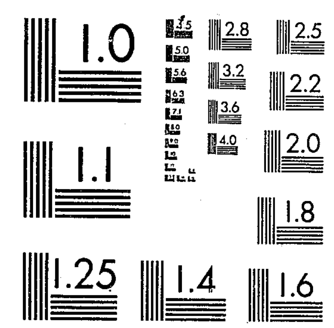

MICROCOPY RESOLUTION TEST CHART
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Energy Conservation Opportunities

Prince Georges County Detention Center

at

Upper Marlboro, Maryland

Prepared for
Law Enforcement Assistance Administration
U.S. Department of Justice
Washington, D.C. 20531

Prepared by
Unified Industries Incorporated
6551 Loisdale Court
Springfield, Virginia 22150

and

JRB Associates, Incorporated
8400 Westpark Drive
McLean, Virginia 22102

August 21, 1981

This project was supported by Contract Number J-LEAA-016-80 awarded by the Law Enforcement Assistance Administration, U.S. Department of Justice, under the Omnibus Crime Control and Safe Streets Act of 1968, as amended. Points of view or opinions stated in this document are those of the author(s) and do not necessarily represent the official position or policies of the U.S. Department of Justice.

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1. INTRODUCTION AND GENERAL BACKGROUND INFORMATION

1.1 BACKGROUND

The Law Enforcement Assistance Administration (LEAA) national program for improved energy conservation in correctional facilities has three major objectives. These are:

- o To demonstrate that there are cost-effective, readily available energy conservation strategies that are particularly effective in a correctional environment.
- o To develop and disseminate accurate energy conservation information to corrections personnel.
- o To provide guidance and technical assistance in developing and implementing an energy conservation program for various types of correctional facilities.

To meet these objectives and to initiate allied energy conservation programs, LEAA sought the services of Unified Industries Incorporated (UII) and JRB Associates (JRB). The coordinated effort by these two firms has provided several areas of emphasis in this project. They are onsite energy conservation surveys of two maximum security prisons, two medium security prisons, and three jails at locations selected by LEAA; preparation of an energy conservation handbook as a guide to facility management and engineering personnel; and the conduct of four regional energy conservation workshops for facility management and engineering personnel at sites selected by LEAA. This report deals with the energy conservation survey conducted October 31 and November 5 and 7, 1980, at the Prince Georges County Detention Center, located at the intersection of Pratt and Douglass Streets, Upper Marlboro, Maryland.

The site survey involved investigation into several areas of potential energy conservation, including, but not limited to, the following:

- o HVAC system analysis for enthalpy control and temperature setbacks

- o Equipment shutdown during periods of non-use
- o Electrical demand-limiting methods
- o Analysis of lighting systems
- o Electric power factor correction
- o Heat recovery for water heating systems
- o Evaluation of the building envelope for reduced heat loss and infiltration

1.2 CONTENTS OF THE REPORT

The purpose of this report is twofold. It will detail the findings of the energy conservation survey at Prince Georges County Detention Center and make recommendations concerning measures which can be taken to reduce consumption. These measures are presented in section 3, Retrofit Options. Also, the potential cost savings associated with each option are presented to aid Prince Georges County in selecting the most cost-effective techniques for reduction of energy use.

1.3 GENERAL FACILITY DESCRIPTION

Prince Georges County Detention Center is a jail, which utilizes 26.8 percent of its 56,000 square feet of floor space to house approximately 550 inmates. This space was originally designed to accommodate 140 inmates. The physical facility consists of three structures, all interconnected to form one three-story building. The three structures, ranging from the smallest to the largest, were built in 1894, 1928, and 1976, respectively. The newest and largest structure (referred to in this report as the new jail) houses the staff administrative offices, male receiving and discharge unit, several male cell blocks, kitchen, dining area, gymnasium and mechanical services. The next largest structure (referred to in this report as the old jail) houses the female receiving and discharge unit, female cell blocks and large holding areas for male inmates who have been sentenced. The smallest structure (referred to as the S.P. barracks) houses the staff support services section.

Surrounding the facility is a security fence which also encloses a small exercise yard. Although the facility is occupied 24 hours a day, 7 days a week, there are areas of the building which are utilized only a portion of the time, generally during daylight hours. The occupancy pattern of these areas will be addressed in the section on retrofit options.

1.4 GENERAL SURVEY INFORMATION

An onsite energy conservation survey was conducted at Prince Georges County Detention Center on October 31 and November 5 and 7, 1980, by Messrs. M. Katz, P. Wilson and D. Gray of JRB, J. Conmy and J. Beeman of UII, and D. Graves of LEAA. The daily weather conditions remained fairly constant during the period of the survey and were also typical of the area for this time of the year. The temperatures ranged from 40° F to 65° F and the relative humidity from 50 percent to 95 percent. There were scattered clouds every day. All of the energy systems were in operation at some time during the visit.

The information obtained during the course of the survey included, but was not limited to, the following:

- o Reviewing the as-built plans for the heating and ventilating systems
- o Obtaining the energy use and cost history
- o Measuring energy consumption of pumps, fans, and other equipment
- o Determining operating times for equipment
- o Reviewing the operation and relevant schedules of the facility
- o Measuring space temperatures
- o Evaluating the energy equipment control systems
- o Measuring lighting levels and counting lamps
- o Studying the operation of the central power plant

- o Testing the facility steam distribution system for leaks and/or malfunctioning steam traps
- o Assessing the electrical demand-limiting methods.

In addition, the total cooperation that the survey team received from the staff at Prince Georges County Detention Center was greatly appreciated. Much of the information contained in this report would not have been possible to collect without the aid of the support services staff. To expedite the process of locating and examining the HVAC equipment, the maintenance team accompanied the survey team at all times and participated in several meetings, providing critical information on the operation of the jail energy systems.

2. SUMMARY OF RECOMMENDED RETROFIT PROJECTS

Option	Description	Annual Energy Savings	Annual Cost Savings	Capital Cost	Payback Period (Yrs.)
1	Replace incandescent lights (shower)	2,321 kWH	$ 137	$ 625	4.6
2	Insulate steam and condensate return lines	70.2 MBtu	$ 531	$ 171	0.32
3	Weatherstrip outside door	1.65 MBtu	$ 12	$ 36	3.3
4	Use energy-conserving fluorescent lamps		See associated table		
5	Install storm windows	16.7 MBtu	$ 176	$ 490, $ 2,303	2.8, 13.1
6	Replace mercury vapor lamps	2,100 kWh	$ 124	$ 1,750	14
7	Chilled water control system	3,548 MBtu	$ 1,674	$ 4,800	2.9
8	Install time clock controls, heat pump	9,642 kWh, 175 MBtu	$ 3,514	$ 5,182	1.5
9	Install Outdoor Temp. Reset Device, Heating H.W. Boilers	322 MBtu	$ 2,438	$ 2,340	0.96
10	Install enthalpy controls, increase AHU capacity	47,810 kWh	$ 2,821	$58,921	21
11	Replace incandescent with fluorescent lighting	29,346 kWh 26,411 kWh	$ 1,731 $ 1,558	$1,206, $6,700, $3,350	0.7 4.3 2.2

3. RETROFIT OPTIONS

3.1 OPTION 1 - REPLACE INCANDESCENT SHOWER LIGHTS

Fluorescent lamps provide levels of lighting equivalent to incandescent bulbs, with 20 percent of the power used by incandescents. The survey team found three 100-watt and two 60-watt incandescent fixtures in the shower area. These should be replaced with vandal-proof and vapor-tight fluorescent fixtures, using 39 watts and 13 watts respectively.

Energy Savings	o Fixtures	Incandescent Wattage	Fluorescent Wattage	Operation (1000 hr.)	Energy Saved (kWh/Yr.)
	3	100	39	8.76	1,603
	2	60	19	8.76	718
				Total	2,321

Energy Cost Savings: 2,321 kWh/yr. x $0.059/kWh

= $137/yr

Capital Cost: 5 fixtures x $125/fixture

= $625

Payback Period: $625 ÷ $137/yr

= 4.6 yr.

OPTION 2 - INSULATE STEAM LINES AND CONDENSATE RETURN LINES

Insulation of steam system lines, especially in unheated areas, can save large amounts of energy in a steam distribution system. The survey team found 15 feet of 3-inch steam line, 15 feet of 1-inch steam line, 10 feet of 1½-inch condensate line and 30 feet of 1-inch condensate line exposed. The addition of 1-inch insulation to all exposed lines will achieve significant reduction in heat losses.

Energy Savings:

o Type	Pipe Diameter	Average Loss Rate (Btu/hr/ft.)	Steam Line Operation (hrs/yr)	Pipe Length	Annual Losses (10^6 Btu/yr)
Steam	3 inches	422	3780	15 ft	23.9
Steam	1 inch	160	3780	15 ft	9.1
Condensate	1½ inches	150	3780	10 ft	5.7
Condensate	1 inch	100	3780	30 ft	11.3
				Total	50.0

Annual Energy Savings: 50 x 10^6 Btu/yr x 85% reduction ÷ 60.5%

= 70.2 x 10^6 Btu/yr

Energy Cost Savings: 70.2 x 10^6 Btu/yr x \$7.57/10^6 Btu

= \$531/yr

Capital Costs

Pipe Diameter	Unit Insulation Cost (\$/ft)	Pipe Length (ft)	Insulation Costs
1 inch	2.20	45	\$ 99.00
3 inches	3.10	15	\$ 47.00
1½ inch	2.50	10	\$ 25.00
			\$171.00

Payback Period: \$171 ÷ \$531/yr

= 0.32 yr

OPTION 3 - WEATHERSTRIP OUTSIDE DOOR

Weatherstripping is used to block infiltration of cold air around doors and windows. The survey team reported inadequate weatherstripping of the front door (3 feet by 7 feet) which allowed air to infiltrate through the 1/8-inch by 20-feet perimeter door crack. It is recommended that the perimeter of the front door be weatherstripped to save energy used to heat incoming outside air.

Energy Savings: o Air infiltration = 27 cf/hr/ft @ 10 mile average wind speed, 1/8 inch crack width

4,700 hrs/yr x 27 cf/ft/hr x 20 linear feet x .018 Btu cf°/F x (70° F - 44° F) ÷ 0.72

= 1.65 x 10^6 Btu/yr

Energy Cost Savings: 1.65 x 10^6 Btu/yr x \$7.57/10^6 Btu = \$12/yr

Capital Costs: 20 ft weatherstripping @ \$1.80/ft installed = \$36

Payback Period: \$36 ÷ \$11/yr = 3.3 yr

OPTION 4 - USE ENERGY-CONSERVING FLUORESCENT LAMPS

Replacement of existing 40-W fluorescent lamps with now commercially available high-efficiency lamps rated at 35 watts can save 7 kWh per 1,000 hours of operation. (Including ballast requirements, the lamps draw 46 watts and 39 watts of power respectively.) The survey team identified 370 40-W lamps in full-time use (8,760 hrs/yr) and 340 lamps in part-time use. Replacement of lamps in full-time use only achieves a payback of 1.7 years. Replacement of all lamps results in a somewhat longer payback of 2.3 years.

Energy and Cost Savings For Energy-Conserving Fluorescent Lamps

Building	Lamp Type	No. of Lamps	Annual Hours of Operation	Energy Savings Per Lamp (Watts)	Total Energy Savings (kWh)	Cost Savings (@ $0.059/kWh)
New	F40LW/RS	370	8760	7	22688	$1339
New	F40LW/RS	166	4380	7	5090	300
New	F40LW/RS	88	2500	7	1540	91
New	F40LW/RS	86	3650	7	2197	130
Old	F40LW/RS	64	8760	7	3924	232
Old	F96T12/LW	8	8760	15	1051	62

Capital Cost		Payback Period (Years)		
Burnout Replacement	Group Relamp	Burnout Replacement	Group Relamp	Lamp Life (Years)
$300	$1480	0.22	1.1	3
134	664	0.45	2.2	5
71	352	0.78	3.9	8
70	344	0.54	2.6	5
52	256	0.22	1.1	1.4
3	44	0.05	0.7	1.4

OPTION 5 - INSTALL STORM WINDOWS

Installation of storm windows will reduce heat losses through single-glazed windows. The survey team identified 49 windows that could be retrofitted with storm windows. If the trustees build and install storm windows, it is imperative that the windows be caulked and weatherstripped to obtain optimum insulating characteristics. Presently, there are several of these windows in place but each is in need of additional sealing.

Energy Savings

Orientation	Unit Energy* Loss Reduction (Btu/ Square Foot/Yr)	Window Area (Square Feet)	Energy Savings (10^6 Btu/Yr)
North	37000	152	5.6
East/West	29000	348	10.1
South	27000	36	1.0
		Total	16.7

* 4650 HDD

Raw Source Energy Savings (72% boiler efficiency)

$= 16.7 \times 10^6$ Btu/yr $\div$ 0.72

$= 23.2 \times 10^6$ Btu/yr

Energy Cost Savings: 23.2×10^6 Btu/yr x $7.57/$10^6$ Btu

= $176/yr

Capital Cost*: 49 windows x $47/window = $2,303

Payback Period: $2303 ÷ $176/yr = 13.1 yr*

*Note: If polyurethane/scrapwood storm windows can be made and installed by detention center trustees for approximately $10 each (49 x $10 = $490) (as indicated by Officer Selby), the payback period would be 2.8 years.

OPTION 6 - REPLACE MERCURY VAPOR LAMPS

High-pressure sodium lamps operate at approximately 50 percent of power required by mercury vapor lamps. The survey team found seven outdoor mercury vapor lamps that could be replaced. These lamps are rated at 125 W and use 205 W, including ballast requirements. High-pressure sodium lamp replacements would be rated at 100 W and use 130 W operating power.

Energy Savings	o 7 lamps x (205 W - 130 W) x 4,000 hr/yr
	= 2,100 kWh/yr
Energy Cost Savings	2,100 kWh/yr x $0.059/kWh
	= $124/yr
Capital Costs	7 fixtures @ $250/fixture = $1,750
Payback Period	$1,750 ÷ $124/yr
	= 14 yr

OPTION 7 - CHILLED WATER CONTROL SYSTEM

Chilled water for the new addition is supplied from two 80-ton Westinghouse centrifugal chillers. The chilled water season is from May 15 to October 15 as stated by operating personnel. A cooling tower is located on the low roof for the chillers. The chillers are located in the penthouse mechanical equipment room.

The chillers currently operate from a discharge temperature controller which operates the inlet vane unloaders for chiller operation. Discharge water temperature is set for 44° F; return water temperature is 56° F.

To gain energy savings, we recommend optimizing the chillers with a chilled water reset system which measures the load requirements through a return water sensor and automatically resets discharge water temperature from the chiller to satisfy load requirements.

Energy Savings	o <u>Annual chiller operating energy calculation</u>:
	160 tons x .5 x 12,000 Btu/ton x 22 weeks x 168 hours/week
	= 3548 x 10^6 Btu/yr
	o <u>Annual savings using chiller optimization</u>:
	3548 x 10^6 Btu x 4° F average reset x .02/° F reset
	= 284 x 10^6/Btu/yr (28,385 kWh/yr)
Energy Cost Savings	160 tons x 0.5 x 1.2 kW/ton x 22 weeks/yr x 168 hours/week x 8%
	x $0.059/kWh
	= $1,674
Capital Cost	Chilled Water Reset System
	$2,400 x 2 sets = $4,800 total cost
Payback Period	$4,800 ÷ 1,674/yr
	= 2.9 yr

OPTION 8 - INSTALL TIME CLOCK CONTROLS AND HEAT PUMP

Time clocks to control HVAC operation when spaces are unoccupied save energy to move supply and return air and to heat/cool ventilation air. Figure 8-1 indicates the control sequence for the time clock controller for HVAC unit No. 1. Since HVAC unit No. 1 supplies the records section, a 24-hour operation, separate heating/cooling equipment is required when the main HVAC unit is shut down. The installation of a heat pump will provide the necessary heating and cooling during off hours for the remainder of the administration area.

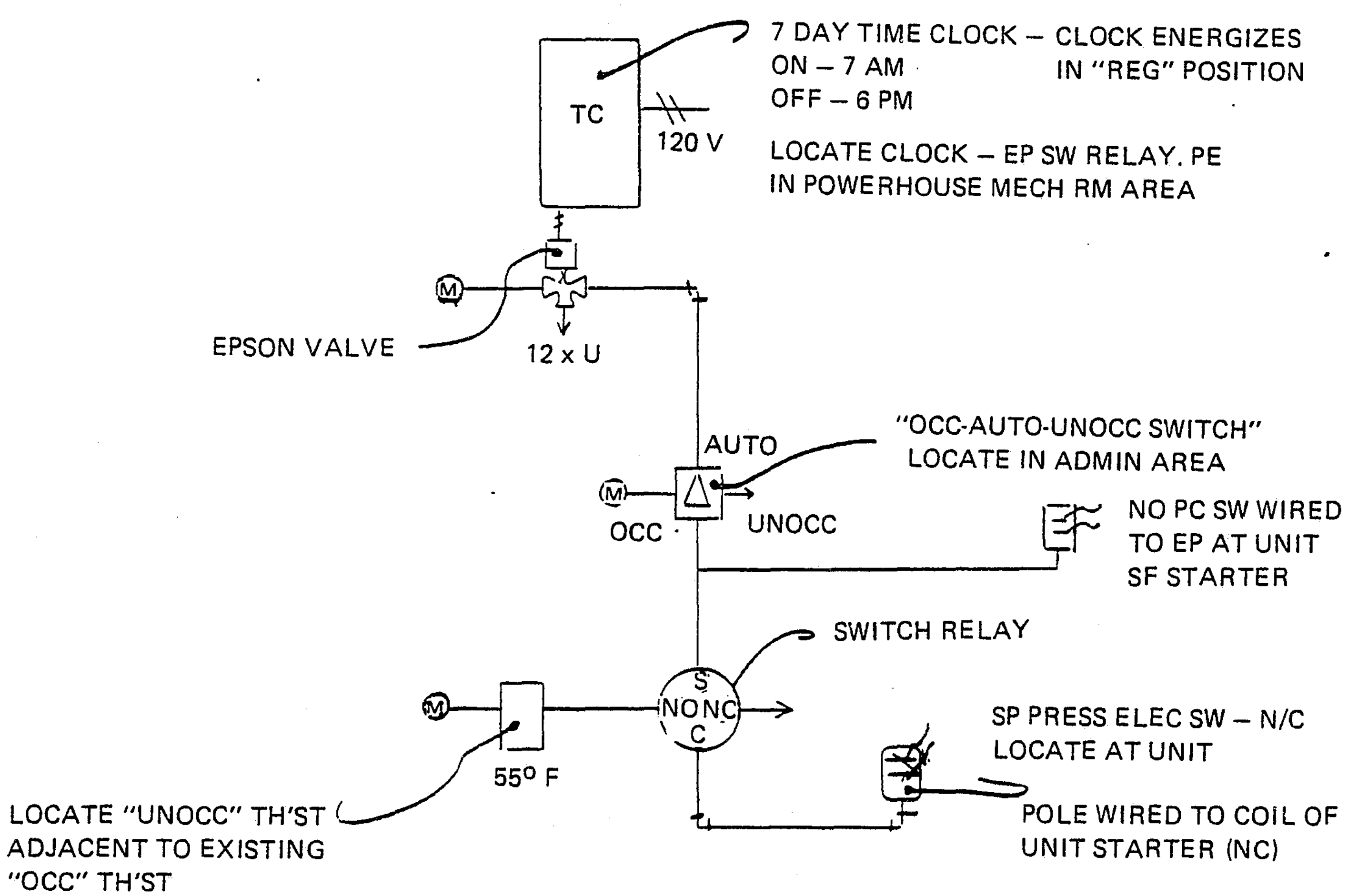


Figure 8-1. Time Clock Control HVAC Unit No. 1

Sequence of Operation:

A 7-day time clock shall maintain the system as follows:

o "OCC Cycle" - Unit SF and RF shall operate continuously and existing controls shall maintain zone temperature.

o "UNOCC Cycle" - Unit SF and RF motors shall be cycled intermittently to maintain lowered "UNOCC" zone temperatures. A three-position switch shall be furnished to provide override of the time clock if required. Unit shall cycle on 100 percent return air.

Energy Savings

- o Time Clock Control of HVAC No. 1
- o Supply fan hp = 7.5
- o Return fan hp = 1.5
- o Total hp = 9.0
- o Cooling season May 15 - October 15
- o Heating season October 15 - May 15
- o Occupancy schedule: (7 a.m. - 6 p.m.) x 7 days/week x 52 weeks/yr = 4,004 hr/yr
- o cfm of HVAC No. 1 - 8800 cfm
- o Scheduled outside air (OA) (Fixed) - 2170 cfm
- o UNOCC schedule (6 p.m. - 7 a.m.) x 7 days/week x 52 weeks/yr = 4732 hr/yr

Electrical Fan Savings:

Winter Season

9 hp x 0.746 kW/hp x (28 weeks/yr x 7 days/week x 13 hr/day - 20% for night cycling) ÷ 85% motor efficiency

= 16,100 kWh/yr

Summer Season

9 hp x 0.746 kW/hp x 24 weeks/yr x 7 days/week x 13 hr/day

÷ 85% motor efficiency

= 17,251 kWh/yr

Annual Fan Energy Savings: 16,100 kWh/yr + 17,251/kWh/yr

= 33,351 kWh/yr

Heating Ventilation Energy Savings: 8,800 cfm x 25% outside air

x 60 min/hr x 0.018 Btu/cf° F x (70° F - 44° F) x 28 weeks/yr

x 73 hours/wk

= 126 x 10^6 Btu/yr

Raw Source Energy Savings (@ 72% boiler efficiency):

126 x 10^6 Btu/yr ÷ 72%

= 175 x 10^6 Btu/yr

Cooling Ventilation Energy Savings: 8,800 cfm x 25% OA x

60 min/hr x 0.465 Btu/cf x 2,184 hr/yr

= 134 x 10^6 Btu/yr (cooling)

Annual Cooling Ventilation Energy Savings: 134 x 10^6 Btu/yr

x 1.2 kW/ton ÷ 12,000 Btu/ton/hr

= 13,400 kWh/yr

Total Cooling Savings: 34 x 10^6 Btu/yr (shutdown period)

Total Heating Savings: 126 x 10^6 Btu/yr (shutdown period)

Heat Pump for records section - 20% of administration floor space*

Energy required to heat/cool records section

= 20% x 134 x 10^6 Btu/yr +

20% x 126 x 10^6 Btu/yr

= 26.8 x 10^6 Btu/yr (cooling) + 25.2 x 10^6 Btu/yr (heating)

*Heat pump with time clock operates from 6 p.m. - 7 a.m. Remainder of time, use main air handling unit (AHU).

Heat pump

Coefficiency of performance (COP) for heating = 2.0

(6,826 Btu heating/kWh)

COP for cooling = 2.5 (8,532 Btu cooling/kWh)

Heat Pump Electrical Energy Usage

(26.8 x 10^6 Btu/yr ÷ 8,532 Btu/kWh) +

(25.2 x 10^6 Btu/yr ÷ 6,826 Btu/kWh) +

(1/2 hp fan x 0.746 kW/hp x 13 x 365 days ÷ 63%)

= 9,642 kWh/yr

Total Annual Energy Savings: (33,351/kWh/yr + 13,400 kWh/yr) +

175 x 10^6 Btu/yr - 9,642 kWh/yr

= 37,109 kWh/yr and 175 x 10^6 Btu/yr

Energy Cost Savings

37,109 kWh/yr x $0.059/kWh +

175 x 10^6 Btu/yr x $7.57/$10^6$ Btu

= $3,514/yr

			Material	Install
Capital Cost	1 - 7 Day Time Clock		$125	$100
	2 - Electric Pneumatic Solenoid Valve		40	10
	1 - Manual-Automatic Override Switch		50	20
	1 - UNOCC Thermostat		50	100
	1 - Switch Relay		50	25
	1 - Double-Pole, Pneumatic-Electric Switch		50	100
			$365	$355
		(O&P 20%)	73	71
			$438	$426

	Material		Install	
5 ton cool unit	$2,015	+	$430	= $2,455
		Profit		380
				$2,825
Ductwork				1,100
				$3,925
			+10%	393
				$4,318

Total Capital Cost	$438 + $426 + $4,318 = $5,182
Payback Period	$5,182 ÷ $3,514/yr = 1.5 yr

*During site survey, the audit team was informed that a through-the-wall A/C unit was being installed for the records section. The same opening can be used for the heat pump since it will replace the A/C unit.

OPTION 9 - INSTALL OUTDOOR TEMPERATURE RESET DEVICE ON HEATING HOT WATER BOILERS

The existing center portion of the institution is equipped with two hot water boilers and a 500 gallon domestic hot water tank that is supplied with hot water from the heating boilers.

Data obtained is as follows:

Two H.B. Smith Boilers

Fired with No. 2 fuel oil at 14-35 gallons per hour each

Rating - 1,373,900 Btuh

Two 1-hp circulating pumps are provided for the hot water heating system

Domestic hot water is provided with a 3/4 hp circulating pump

Domestic hot water tank has a 500-gallon capacity

The system according to operating personnel is run as follows:

One hot water boiler is run during the heating season until the outside air temperature drops low enough to make it necessary to turn the second boiler on. One hot water boiler is kept on during seasons when heating is not required to meet domestic hot water requirements.

There are no automatic controls to vary the temperature of hot water supplied to the institution. Flow control valves are manually adjusted to vary flow to the radiator supplied by the system.

During seasons when the primary boiler must be turned on to supply heat, the temperature of hot water supplied is 160° F. The hot water of the same temperature is supplied when heating is not required but supply water is required for domestic hot water purposes.

When the outside temperature drops (average 44° F), both boilers are on, delivering hot water at a fixed temperature of 195° F. Again, manual flow valves are used to maintain temperature control by varying flow to the hot water supplied to each location.

Recommendation

We recommend the addition of a compensated hot water system of automatic temperature control for the boilers. Figure 9-1 displays the recommended system. We recommend the system because supply water temperatures are now set to maintain occupant comfort during the coldest days and therefore are higher than needed most of the time. By resetting supply water temperature to match anticipated loads, energy losses through transmission lines and because of poor control can be reduced. Occupant comfort levels are also increased because heat input is more closely matched to needs instead of being supplied in high-temperature bursts. Up to 14 percent savings in heating energy costs can be achieved with a compensated control system.

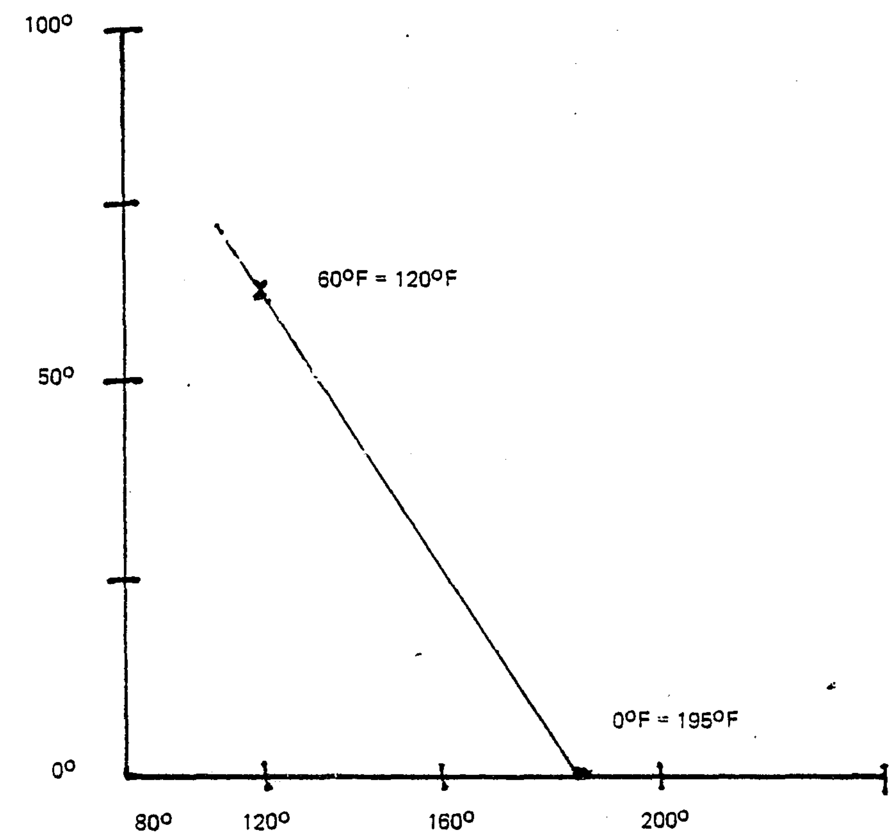
From weather data for this area heating season, the following is disclosed:

Outside Air Temp. (OAT)	No. of hours	% of hours
Range 60 - 65° F	328	7.1
50 - 59° F	924	20.0
40 - 49° F	1,284	27.9
30 - 39° F	1,313	28.5
20 - 29° F	598	13.9
10 - 19° F	149	3.2
0 - 9° F	13	.2
Total hours	4,609	100.0%

The average outside air temperature for the area during the heating season is 440° F.

We would anticipate that one boiler would be in use down to the 40-49° F range. Below that range we would anticipate that two boilers would be in use. The domestic hot water tank temperature could be maintained at its current condition, but the supply water temperature both to the radiators and the existing heating and ventilating unit would be varied inversely with outside air temperature to match load demand.

Additionally the hot water circulating pumps would be turned off when the outside air temperature reached 65° F. The following indicates the relationship of the compensated hot water system with the pneumatic controls to be added:



The system would be direct acting with reverse reset. The relationship is as follows:

OA Reset Pressure	OAT Range	Reset Water Temp.	Boilers
15 psi	60 - 65° F	120° F	1
12 psi	50 - 59 ° F	135° F	1
10 psi	40 - 49° F	150° F	1
8 psi	30 - 39° F	165° F	2
6 psi	20 - 29° F	180° F	2
3 psi	10 - 19° F	195° F	2

Ranges adjustable - manual override provided to overcome unusual conditions. Pumps off at +65° F.

The existing pneumatic air compressor would be reused and all work would be done in the boiler room.

Reset savings would be 14% of current operating costs for the system.

Energy Savings — o Existing heating energy use - $2,300 \times 10^6$ Btu/yr

Annual energy savings: $2,300 \times 10^6$ Btu/yr x 0.14

= 322×10^6 Btu/yr

Energy Cost Savings — 322×10^6 Btu/yr x \$7.57/10^6 Btu

= \$2,438/yr

Capital Cost

	Material	Installation
Pneumatic sub master receiver controller	\$ 190	\$ 125
1 outside air sensor	50	50
1 HW discharge sensor w/well	50	140
2 Pressure electric switches @ \$50	100	125
1 three-way 3° control valve	800	700
Total capital cost = \$2,330	\$1,190	\$1,140

Payback Period — $\frac{\$2,330}{\$2,438/\text{yr}}$ = 0.96 yr

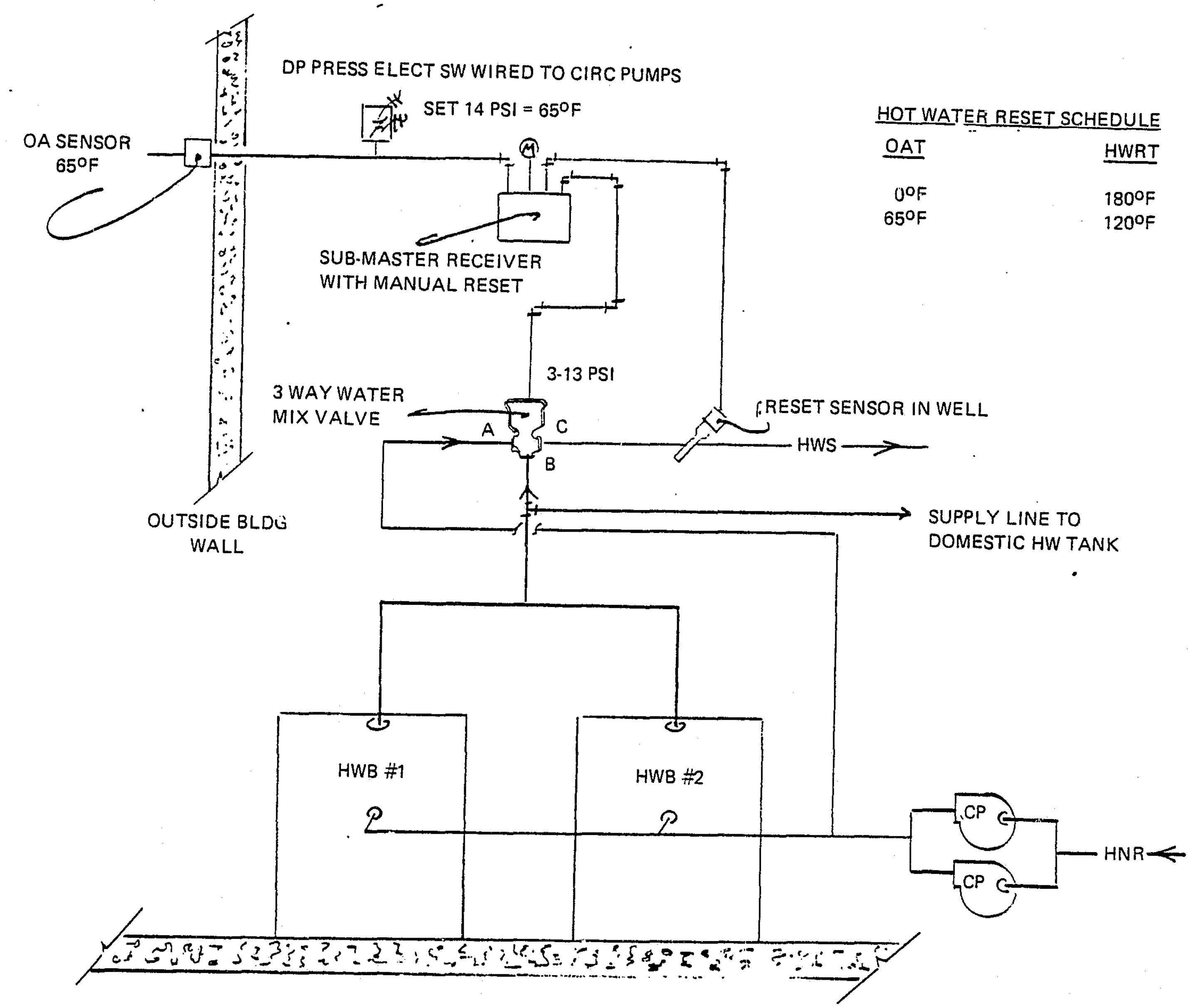


Figure 9-1. Compensated Hot Water Reset - Oil Jail

OPTION 10 - INSTALL ENTHALPY CONTROLS AND INCREASE OUTSIDE AIR CAPACITY OF AIR HANDLING UNITS

Our examination of the new building penthouse disclosed that AHU's No. 1, 2, 6, 7, 9, and 10 are served by a common sheet metal duct that supplies outside air to the units. From temperature readings taken at the outside-air connections to each unit, we determined that the correct air temperature (59° F) was being supplied to AHU's No. 1 and 7, but the outside air temperature being supplied to AHU's No. 2, 6, and 9 was 80° F at the fresh air inlet. (See figures 10-1 and 10-2.) AHU No. 10 was off, and our conclusion was that through back pressure, heated kitchen air is being introduced to the inlet connections of AHU's No. 2, 6, and 9. AHU No. 10 was briefly energized and the entering air temperature to the AHU's dropped to 74° F, a reduction of 6° F.

Visual and temperature readings disclosed that the outside air dampers were in some instances fully closed on some units and open above design on others. This combined situation means that more ventilation is being supplied to certain areas and inadequate amounts of controlled ventilated air is being supplied to other areas.

The readings taken were as follows:

	Outside Air Temperature (OAT)	Return Air Temperature (RAT)	Mixed Air Temperature (MAT)	(SAT)
AHU No. 1	59° F	80° F	68° F	74° F
AHU No. 2	80° F	80° F	80° F	85° F
AHU No. 6	80° F	80° F	80° F	85° F
AHU No. 9	80° F	80° F	80° F	85° F
AHU No. 7	59° F	80° F	60° F	68° F

Utilizing the formula:

$$\% \text{ of Outside Air} = \frac{\text{Temp. of Return Air} - \text{Temp. Mixed Air}}{\text{Temp. of Return Air} - \text{Temp. Outside Air}}$$

$$\text{AHU No. 1} = \frac{80° - 68°}{80° - 59°} = 57\% \text{ Outside air}$$

$$\text{AHU No. 7} = \frac{80° - 60°}{80° - 59°} = 95\% \text{ Outside air}$$

$$\text{AHU's No. 2, 6, \& 9} = \frac{80° - 80°}{80° - 80°} = 0\% \text{ Outside air}$$

The outside air damper on AHU's 3, 4, 5, and 8 was closed.

Our conclusion and recommendation is to provide new automatic temperature controls for all units and to increase the outside-air-handling capacity of units 1, 2, 6, 7, and 9. The revised system would enable the air handling system to utilize "free" outside air for improved ventilation performance during seasons when full cooling is not required. Additionally, a tight shut-off damper would be provided to prevent back pressure from AHU No. 10 when not in use.

Energy conservation would be achieved through the use of "Free Energy Band Thermostats" year-round and enthalpy/economizer controls for seasons when cooling is required. All new work can be performed either in the penthouse mechanical room or on the low roof; the only work to be done outside of these areas would be the revisions to the duct-mounted thermostats. No changes would be made to the life safety systems.

<u>Miscellaneous Other AHU Recommendations to be Incorporated Into This Option</u>

o Single zone units 2, 7, 9, located in the penthouse, would have enthalpy/economizer controls added; they should also have outside-air connections to their combination filter and mixing boxes so as to have maximum outside air available for "free" atmospheric cooling.

o Kitchen AHU No. 10 shall have a stay-put positive positioning relay added and a new heavy-duty damper installed to insure tight closure when the unit fan is off and to prevent back pressure from occurring.

o Single zone units 4 and 5, located on the new roof, shall have economizer/ enthalpy controls installed for "free" atmospheric cooling use of their associated dampers. No duct-work changes would be required.

o All unit life safety devices and purge systems would be interlocked to operate as now installed - no change.

Energy Savings: Enthalpy/Economizer Controls

- o 3226 hours in operating year when OAT is between 55° F and 75° F. allowing units to operate on 100% outside air[1].
- o 925 of the above hours would be when the outdoor wet bulb would cause the units to go to minimum outside air position (2%).
- o The average dry bulb temperature during the summer season is 75.1° F.
- o The average outside air relative humidity during the same period is 67.8%.
- o Return air conditions during the summer operating period are 75° F dry bulb - 50% relative humidity.
- o Annual Energy Savings: 925 hours x (37,580 total cfm - 9395 min cfm) x 4.2 Btu x $\frac{60 \text{ min/hr}}{13.7 \text{ cu ft/hr}}$ = 478.1×10^6
- o Electrical Energy Savings: $\frac{478.1 \times 10.6 \text{ Btu/yr} \times 1.2 \text{ kW/ton}}{12,000 \text{ Btu/ton hr}}$

  = 47,810 kWh/yr

Energy Cost Savings 47,810 kWh/yr x $0.059/kWh

= $2,821/yr

Costs to improve ventilation and to provide enthalpy/economizer controls for cooling cost reduction [2]

AHU	Material	Cost of Material/Unit	Installation Cost Unit	No. of Units	Total Cost
2,4,5	Enthalpy Controls	$900	$400	5	$ 6,500
7,9	ET-1, ET-2, EC-1				
	T-3	70	50	5	600
	MPR-1	45	15	5	300
	R-2	45	15	5	300
	RC-1	125	50	5	875
1,3,6,8	Enthalpy Controls	900	400	4	5,200
	ET-1, ET-2, EC-4				
	T-3	70	50	4	480
	MPR-1	45	15	4	240
	R-2	45	15	4	240
	R-1	45	15	4	240
	T-1, T-2	50	75	14 Thsts	1,750
10	Damper	200	150	1	350
Ductwork Renovations Penthouse Mechanical Room[3]					30,064
Cost including material and labor					$47,139
	Contractors Overhead & Profit 25%				11,782
Capital Cost					$58,921

Payback Period $58,921 ÷ $2,821/yr

= 21 yr

(1) Outside air temperature utilization (OAT):

From weather data, the OAT would average 57.4° F during periods when it can be utilized for ventilation purposes.

Assuming: 75° F Return air temperature (RAT)

75° F Mixed air temperature (MAT)

57.4° F Outside air temperature (OAT)

Outside air for ventilation would be 58% to maintain a discharge air temperature of 70° F.

$$\frac{\text{RAT } 75° - \text{MAT } 65°}{\text{RAT } 75° - \text{OAT } 57.4°} = \frac{10°}{17.6°} \quad 58° \text{ outside air}$$

(2) Installation of new outside air ductwork to provide full outside air capability to all AHU's.

(3) Ductwork renovations to include demolition and removal of existing outside air supply ductwork in mechanical equipment room (penthouse).

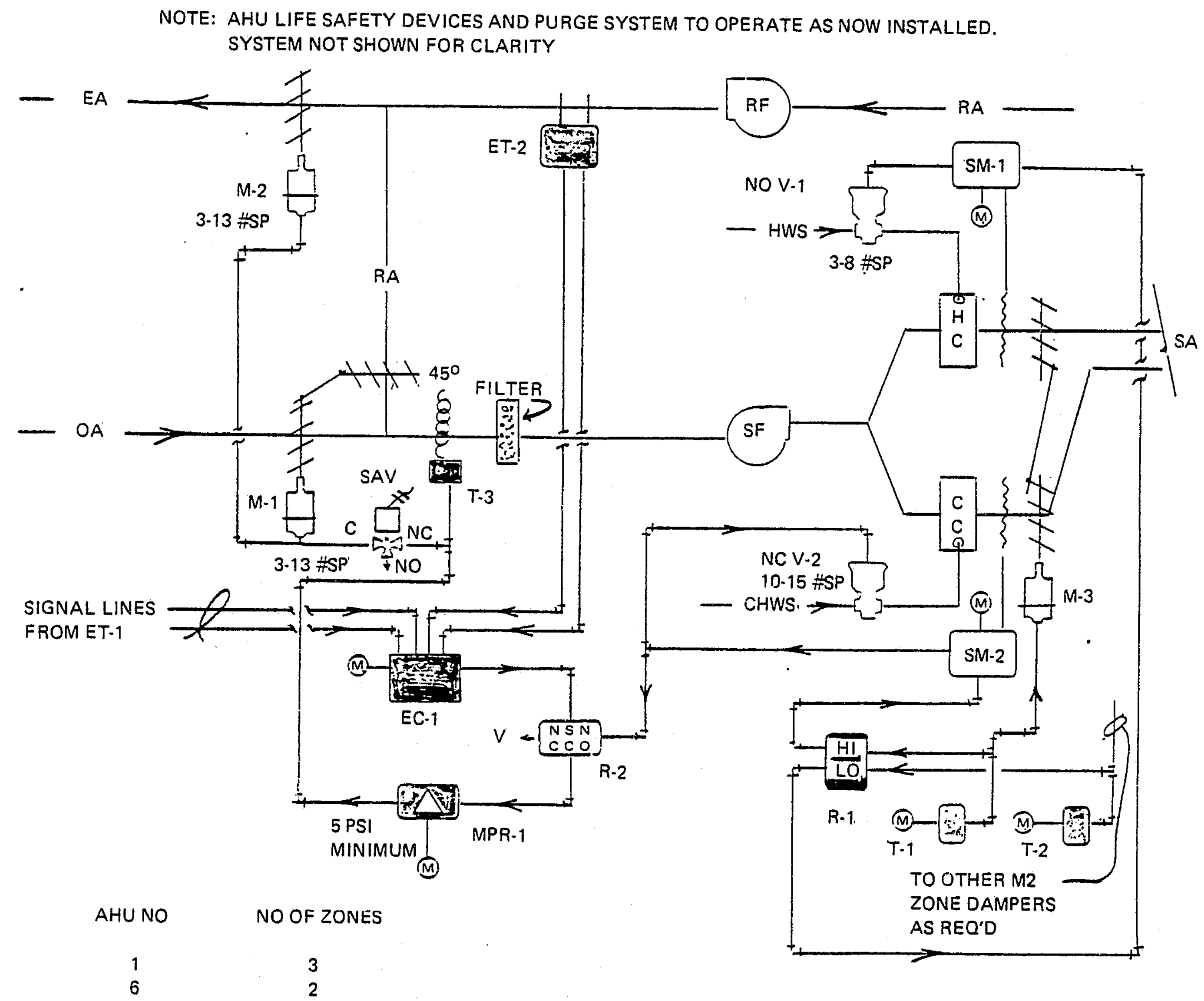


Figure 10-1. Penthouse Multizone Unit, Typical for AHU's 1 and 6

NOTES:

AHU 4 AND 5 TO HAVE ET-1
LIFE SAFETY SYSTEMS TO OPERATE AS NOW INSTALLED

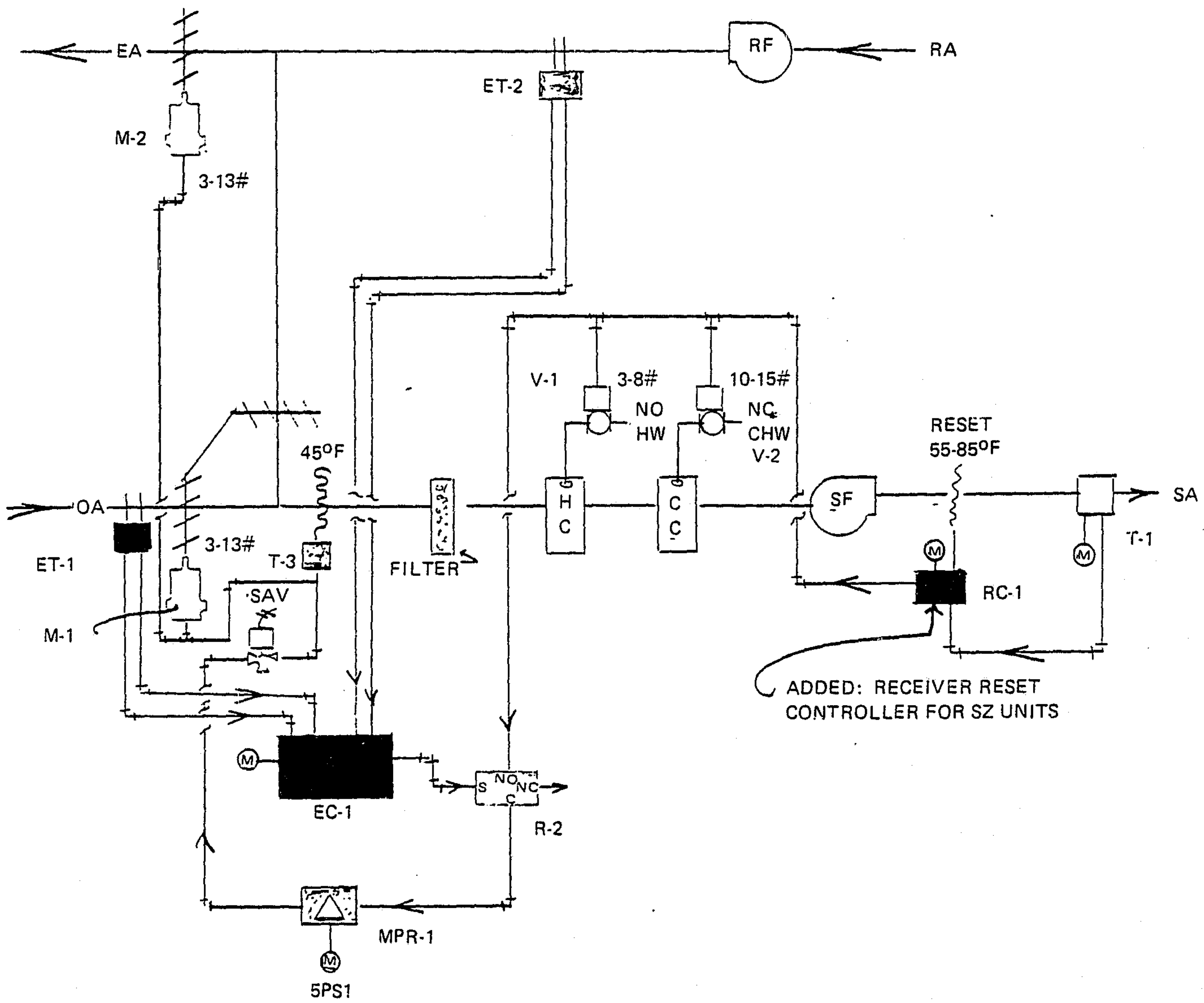


Figure 10-2. Single Zone Air Handler, Typical for AHU's 2, 4, 5, 7, and 9

Penthouse Multizone Unit - Typical for AHU 1 and 6 (Figure 10-1)

Legend

Symbol filled in solid indicates new controls added to system

Symbol outlined indicates existing controls to be reused

Arrowed lines indicate pneumatic main supply air to controller

┼	Indicates pipe to be connected in field
M-1, -2, & -3	Existing pneumatic damper motors (reuse)
V-1, V-2	Existing pneumatic oil valves (reuse)
SM-1, SM-2	Existing discharge sub-master th'sts (reuse)
SAV	Existing pneumatic/electric solenoid (reuse)
ET-1, -2	Enthalpy/economizer transmitters
EC-1	Enthalpy/economizer receiver controller
R-1	Load analyzing relay
R-2	Switching relay
MPR-1	Minimum damper positioning relay
T-1, T-2	Free energy band thermostats
T-3	Low-limit mixed-air thermostat, set 45° F

Sequence of Operation:

The outside air ductwork connections to the units shall be revised to allow full-size outside air connections to the combination filter and mixing box for each unit.

The unit supply fan and return fan motors shall be started.

Winter/Intermediate Weather Cycle of Control:

When the supply fan motor is energized, the interlocked return air fan motor shall start. Summer air ventilation (SAV) shall be energized, allowing control air to pass to damper motors M-1 and M-2. MPR-1 shall be set so as to allow the dampers to open to their minimum outside air ventilation position. T-1 and T-2 shall directly control their respective zone mixing dampers so that on a fall-in zone temperature the hot deck damper shall modulate open and the cold deck damper shall modulate closed; on a use-in zone temperature the reverse sequence shall occur. Additionally, each thermostat branch line pressure shall be fed to relay R-1. R-1 shall select and transmit zone thermostat requirements to hot deck sub-master SM-1, which shall reset V-1 to meet each zone heating requirements.

"Free" cooling for atmospheric ventilation shall be achieved in the "free" energy band range of T-1 and T-2 by modulating control of the outside air, return air, and exhaust air dampers. T-3 shall serve as a low limit and shall override the control system to prevent the mixed-air temperature from falling below 45° F by assuming command of the dampers.

Cooling Season Cycle

During the cooling season, the system shall operate in a similar manner with the exception that enthralpy/economizer control shall be provided for economy purposes.

ET-1, located in the entering air stream to the unit, and ET-2, located in each unit's return air stream, shall constantly monitor and measure the total heat content of each respective air stream.

When the "total heat" of the outside air is less than the "total heat" of the return air, outside air would be utilized for "free" atmospheric cooling. When the "total heat" of the outside air is greater than the "total heat" of the return air, the outside air damper would be positioned to admit its pre-set quantity of minimum ventilation air. (The outside air damper is adjustable.)

T-1 and T-2 would, through R-1, reset SM-2 and V-2 to satisfy zone conditions; the unit zone mixing dampers would be controlled in a direct acting manner. On a use-in zone temperature, the cold deck damper would open and the hot deck damper would close. On a fall-in zone temperature, the reverse sequence would occur.

All Seasons

Existing life safety devices and the "purge" system would be interlocked to operate exactly as they do at the present time.

Low-roof multizone units 3 and 8 will operate in a similar manner with the exception that no outside air ductwork changes are required, and each unit will have its individual entering air-sensing enthalpy transmitter. Added pneumatic controls for these units shall be located in the mixed air section of the units to prevent moisture in the air lines from freezing. Any pneumatic air lines run exposed shall be heat-traced.

OPTION 11 - REPLACE INCANDESCENT LIGHTING WITH FLUORESCENT LIGHTING

The existing lighting on the ceilings and hallways in the old section is incandescent. Most of the lamps are 75-watts, with a few of higher and lower wattages. If the existing lighting level is satisfactory, generally under 5 footcandles, then a new self-ballasted fluorescent bulb developed by the North American Philips Lighting Company (NAPLCO) is a cost-effective replacement. To increase the footcandle levels, F30T12/CW/RS (energy-conserving lamp) fixtures and tubes could be installed instead. Since a new fixture is required, this alternative is not as cost-effective as the NAPLCO self-ballasted bulb.

Energy Savings
- o NAPLCO: 67 lamps x (75 watts - 25 watts) x 8760 hr/yr ÷ 1,000 W/kW = 29,346 kWh/yr
- o F30T12: 67 lamps (75 watts - 30 watts*) x 8,760 hr/yr ÷ 1,000 W/kW = 26,411 kWh/yr

Energy Cost Savings
- NAPLCO: 29,346 kWh/yr x $0.059/kWh = $1,731
- F30T12: 26,411 kWh/yr x $0.059/kWh = $1,558

Capital Cost
- NAPLCO: $18/lamp x 67 lamps = $1,206
- F30T12: $100/fixture (vandal-proof) x 67 fixtures = $6,700
- $50/fixture (standard) x 67 fixtures = $3,350

*Includes ballast losses

Payback Period*
- NAPLCO: $1,206 ÷ $1,731/yr = 0.7 yr
- F30T12: $6,700 ÷ $1,558/yr = 4.3 yrs
- $3,350 ÷ $1,558/yr = 2.2 yrs

*Lamp Life - NAPLCO - 7,500 hr (1 yr)

F30T12 - 18,000 hrs (2½ years) - replacement lamp cost (installed) - $6

At the end of 5 years, the facility will have invested $90 for NAPLCO lamps, $62 - $112 for F30T12 fixture/lamps.

END