worst case conditions.

Optimum Start/Stop uses outdoor and indoor temperature measurements to turn the equipment on at the latest possible time and still meet the temperature requirements at the beginning of occupancy and to turn the equipment off at the earliest possible time while still meeting occupancy requirements at quitting time.

The Naval Civil Engineering Laboratory (NCEL) has successfully implemented a single building controller that utilizes an Optimum Start/Stop control strategy and a dead-band control mode on a steam heating system. This report covers the development of the single building control system and the results of implementing that system.

BACKGROUND

Energy crises and the continuing rise in the cost of energy have made energy conservation a necessity. Executive Order 12003 has set a target for 20% reduction in energy usage from the adjusted FY75 Baseline energy consumption for all installations. There are many possible ways of reducing energy consumption, including:

- Insulating
- Weatherstripping
- Using alternative energy sources
- Installing more efficient heating, ventilating, and air conditioning (HVAC) equipment
- Tuning up existing equipment
- Upgrading controls
- Installing computer based controls

Large scale computer-based controls known as Energy Monitoring Control Systems (EMCS) have a great potential for energy conservation. EMCS can be installed to control an entire installation, part of an installation, or a single building. They have the capability of implementing many energy conservation control strategies and can help provide better facility operation and maintenance. Large scale EMCS have a high initial cost and many buildings do not have enough energy consumption to justify being placed on such a system. Historically, equipment in these buildings was left on continuously or turned off manually or by time clocks. Obviously, leaving equipment running when not required is unpalatable. Unfortunately, inspiring people to be energy aware and turn off equipment when it is not needed is difficult. Time clocks or a method of turning off equipment based on time seems to be an answer. In fact, electromechanical time clocks have been successful but only when there has not been very many of them and there is only limited access to them. Usually time clocks work fine until the first time change, or seasonal change, or when someone is uncomfortable and disables the time clock. Time clocks also have to be set up for worst case conditions that may only happen one day or one week a year.

To alleviate these problems, NCEL has been investigating computer-based devices suitable for single building application that can implement Optimum Start/Stop control strategies. To demonstrate the feasibility of these devices an Intelligent Time Clock (ITC) was developed by contract and reported in Reference 1. Significant problems were experienced in utilizing the ITC but it successfully demonstrated the validity of the Optimum Start/Stop control strategy. Due to the shortcomings and problems of the ITC, a Single Building Controller using standard off-the-shelf components has been developed. The experience gained from the development has been used to improve the Tri-Service EMCS specifications.

SYSTEM DEVELOPMENT

In the late 1970s NCEL developed an energy controller device as part of the Navy's Energy Conservation R&D Program. The device, called an Intelligent Time Clock (ITC) and described in Reference 1, was intended as a cost-effective alternative to conventional time clocks with the added capability of temperature sensing to intelligently decide when to turn equipment on or off. After extensive software debugging, one of two units was operational by April 1980. That unit was installed in Building 560, NCEL to control its steam heating system. During its first 3 weeks of ITC control, natural gas usage by the boiler plant at the NCEL complex decreased an average of 18.6% from the weekly average for the previous 2 months with a conventional time clock.

Despite the energy savings capabilities, the ITC lacked a good man/machine interface. From the experience gained, it was decided to develop another machine to overcome the ITC difficulties. That device, the NCEL Micro Energy Monitoring and Control System (MEMCS), meets the requirements of the recent micro EMCS guide specification and many of the requirements for the small EMCS guide specification. These specifications (Ref 2 and 3) are now available for implementing single building EMCS.

NCEL Requirements

NCEL's physical location near the ocean in Southern California makes heating loads necessary from November until March. The steam heating system at NCEL consists of boilers, distribution piping, space steam radiators, and motorized steam valves.

ITC

Initially, one motorized steam valve controlled by a conventional time clock fed heat to a major portion of Building 560 (Figure 1).* A time clock turned on the steam for a continuous 7 hours per working day.

The ITC was installed in the late 1970s to control the motorized steam valve, resulting in a reduction in natural gas consumption. Laboratory direction in energy conservation has been to use the experience gained from work with the ITC to replace the ITC with a new machine.

ITC major drawbacks were two: (1) lack of a good man/machine interface, and (2) only a single source for hardware/software. The ITC required a person to load information using toggle switches; the method proved to be slow, prone to errors, and frustrating to the individual. It was realized that, ideally, a machine for implementing energy management should be simple and have a friendly man/machine interface.

MEMCS

As a result of the ITC experience, NCEL developed the MEMCS by adapting off-the-shelf hardware, building a new controller for the motorized steam valve, (see Figure 2(a)). Technical details on the MEMCS hardware and software are presented in the Appendix. System configuration is presented in Figure 2(b).

To improve the man/machine interface, the MEMCS uses a cathode-ray-tube screen and a typewriter-like keyboard for an operator to answer simple questions to define the system configuration. MEMCS also uses a menu-type prompt with the system operator being given a set of choices displayed on the screen, and then being able to select among the choices by using a simple keyboard entry. Figure 3 presents a menu example. If a wrong entry is selected by the operator, the MEMCS repeats the possible choices to let the operator know of the error.

In addition to the controller system, steam flow distribution was improved by installation of several branch motorized steam valves. The steam flow controllability was thus enhanced and the energy savings increased by providing steam only to the areas requiring heat.

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*Heat for the rest of the building was not controlled by this motorized steam valve.

SYSTEM FUNCTION

Control Algorithms

Optimized Start/Stop. When a conventional time clock is used to start and stop a heating, ventilating, and air conditioning (HVAC) system, the system operates on a daily fixed schedule, independent of environmental conditions. In contrast, with an optimized start/stop strategy, the HVAC start/stop signal can be adjusted daily, depending on each day's weather condition.

An optimized start/stop algorithm is shown graphically in Figure 4. Parameters are defined in Table 1. To determine optimum start-up time, the controller senses the building heating system capacity and space temperature during a predefined time interval between earliest turn on (ETO) and latest turn on (LTO). If the space temperature is above the upper limit or below the lower limit, the controller turns on the HVAC. To evaluate optimum shutdown time, the controller monitors the outside air (OA), and space temperatures and compares these to or takes into account the building thermal inertia between earliest shut down (ESD) and latest shut down (LSD). The HVAC then is turned off at the earliest possible time.

All the time and temperature setpoints shown in Figure 4 are programmable or easily changed to allow application in diverse environments and situations.

Run Time Mode. From LTO to ESD the controller operates on a dead band mode, where the heating system valve is closed if the space temperatures are above Run H or open if below Run L (see Figure 4). Care must be taken to set the dead band wide enough to prevent frequent cycling of the steam valve.

The optimum start/stop and run time control strategies have been used in the MEMCS successfully. The algorithms developed are translated into a computer program and executed to control the HVAC system.

Energy Savings at NCEL

Maximum energy savings obtained with the optimum start/stop would occur in the spring and fall when climatic conditions are not severe; less savings would be expected during the winter months.

Table 2 shows energy use at NCEL during the cold weather season in three past fiscal years with energy savings devices controlling the heating system. Degree days are also shown. The following information is derived from Table 2:

Using FY80 as a basis for comparison, note:

- cooler temperatures in FY82, except November
- decrease in natural gas consumption during FY81 and FY82

Total MBtu used for heating:

	MBtu	Money Saved*
FY80	9,985	
FY81	9,273	
difference	712	$8,686.40
FY80	9,985	
FY82	8,611	
difference	1,374	$16,762.80
Total		$25,449.20

Natural gas consumption reduction during the total heating season:

Between FY80 and FY81	7.1%	using the ITC instead of conventional time clocks
Between FY81 and FY82	7%	additional savings with the MEMCS
Total	14.1%	savings with intelligent control

DISCUSSION

The MEMCS field installation has been a valuable learning experience, especially since noncomputer-oriented people have been using the device. Modifications have been made in areas where difficulties were encountered. Basically, those modifications have resulted in clearer messages to indicate to the user what to do next.

Further advantages of single-building controllers include:

- Monitors and controls energy 24 hours a day
- Turns equipment off automatically during weekends or holidays
- Is more reliable than mechanical devices
- Will generate hardcopy records of environmental data
- Has battery backup for memory in case of power failure to remember the working setpoints and time of day
- Priced low (estimated cost is $10,000)

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*Based on a cost of $12.20 per MBtu of natural gas.

Several units already designed to perform energy savings are now commercially available; some of these include the control algorithms. In Reference 4 these commercially available units are surveyed. Another purpose of Reference 4 is to aid the EMCS prospective user in the analysis and modification of existing buildings to reduce both fuel consumption and operating cost. Reference 4 is summarized in NCEL Tech Data Sheet 82-02, published in February 1982.

CONCLUSIONS

It has been demonstrated that a single-building EMCS is capable of saving a considerable amount of energy by using the optimum start/stop and the dead band mode strategies instead of a conventional time clock strategy.* Single-building EMCS can now be obtained off-the-shelf which can implement the optimized start/stop strategy. A good man/machine interface using menu prompting or other techniques to simplify use by Public Works employees is necessary to allow non-computer operators to effectively use these systems.

REFERENCES

1. Civil Engineering Laboratory. Technical Note N-1588: EMCS modules/intelligent time clock (ITC), by D. Shiroma. Port Hueneme, Calif., Sep 1980.

2. Federal Construction Guide Specification. FCGS-13950: Micro energy monitoring and control systems. Washington, D.C., Jul 1981.

3. __________. FCGS-13949: Small energy monitoring and control systems. Washington, D.C. Jul 1981.

.. Naval Civil Engineering Laboratory. Contract Report CR 82.028: Controlling energy consumption in single buildings. Atlanta, Ga., Newcomb & Boyd, July 1982. (Contract No. N62583-81-MR-593)

5. Civil Engineering Laboratory. Contract Report No. 79.002: Dead band controls guide, by J. Paoluccio. La Jolla, Calif., Nov 1978.

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*These savings have been demonstrated on one of the most difficult HVAC systems - a steam distribution system with individual radiator controls.

Table 1. Limits Definition List

ETO	Earliest turn on
LTO	Latest turn on
TLI	Temperature low limit initial (on section)
TLF	Temperature low limit final (on section)
THI	Temperature high limit initial (on section)
THF	Temperature high limit final (on section)
ESD	Earliest shut down
LSD	Latest shut down
OLI	Temperature low limit initial (off section)
OLF	Temperature low limit final (off section)
OHI	Temperature high limit initial (off section)
OHF	Temperature high limit final (off section)

Table 2. Natural Gas Consumption During Test Period

Month	Mechanical Time Clock (FY80)		ITC (FY81)		MEMCS (FY82)	
	MBtu[a]	Degree Days[b]	MBtu[a]	Degree Days[b]	MBtu[a]	Degree Days[b]
Nov	1,908	249	633	154	600	209
Dec	2,052	271	1,904	224	1,776	313
Jan	2,158	246	1,498	250	1,767	382
Feb	1,413	203	1,808	206	1,735	229
Mar	1,262	275	1,858	257	1,660	296
Apr	1,192	203	1,572	202	1,073	210
Total	9,985	1,447	9,273	1,293	8,611	1,639

[a] Natural gas.

[b] To determine degree days, the average daily temperature is subtracted from 65°F; then all differences are added together for each month.

Figure 1 Building 560.

Figure 2a. Photo of MEMCS.

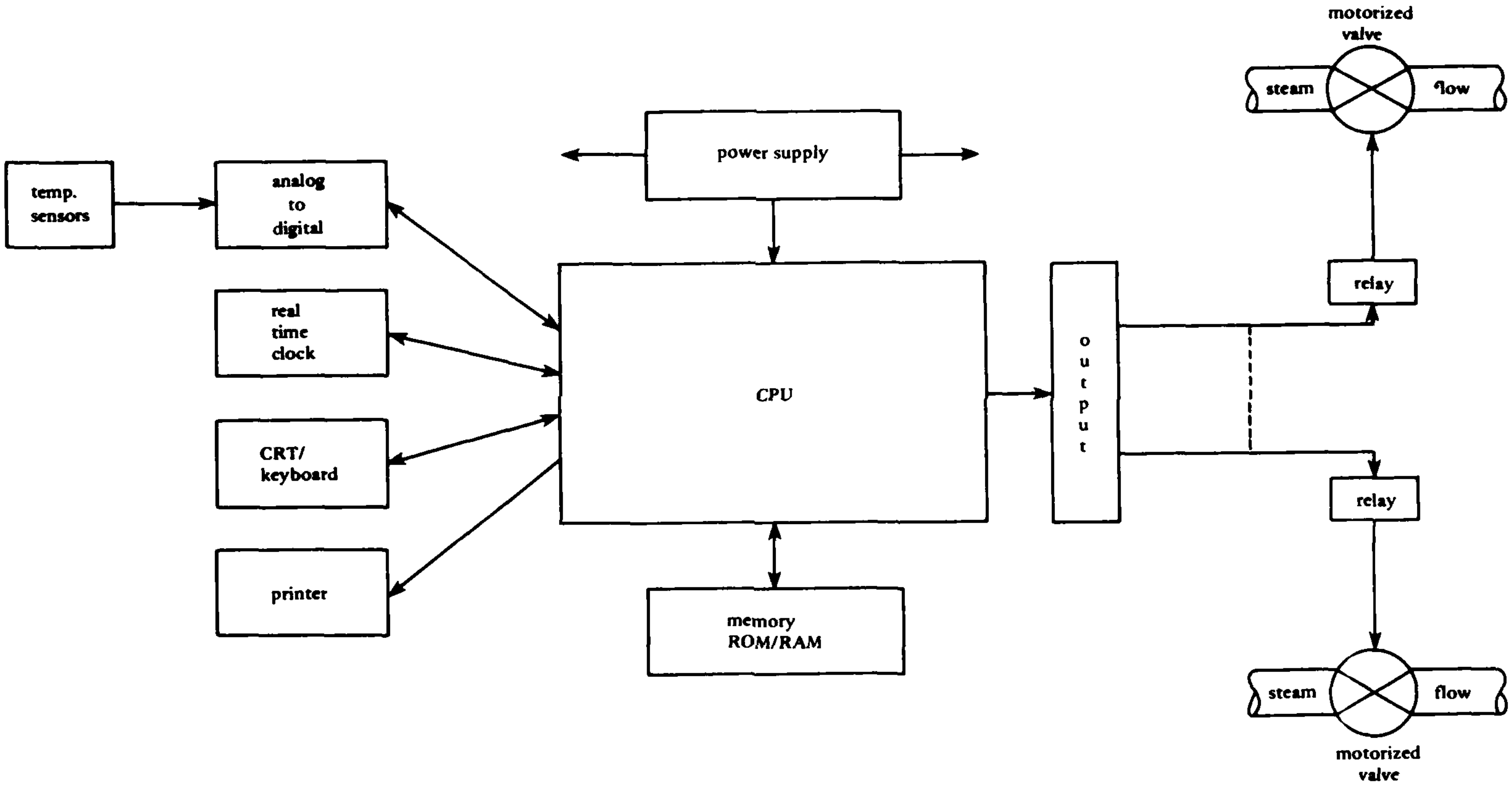
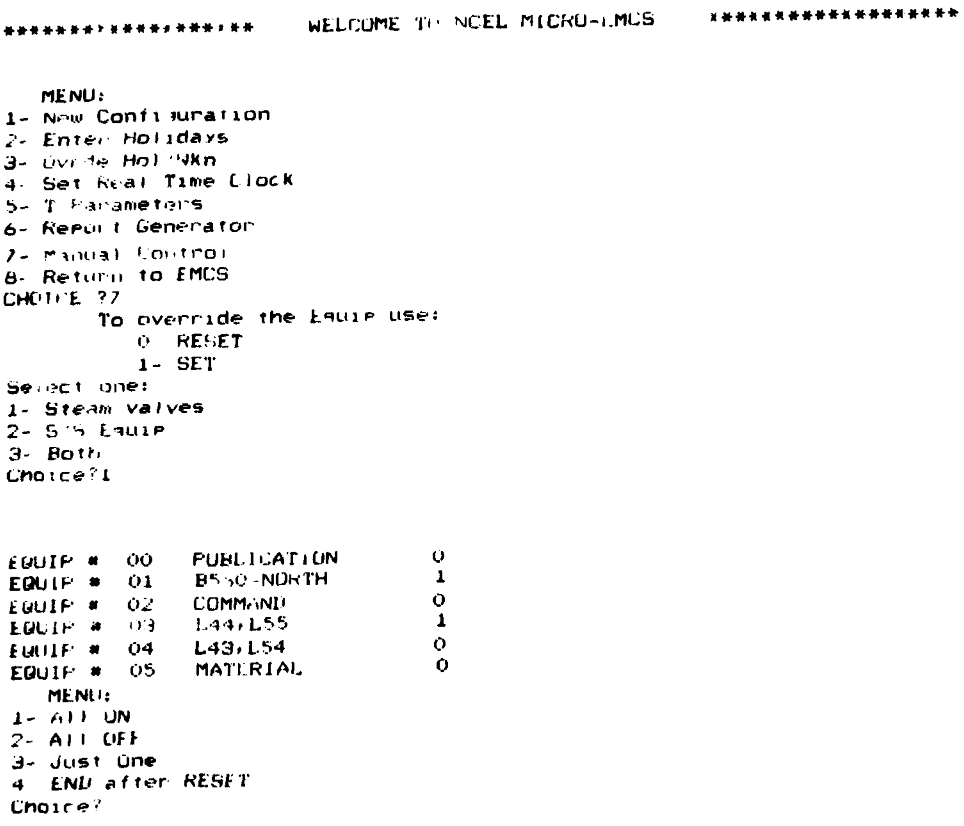


Figure 2b. System configuration.



```
********************     WELCOME TO NCEL MICRO-EMCS     ********************

   MENU:
1- New Configuration
2- Enter Holidays
3- Ovride Hol/Wkn
4- Set Real Time Clock
5- T Parameters
6- Report Generator
7- Manual Control
8- Return to EMCS
CHOICE ?7
        To override the Equip use:
            0  RESET
            1- SET
Select one:
1- Steam valves
2- S/S Equip
3- Both
Choice?1


EQUIP #  00   PUBLICATION       0
EQUIP #  01   B550-NORTH        1
EQUIP #  02   COMMAND           0
EQUIP #  03   L44,L55           1
EQUIP #  04   L43,L54           0
EQUIP #  05   MATERIAL          0
   MENU:
1- All ON
2- All OFF
3- Just One
4  END after RESET
Choice?
```

Figure 3. Menu example.

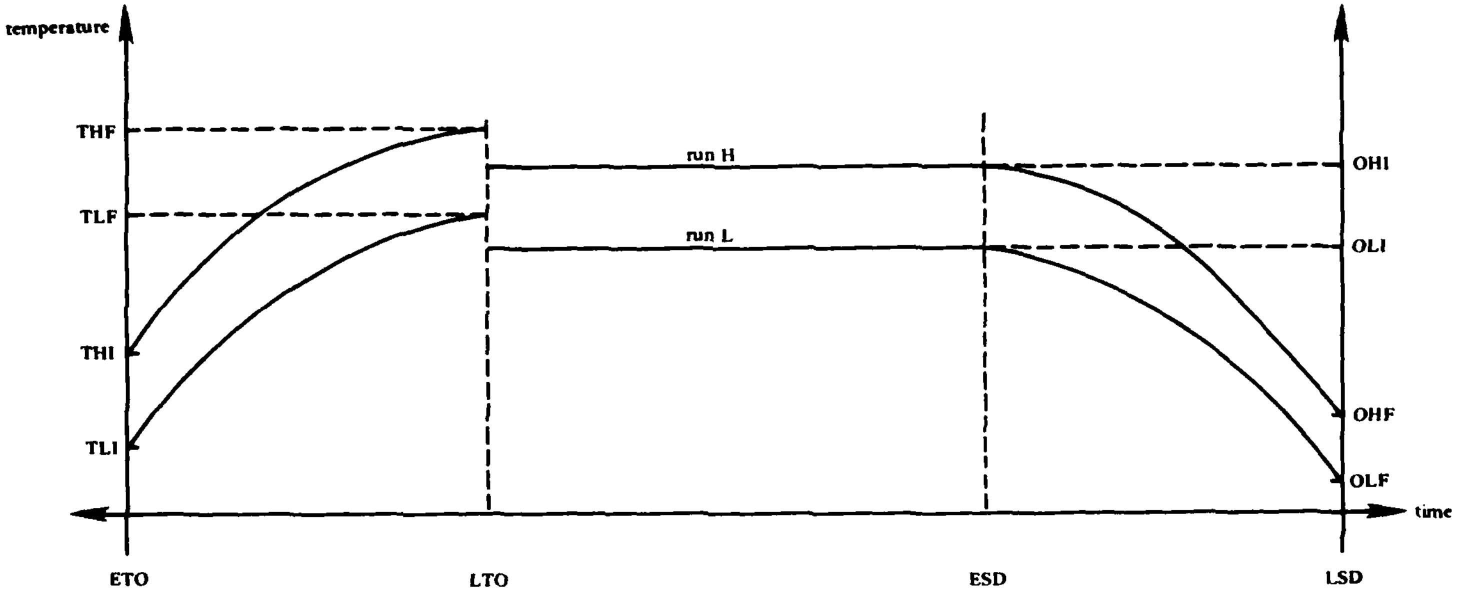


Figure 4. Sliding start/stop graphical representation.

Appendix

MEMCS HARDWARE AND SOFTWARE

HARDWARE (see Figure 2b)

Central Processing Unit (CPU)

The CPU is a single-board computer made by INTEL Corp., Model No. ISBC 80/10B, featuring:

- MULTIBUS compatible IEEE-796
- Up to 4K bytes onboard RAM (random access memory)
- Up to 16K bytes onboard ROM (read only memory)
- One serial input/output (I/O) port RS-232C standard
- Six programmable 8-bit I/O ports
- Direct addressing up to 64K bytes of memory
- One multimodule connector (ISBX bus)

One reason the INTEL Single Board Computer products were selected is that a development system purchased by NCEL several years ago could be used to write the EMCS control algorithms in assembly language, which could then be converted to machine language and programmed into EPROMS (erasable PROM) by the NCEL development system.

Multimodule boards are special-purpose, add-on circuit boards that reside on the component side of the ISBC 80/10B board and are interfaced through the multimodule connector (ISBX bus). The multimodule board used is the ISBX 331 Fixed/Floating Point Math Multimodule Board, which performs fairly high-speed mathematic functions. It can accept data and commands from an ISBC microprocessor and performs a repertoire of 43 floating point/fixed point commands faster than is possible through conventional programming routines. This board contains an 8231 Arithmetic Processing Unit (APU). Some of the operations that can be performed are:

- Square root, logarithm, and exponential functions
- Add, subtract, multiply, and divide functions
- Trigonometric and inverse trigonometric functions
- Floating-to-fixed or fixed-to-floating conversions

Exponentation, multiplication, and division functions are mainly used in the control algorithms.

Memory Boards

4K Bytes of CMOS RAM for MULTIBUS. This RAM board, model no. ISBC 094, has an onboard rechargeable battery which supplies power in case of a power failure. The time variant parameters are stored in this board; therefore, a battery backup system conveniently maintains those setpoints and protects the system against a power failure. The memory is protected for up to 96 hours after power is removed.

16/32/64K Bytes of ROM for MULTIBUS. This ROM board has variable storage capacity, depending on the type of ROM used.

ROM	Capacity (K bytes)
2758	16
2716	32
2732	64

Thus, system software can be expanded in the future if it is required to do so.

ROM, a nonvolatile memory device, does not require battery backup. In this board the main MEMCS control algorithms are stored.

Analog to Digital Board

This board, National Semiconductor Model No. BLC 711, has 32 single-ended input channels with an analog-to-digital conversion rate of 50 kHz. Its main function is to scan all the temperature transducers and convert each of them into a digital word. It is also compatible with the INTEL MULTIBUS.

Real Time Clock (RTC) Board

This board, a self-supporting timekeeper designed to operate in an I/O slot of the INTEL MULTIBUS, can provide: seconds, minute, hour, day, month, and year by interrogating the appropriate port. This board, Model No. TCU-410 by Digital Pathway, is also battery-backed for 3 months since the current time/date must be power failure proof.

For the machine-to-outside-world interface, an optically isolated digital I/O board made by DATEC under the 80001-3001 model number, with capacity for 32 channels of input/output, was used. The logic supports a full bi-directional circuit. Optical coupling of each channel enables external circuits, which exhibit different common mode voltages (up to 600 volts), to be directly connected to the system without interchannel operational interference due to ground loops, damage to hardware, or performance.

This I/O board is memory-mapped into the system so that it can be treated as four continuous memory locations.

Power Supply and System Chassis

The previously mentioned boards require regulated DC voltage at +12, -12, +5, and -5 volt levels and were met by using the ISBC 640 Power Supply. The supply provides sufficient power for a fully loaded INTEL Single-Board Computer and up to 11 other expansion modules such as memory, I/O, or disc control.

All outputs have current limiting and overvoltage protection capabilities. Special logic allows sensing for power failure and generates a TTL (transistor-transistor-logic) level signal for orderly system power-down control. The DC output power is accessible on keyed connectors that mate directly with the ISBC 604/614 Cardcage Assemblies.

SYSTEM SOFTWARE

Monitor (Modified)

The Monitor is used as the basic block for more complex subroutines, such as making inputs or outputs from or to the console. The monitor was modified so that after initializing the UART (universal asynchronous receiver transmitter), a specific location in memory is examined to determine if this is the first program execution. If it is, then the setpoints and all other information required to run the main program will be prompted. In a warm start, such as after a power failure, the initialization session is bypassed and program execution is started automatically because the necessary information is contained in battery backed memory boards.

Application Programs

The following application programs are used to control the HVAC.

Optimized Start/Stop. This program automatically adjusts the start/stop signal for the HVAC equipment in accordance with indoor temperatures, heating system capacity, building thermal inertia, and outside air (OA). By using the optimized start/stop the HVAC saves energy by being turned on/off when it is really necessary, not just on a schedule of a time clock. A graphical illustration of an optimized start/stop control strategy is presented in Figure 4.

Basically the program starts as soon as ETO is reached as long as it is a working day (not a holiday or a weekend).

Between ETO and LTO the inside/outside temperatures are compared with a continuous function such as an exponential. Depending on the heating system capacity, the program determines an optimum start time to warm up or cool down the working spaces to a predetermined setpoint.

Between ESD and LSD the program also looks at inside/outside temperatures and, depending on the building thermal inertial, it determines a convenient stop time before the close of working time (COW). The stop time can be before the COW time because the building retains warmth or coolness for several hours.

Run Time Mode Program. This program runs from the time the equipment is turned on until it is turned off. The controller operates as a dead band temperature controller (see Reference 5), maintaining the building temperature within a temperature band set by Run H and Run L (see Figure 4).

System Programs

Menu. With this program the user inputs:

- temperature setpoints
- time-related parameters
- controller configuration
- holidays
- setting of the real time clock (RTC)
- requests for a hardcopy record of temperature sensors
- requests for manual control of the system

Temperature setpoints are those used in the optimized start/stop algorithm (see Figure 4).

The time-related parameters used in the optimized start/stop are: ETO, LTO, ESD, and LSD (see Table 1 for definitions).

The controller configuration includes:

- Entering how many motorized steam valves to be controlled
- Assigning names to each of the areas served by each steam valve
- Assigning four temperature sensors for each motorized steam valve to monitor the representative area served by that valve
- Assigning weighting factors for each of the four temperature sensors for calculating an average total temperature

$$\text{Average Total Temperature} = \frac{W_1 T_1 + W_2 T_2 + W_3 T_3 + W_4 T_4}{W_1 + W_2 + W_3 + W_4}$$

where W_{1-4} are weighting factors

T_{1-4} are temperature sensors

A larger weighting factor can be assigned when the particular temperature sensor monitors a larger area. Also, a null factor can be assigned in case of a temperature sensor failure.

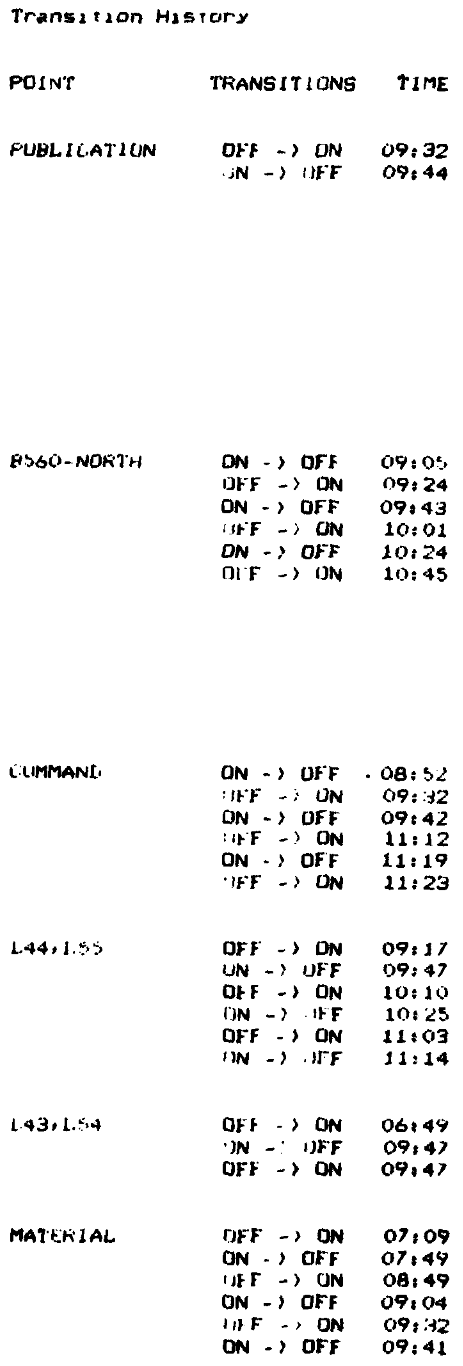
Holiday input is used to load up to 10 holidays in memory in advance. The controller enters a holiday mode when a match occurs between the present date and a holiday stored in memory. During the holiday mode, no heat is supplied for 24 hours.

When initializing the RTC, the correct time and date is loaded into the RTC board and the day of the week stored in memory. The memory and RTC are battery-backed to preserve that information in case of a power failure.

The hardcopy record of temperature sensors is a convenient way to verify the correct operation of the controller. The six last transitions of each steam valve and times of occurrence are also printed (see Figure A-1 for example printout).

When manually controlling the system, the operator can override each steam valve to an on or off state. This feature proved handy when Public Works needed to work on the heating system.

All inputs are done on the typewriter-like keyboard. The menu-type prompts have allowed noncomputer people to operate the machine successfully. Figures A-2 through A-8 are basic flow charts and also describe the MEMCS software.



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Transition History

POINT             TRANSITIONS   TIME

PUBLICATION        OFF -> ON    09:32
                   ON -> OFF    09:44




8560-NORTH         ON -> OFF    09:05
                   OFF -> ON    09:24
                   ON -> OFF    09:43
                   OFF -> ON    10:01
                   ON -> OFF    10:24
                   OFF -> ON    10:45




COMMAND            ON -> OFF    08:52
                   OFF -> ON    09:32
                   ON -> OFF    09:42
                   OFF -> ON    11:12
                   ON -> OFF    11:19
                   OFF -> ON    11:23

L44,L55            OFF -> ON    09:17
                   ON -> OFF    09:47
                   OFF -> ON    10:10
                   ON -> OFF    10:25
                   OFF -> ON    11:03
                   ON -> OFF    11:14

L43,L54            OFF -> ON    06:49
                   ON -> OFF    09:47
                   OFF -> ON    09:47

MATERIAL           OFF -> ON    07:09
                   ON -> OFF    07:49
                   OFF -> ON    08:49
                   ON -> OFF    09:04
                   OFF -> ON    09:32
                   ON -> OFF    09:41
```

Figure A-1. Sample printout of transition history at NCEL.

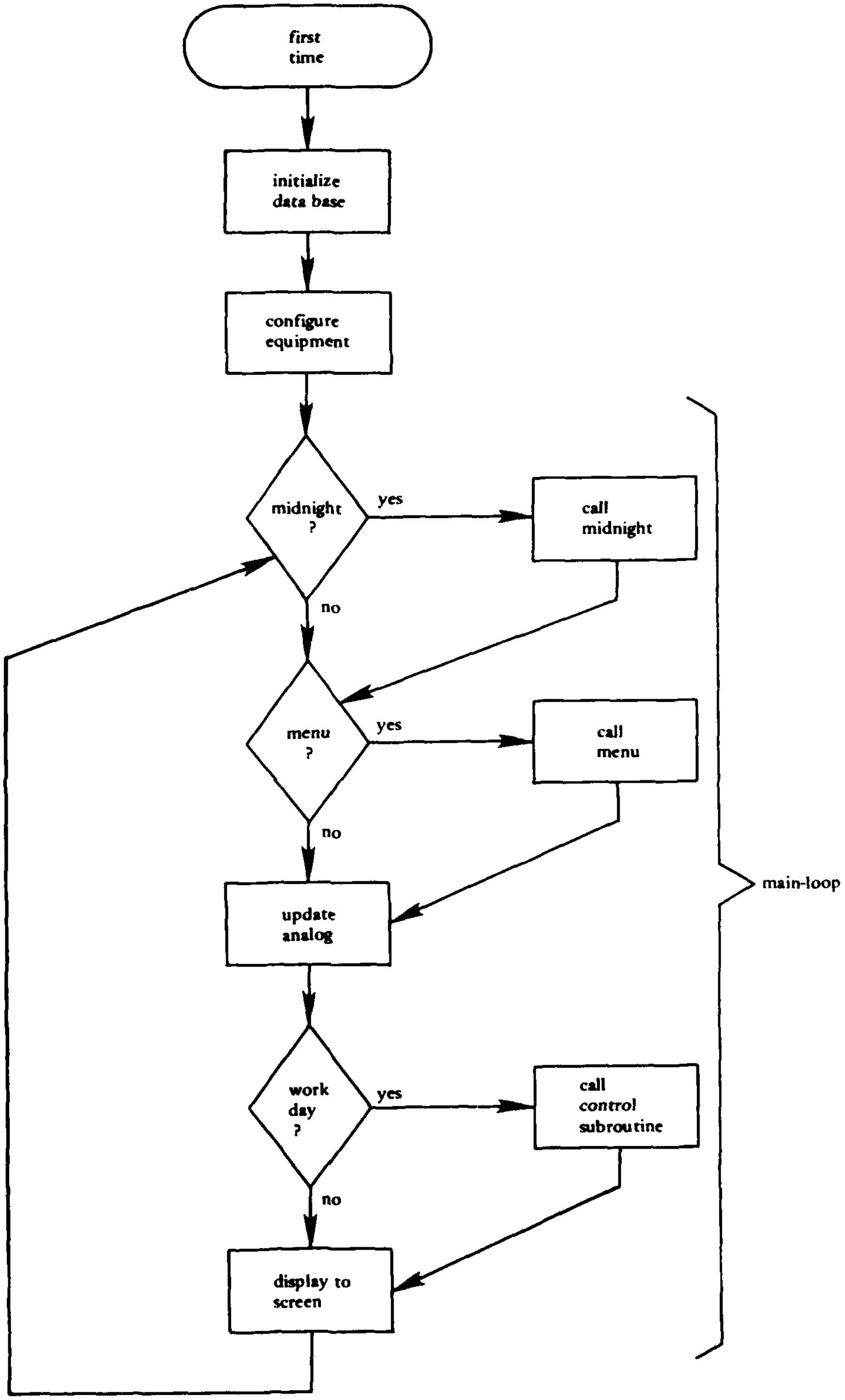


Figure A-2. MAIN-LOOP where all main routines are stored.

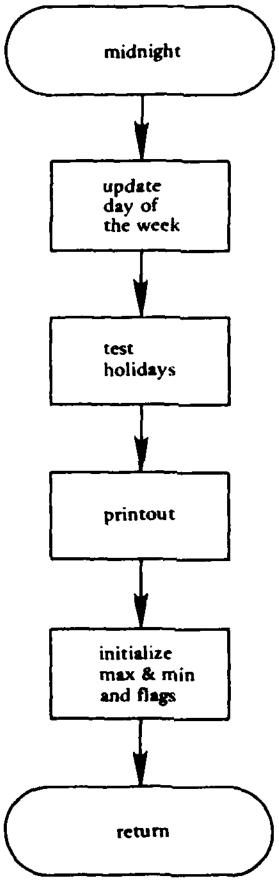


Figure A-3. Midnight routine executed at 00:00:00 hour to update, print out information, and reinitialize variables.

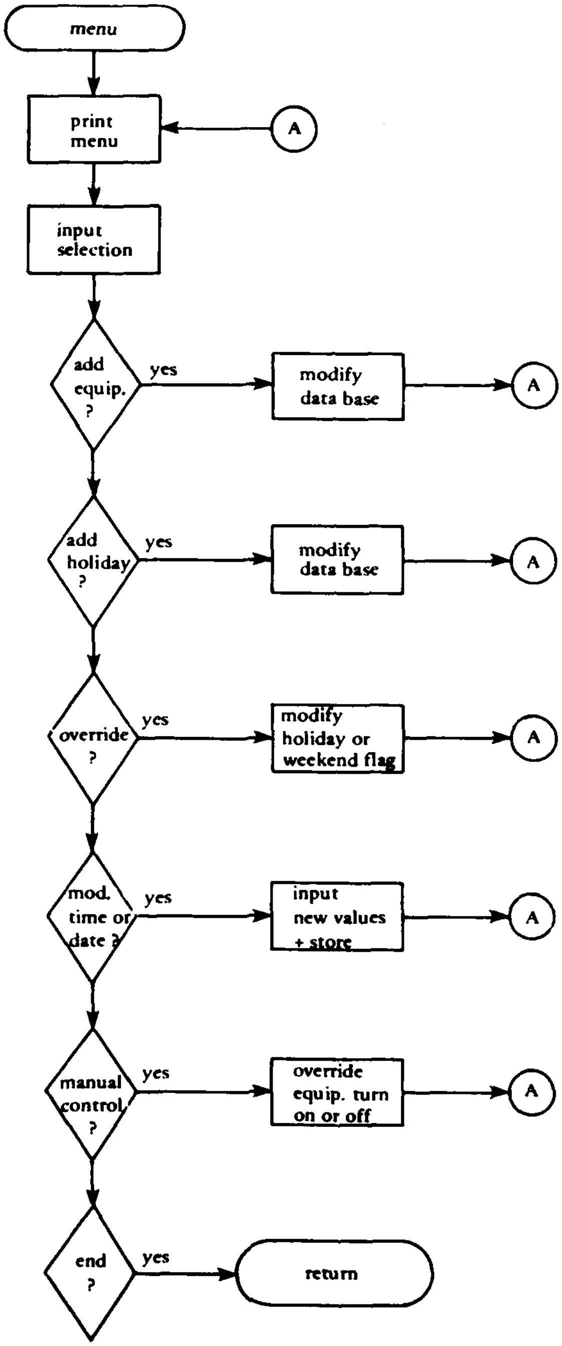


Figure A-4. Menu routine to modify the program flow, depending on user selection to the prompt.

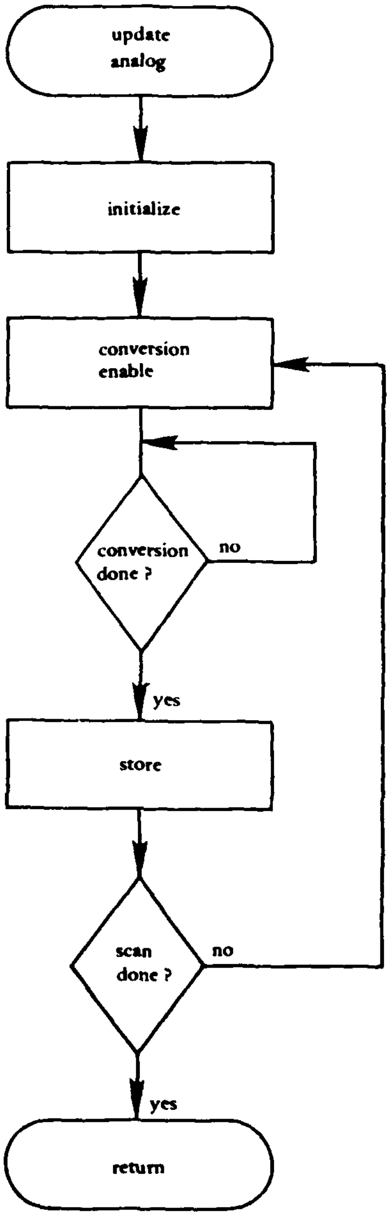


Figure A-5. Routine to drive the A/D board to perform the analog conversions.

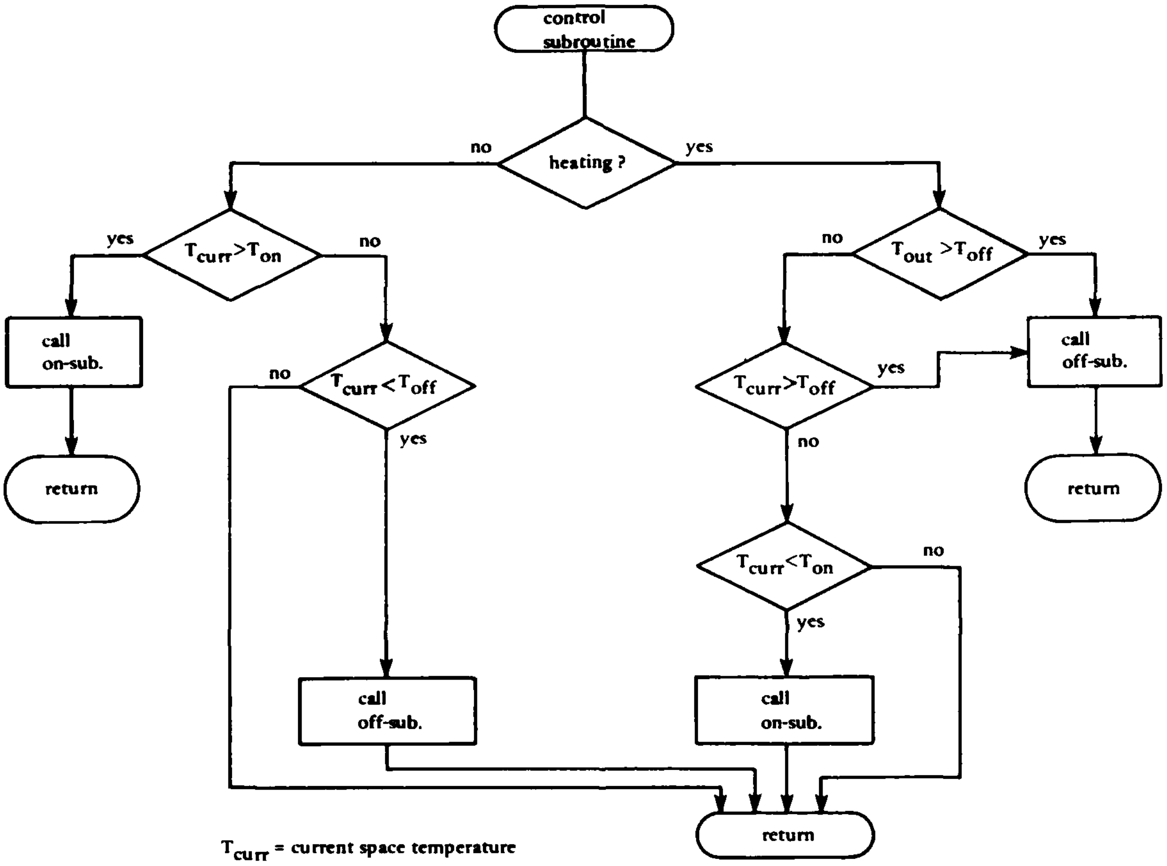


Figure A-6. Routine to compare space temperature with the stored limits and to open or close the equipment relays.

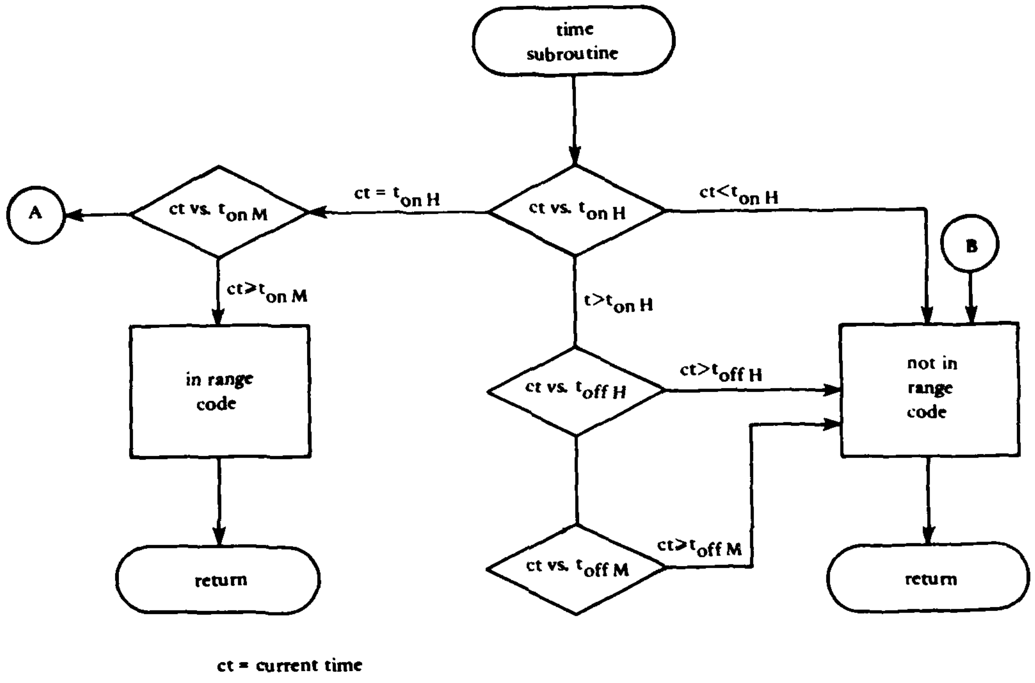
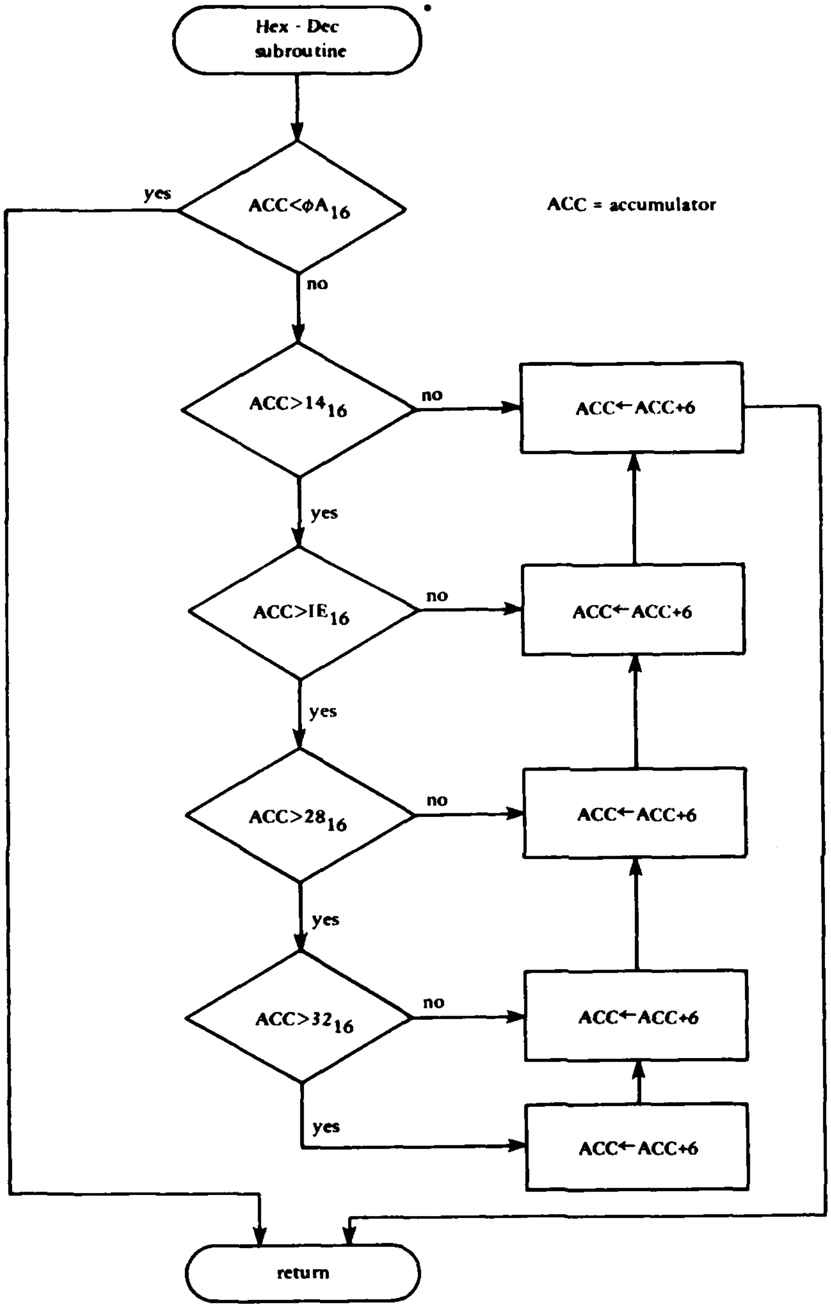


Figure A-7. Routines to compare the current time from the RTC with the timing parameters and return a code, depending on the time limits.



Range:

Hex		Dec
00	→	00
3B	→	59

Figure A-8. Routine to convert time clock information from Hex to Dec.

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