

**HOT WATER RESET  
REPORT  
CONSIDERING  
OCCUPANTS' COMFORT  
AS WELL AS  
SYSTEM ENERGY  
CONSUMPTION**

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**NOTE**

This case study's data was collected in a school at two locations: one illustrating the actual temperature in the supply water required, satisfying the coolest room: the other illustrating the supply water temperature variation impact on the energy use and comfort levels in the occupied space.

The logic presented in this report does not relate only to school systems. It can be applied to any heating system that only considers outside air temperature in determining supply water or supply air temperature in base building systems.

## EXECUTIVE SUMMARY

In many classrooms in Ontario, the heating and ventilation is provided by a fan system called a unitventilator. (See Figure #1 at the back of this report.)

The unitventilator is a small fan system dedicated to only one room.

Figure #1 is a drawing of the type of unitventilator, which is the subject of this report. They are very inefficient and, at times, have difficulty maintaining the comfort conditions in the classrooms.

Over the years, during service, we have witnessed the symptoms of excessive energy use and discomfort in many buildings with unitventilators. This report graphically illustrates the problems with these units and a solution that improves both the energy use as well as the controllability.

**The problem, from an energy point**, with this type of unitventilator is that the hot water flows continuously through the heating coil. A damper arrangement is used to allow the air to flow through the heating coil, deflect the air to bypass the heating coil or blend the air to various temperatures to select the amount of heat the room requires. Even when all the air is theoretically bypassing the coil, heat escapes into the air stream. This causes the unit to automatically bring in excessive fresh air to compensate for the unwanted heat.

**The problem, from a comfort point**, is that often the amount of heat escaping is greater than the cooling capability of the unit, even when the unit is on full cooling. The room over-heats while it is actually ventilating with about 500% more cold fresh air than required by code.

Figure #2, at the back of this report, is a drawing of the Energy Conservation Control Circuit that replaced the original heating supply water control circuit. The original circuit was reset based on only the outside air temperature.

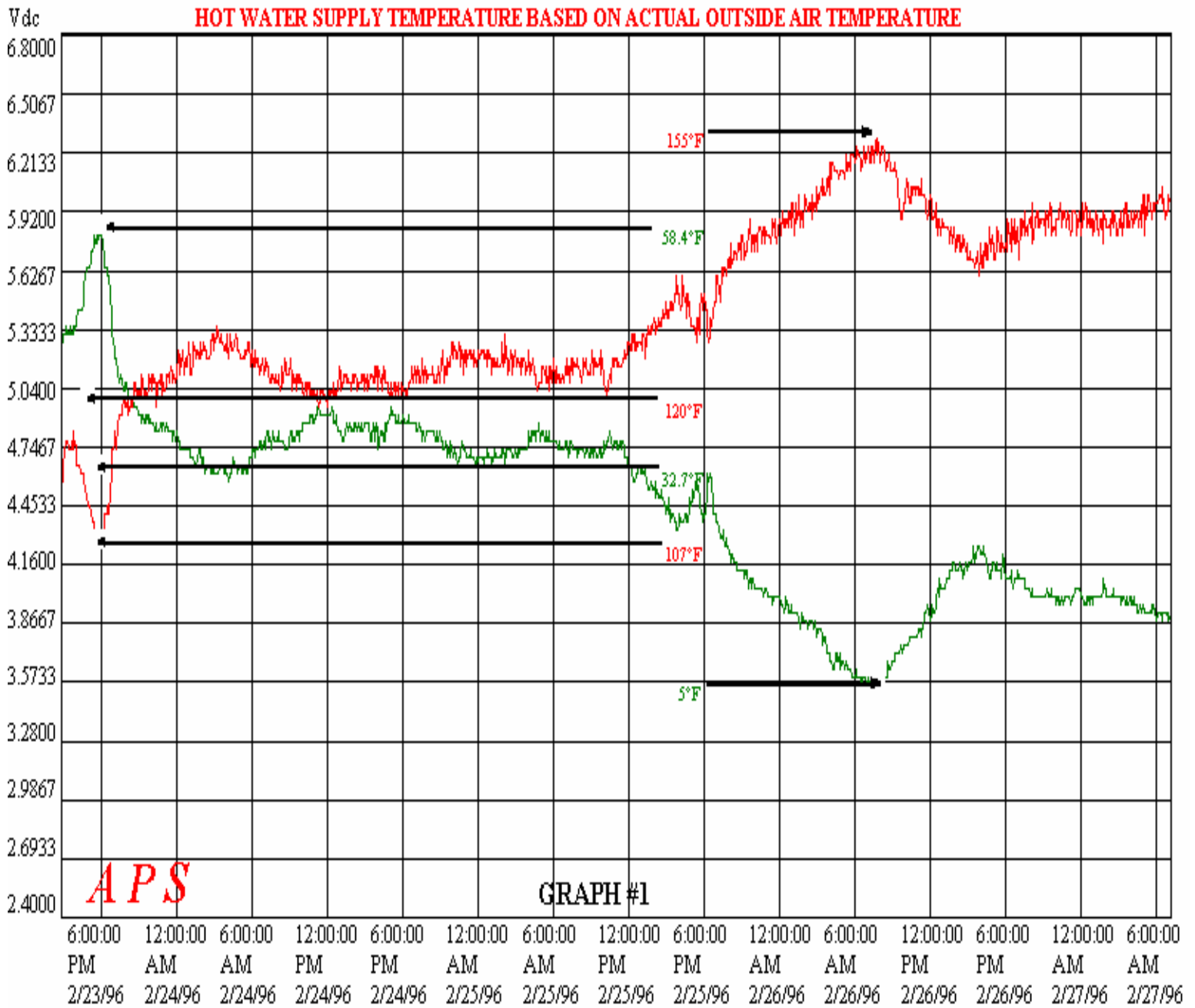
By modifying the controls to the Energy Conservation Circuit, the system saved:

- ✓ 81.7% on heating energy, on day operation, compared to a system supplied with 171°F supply water (boiler temperature)
- ✓ 58.4% on heating energy, on day operation, compared to a system supplied with water reset from the outside air temperature
- ✓ the unit used 247% more heat with the 171°F supply water **on full cooling** than the Energy Conservation Circuit used **on full heating**
- ✓ comfort levels are superior in the occupied space when using the Energy Conservation Circuit

SECTION 2.0  
2.1

ACTUAL OUTSIDE AIR TEMPERATURE

HOT WATER SUPPLY TEMPERATURE BASED ON ACTUAL OUTSIDE AIR TEMPERATURE



## **GRAPH #1**

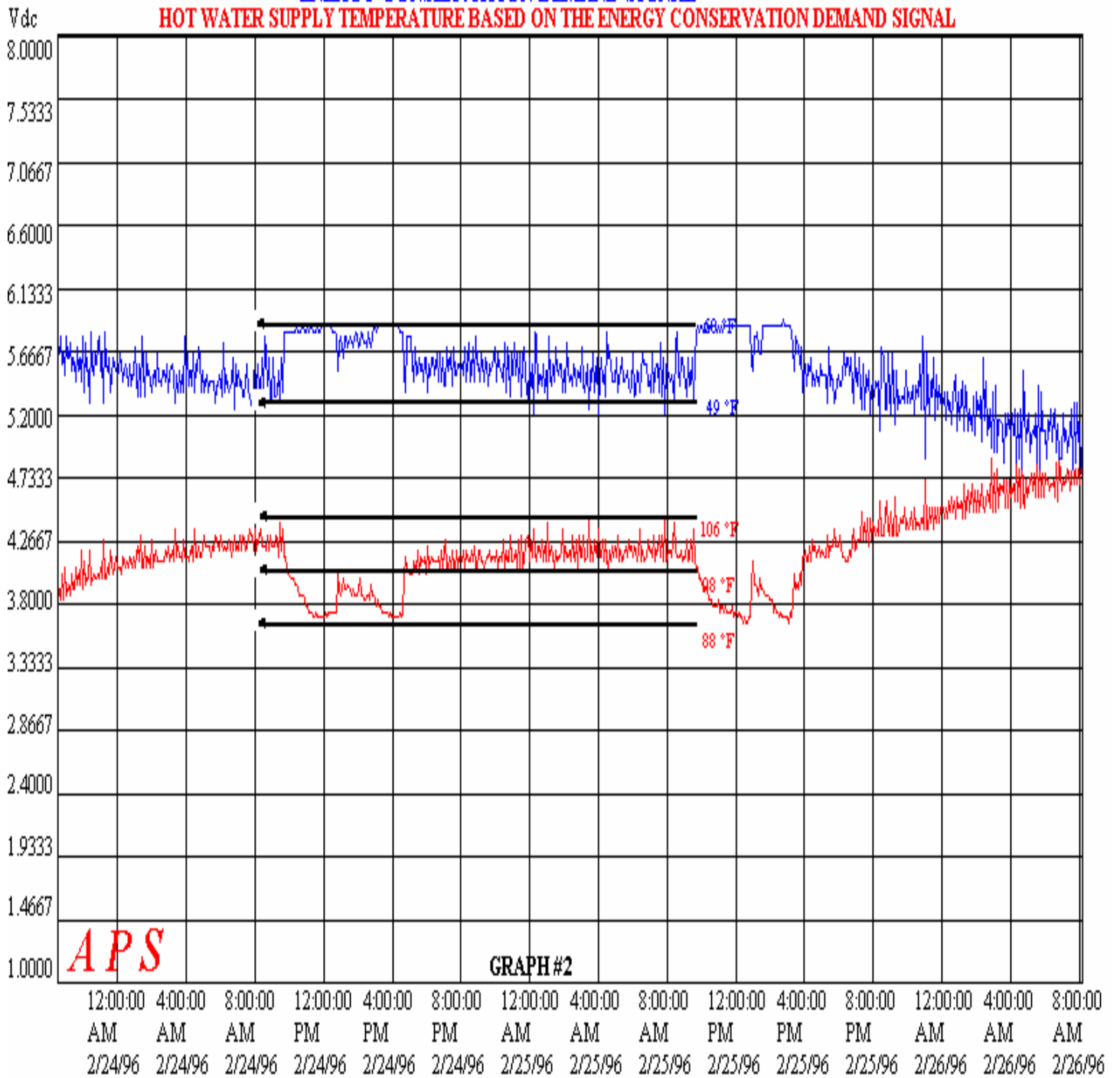
Graph #1 shows the relationship of the supply water temperature with respect to the actual outside air temperature. This graph illustrates the performance of a typical indoor/outdoor reset system circuit. This was the existing design reset schedule for this case study.

Sensing point (F) on FIGURE #2 is the location where the supply water temperature readings were obtained and sensing point (G) on FIGURE #2 is the location where the actual outside air temperature readings were obtained.

The supply water temperature increases as the outside air temperature decreases.

Control from only the outside air temperature mistakenly assumes that the only factor worth considering in hot water reset is the dry bulb outside air temperature.

**ENERGY CONSERVATION DEMAND SIGNAL**  
**HOT WATER SUPPLY TEMPERATURE BASED ON THE ENERGY CONSERVATION DEMAND SIGNAL**





## GRAPH #2

GRAPH #2 shows the relationship of the supply water temperature with respect to the actual amount of heat required by the coldest room on the system. This graph illustrates the performance of an Energy Conservation System Circuit.

Sensing point (F) on FIGURE #2 is the location where the supply water temperature readings were obtained and sensing point (I) on FIGURE #2 is the location where the Energy Conservation Demand Temperature Signal readings were obtained.

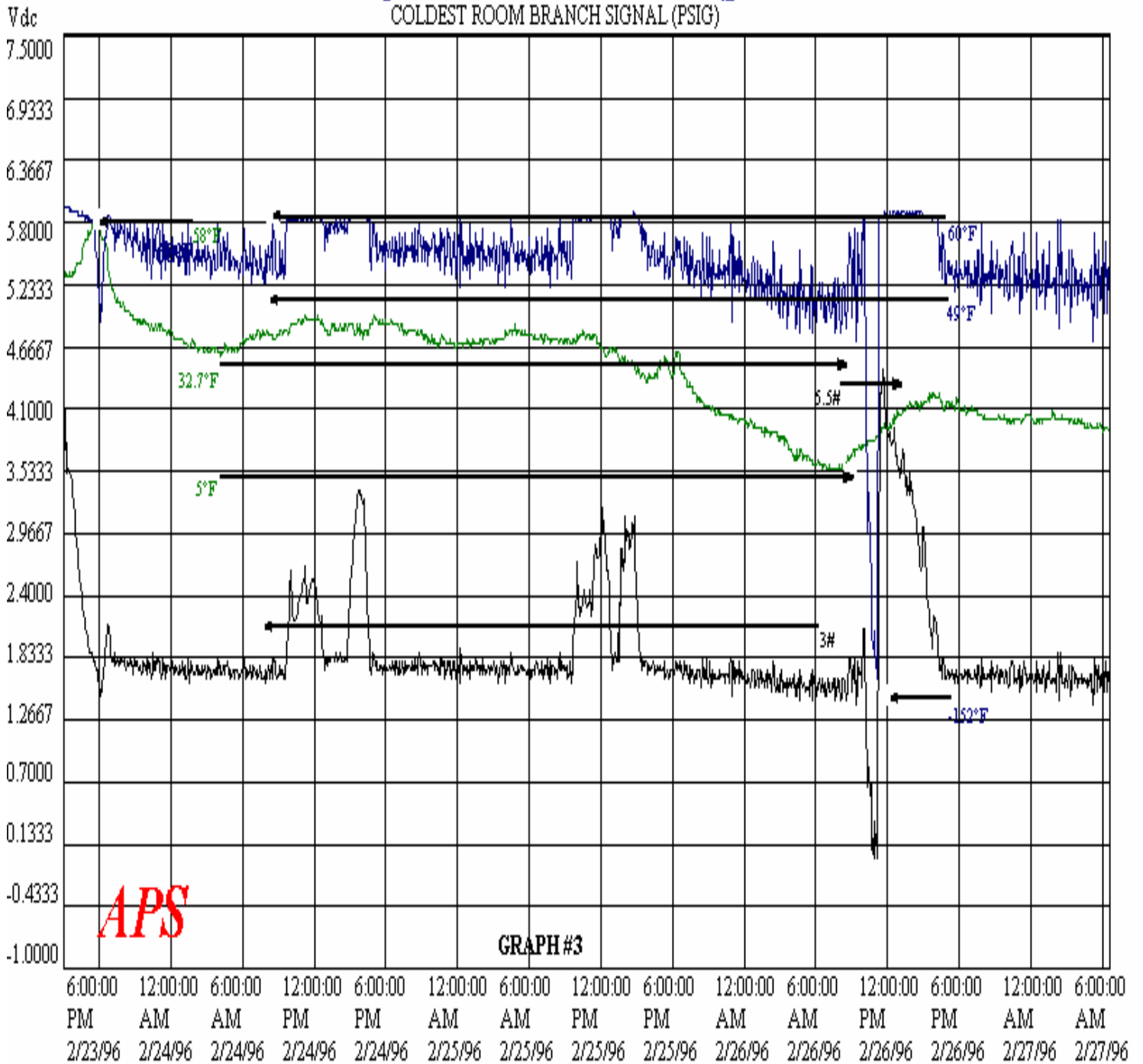
The Energy Conservation Demand Temperature Signal is created by the demand of the coldest room in the system. **The Energy Conservation Demand Temperature Signal "tells" the main heating controller that the outside temperature is warmer than the actual outside condition to allow the system to attain the exact temperature in the supply water to satisfy the building's requirement.**

A multi-selector determines the heating requirement of the coldest room. It selects the lowest signal to indicate the true requirement for heating. Relays are used to offset the coldest room's signal such that it will create an Energy Conservation Demand Temperature Signal of 60°F any time the room has either started to close off its heating device or has closed off its heating device. The only time the coldest room is allowed to ask for more than the minimum level of heat from the main system is after the room thermostat has opened its heating device to maximum flow. This delivers the required BTUs to the room with the minimum degree of temperature in the supply water.

Graph #2 illustrates the supply water temperature dropping when the body load of the students and other internal heat sources are generating enough heat to lessen the load on the heating system. The water temperature rises at night and at lunch when the other heat sources have been removed from the classrooms.

It is worth observing that the supply water temperature graph is symmetrical to both the actual outside air temperature graph as well as to the Energy Conservation Demand Temperature Signal graph on both Graph #1 and Graph #2. The difference is that Graph #1 is using open loop logic which makes the poor assumption that the outside air temperature is the only factor required to determine the heating supply water temperature and Graph #2 is using closed loop logic which assesses the actual heating requirements of the building.

ACTUAL OUTSIDE AIR TEMPERATURE  
 ENERGY CONSERVATION DEMAND SIGNAL  
 COLDEST ROOM BRANCH SIGNAL (PSIG)



### **GRAPH #3**

Graph #3 illustrates the method of creating the Energy Conservation Demand Signal.

The “COLDEST ROOM BRANCH SIGNAL” is attained via a multi-selector, which produces the lowest signal of the rooms that are sampled. The coldest room signal is obtained at sensing point (H) on FIGURE #2.

The lowest signal is sent to a biasing relay which offsets the signal so that the pressure at which the heating function in the unitventilator is fully open will cause a branch signal from the relay to simulate the warmest outside air temperature considered in the building's original reset schedule. The relay's signal is limited to that value, as a maximum, which sets the minimum water temperature at which the system will be allowed to operate. The signal from the limiting relay goes to a high selector, which also receives a signal from the actual outside air temperature transmitter that prevents the supply water temperature from exceeding the original reset water schedule.

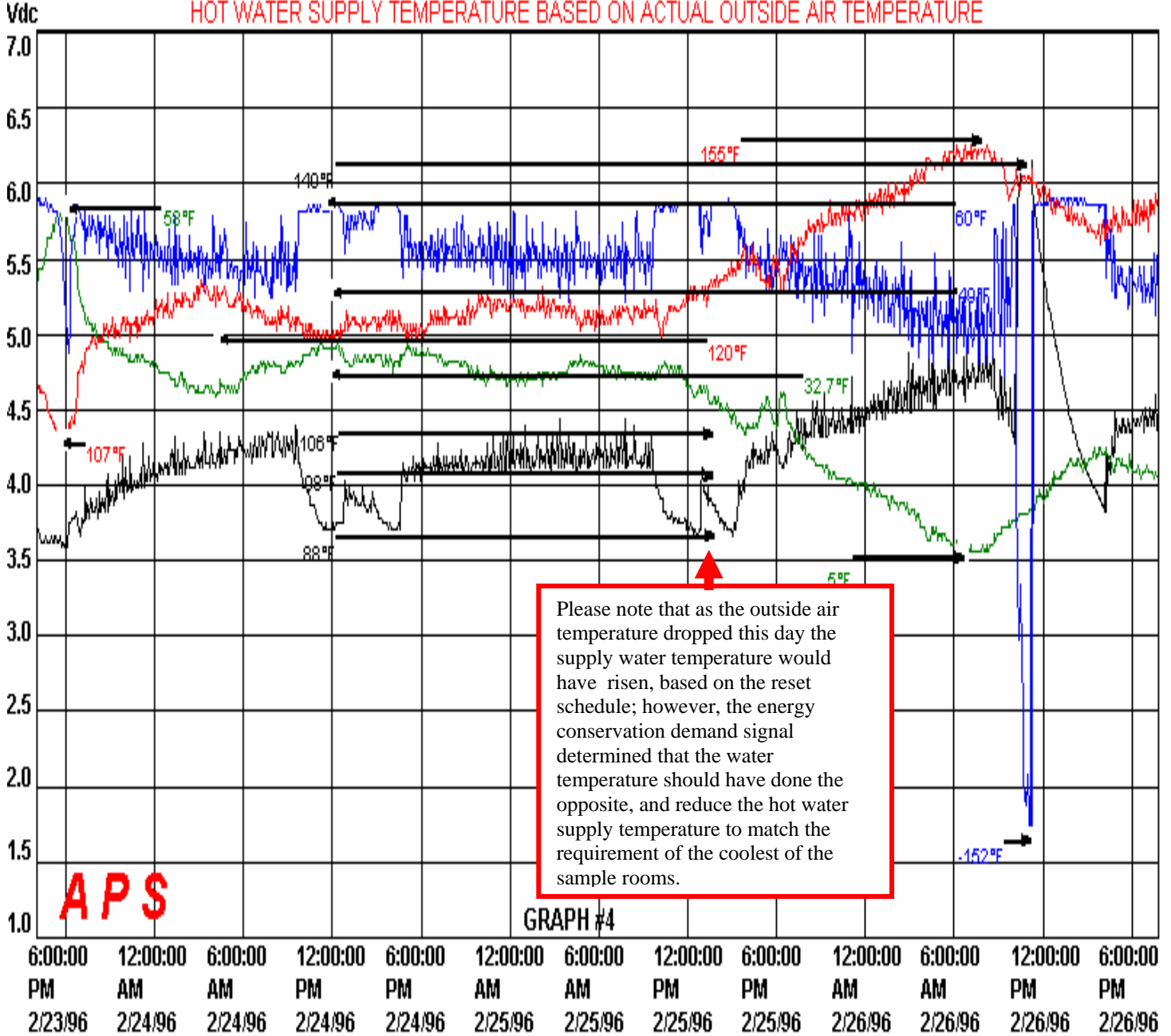
The actual outside air temperature readings were obtained at sensing point (G) on FIGURE #2 and the Energy Conservation Demand Temperature Signal readings were obtained at sensing point (I) on FIGURE #2.

ENERGY CONSERVATION DEMAND SIGNAL

ACTUAL OUTSIDE AIR TEMPERATURE

HOT WATER SUPPLY BASED ON ENERGY CONSERVATION DEMAND SIGNAL

HOT WATER SUPPLY TEMPERATURE BASED ON ACTUAL OUTSIDE AIR TEMPERATURE



## GRAPH #4

Graph #4 illustrates the relationship of the actual outside air temperature and the Energy Conservation Demand Signal. Graph #4 also illustrates the simultaneous relationship of the reset water temperatures for control from the Energy Conservation Demand Signal as well as control from actual outside air temperature.

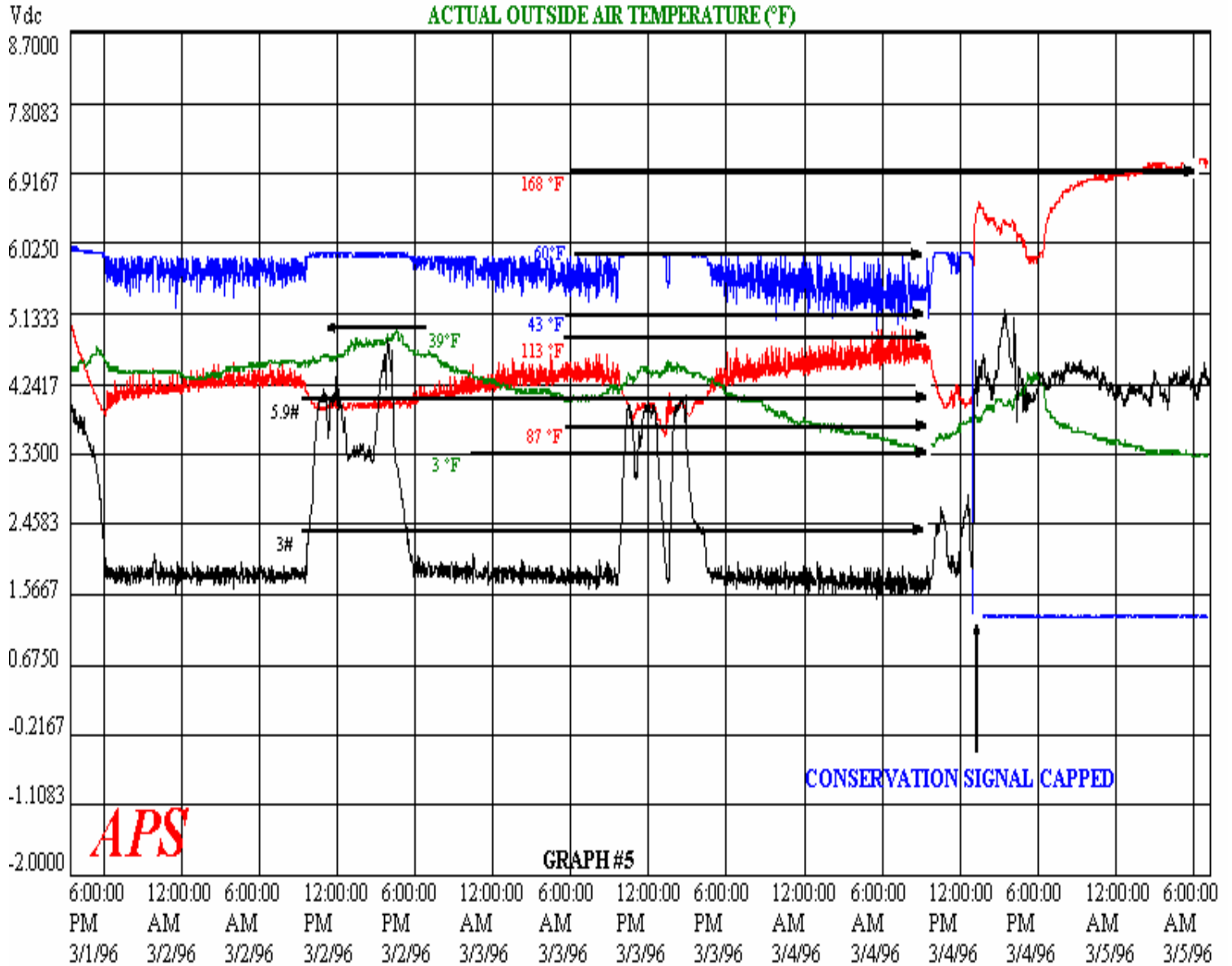
The sensing points for Graph #4 were obtained as shown on FIGURE #2.

The Energy Conservation Demand Signal responds directly to the actual heating requirements of the coolest spot in the building while the outside air temperature sensor is oblivious to the building's needs and only reports the outside air temperature condition. During the afternoon of February 25, 1996 the actual outside air temperature was declining which would have increased the supply water temperature; however, the Energy Conservation Demand Signal was increasing because of the return of the body heat from the students to the classrooms. This caused the supply water temperature to be reduced to reflect the actual heating requirements of the building.

In the morning of February 26, 1996 the Energy Conservation Demand Signal dropped to -152°F. The actual outside air temperature was only 10°F. The system is designed to believe the higher of the actual outside air temperature or the Energy Conservation Demand Signal; therefore, the supply water temperature was limited to the temperature which was the old outside air reset schedule desired.

The reason the Energy Conservation Demand Signal dropped was that an unauthorized person had turned off the circuit breaker for the unitventilator. The room dropped in temperature, which caused the thermostat to demand full heat; however, the heat, which the thermostat was demanding from the building's primary supply system, was prevented from getting to the room because the room's fan was turned off. As you will see later in this report, this caused the other rooms on the same water supply to bring excessive amounts of fresh air into their unitventilators to attempt to compensate for the unwanted BTUs that escape from the coils. The result is a loss of comfort, a waste of energy and an increase in pollution from products of combustion while producing the unnecessary heat.

**ENERGY CONSERVATION DEMAND SIGNAL  
 COLDEST ROOM DEMAND SIGNAL (PSIG)  
 RESET SUPPLY WATER TEMPERATURE (°F)  
 ACTUAL OUTSIDE AIR TEMPERATURE (°F)**



## GRAPH #5

Graph #5 illustrates the difference in the supply water temperature, comparing control when the reset system was allowed to sense the Energy Conservation Demand Signal to reset based on only the actual outside air temperature.

The change of reference points was done at noon on March 4, 1996.

The sensing points for Graph #5 were obtained as shown on FIGURE #2.

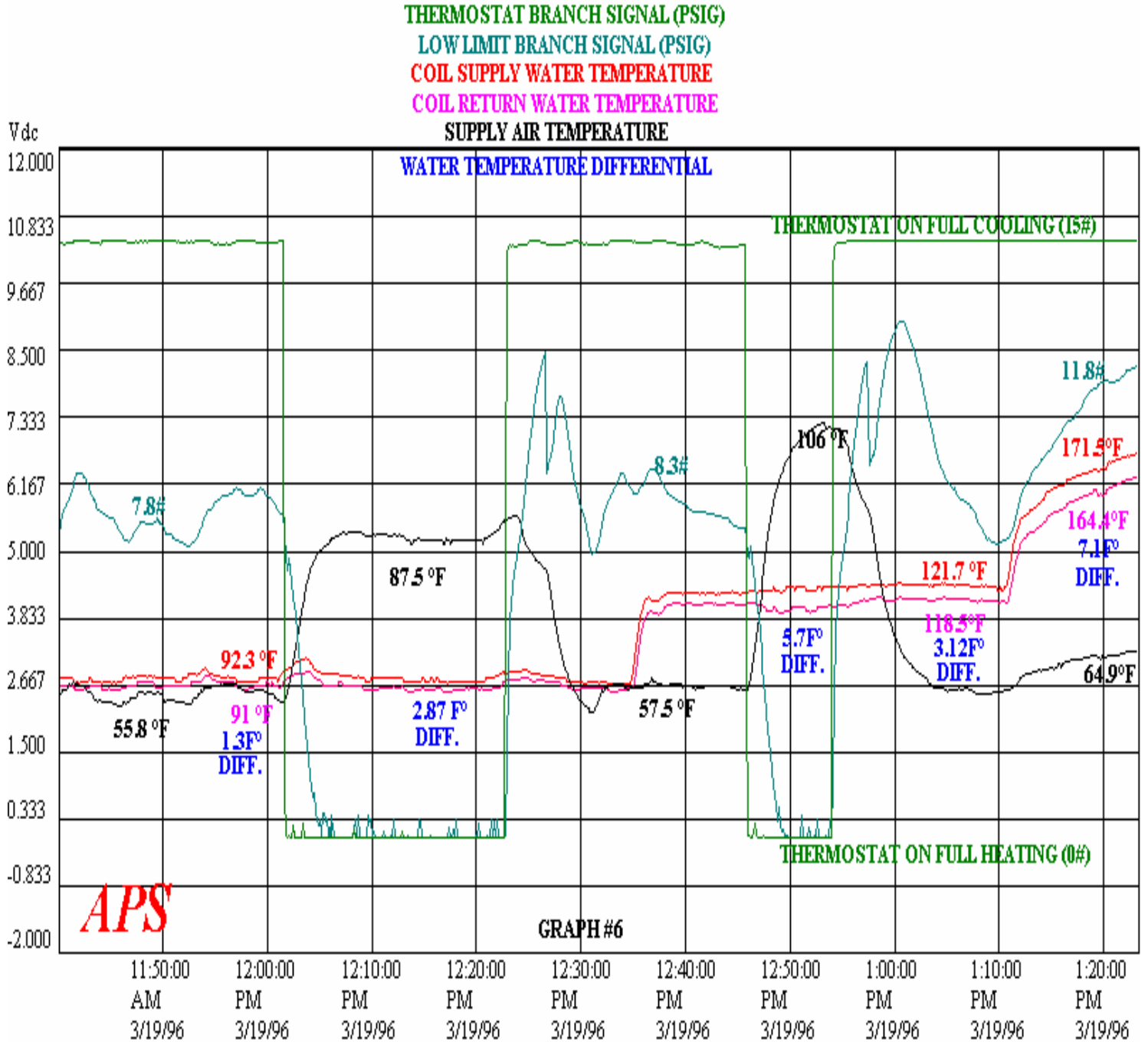
If you look back at Graph #1 and Graph #2 to compare them to Graph #5 you will see that the relationship of the supply water up to noon on March 4, 1996 is similar to Graph #2 which graphed resetting from the Energy Conservation Demand Signal. After noon on March 4, 1996 on Graph #5 the relationship is similar to Graph #1 which graphed resetting from actual outside air temperature.

The coldest room demand signal reflected the impact of the body heat of the students up to noon March 4, 1996. The system required cooling while the students were in the classrooms during the day, but the signal dropped at night when the effect of the student body heat was gone to stop the cooling and only use heating.

After noon on March 4, 1996 the coldest room signal increased to bring in cooling to compensate for the heat which was being forced into the system by the main supply water temperature increase. **The unitventilator in the coldest room required more cooling at night, when the students' body heat was not present, than the room did when the classroom was full of students.**

The increased cooling required is the result of heat escaping into the unitventilator.

NOTE: Graphs 1, 2, 3, 4 and 5 were all developed to illustrate the method and need for controlling the supply water temperature based on the Energy Conservation Demand Signal which is created by the coldest room. This signal activates the main heating supply after the coldest room has opened its heating device to receive the requested heat. The information for these charts was obtained from signals in the boiler room at the main steam heat exchangers for the supply water.





## GRAPH #6

Graph #6 was prepared to illustrate the increased energy loss in the unitventilator and the loss of control in the room as the supply water temperature rises.

All the readings for the graph were taken in a classroom from sensing points shown on FIGURE #1. The thermostat branch pressure was obtained at (C); the low limit branch signal was obtained at (D); the supply air temperature was obtained at (E); the supply water temperature was obtained at (A) and the return water temperature was obtained at (B).

The supply water temperature was provided at three different modes of operation:

1. The first was based on the Energy Conservation Demand Signal logic with an average supply water temperature of 92.3°F.
2. The second was based on actual outside air temperature reset with an average supply temperature of 121.7°F.
3. And the third was based on boiler supply water at an average supply temperature of 171.5°F.

We ran the thermostat on full cooling with a fifteen pound branch pressure and on full heating with a zero pound branch pressure as shown by the green line.

We observed two characteristics of the unitventilator's response. One was the energy use based on the differential of the supply and return water temperatures and the second was the ability to maintain comfort based on the supply air temperature.

The coil always had the same rate of water flow; therefore, the differential temperature was a direct indication of the relative amount of heat escaping into the room when on cooling under the three different supply water temperatures.

The following chart indicates the supply water temperature, the water differential temperature, the discharge air temperature and the low limit branch pressure when the thermostat was demanding full cooling.

SUPPLY TEMPERATURE	DIFFERENTIAL TEMPERATURE	DISCHARGE AIR TEMPERATURE	LOW LIMIT PRESSURE
92.3°F	1.3F°	55.8°F	7.8 PSIG
121.7°F	3.12F°	57.5°F	8.3 PSIG
171.5°F	7.1F°	64.9°F	11.8 PSIG

The information obtained from the chart gives a clear picture of the supply water temperature's impact on the energy use of a unitventilator as well as the effect on the comfort level in the room.

## ENERGY

The building was running on the conservation circuit using the Energy Conservation Demand Signal when we got to the building. The rooms were all satisfied and the water supply temperature was 92.3°F.

On full cooling the unitventilator was only losing 1.3F° of heat from the supply water as it passed through the unit.

When the supply water temperature was raised to the original reset schedule control point of 121.7°F, the unitventilator, which was on full cooling, was losing 3.12F° of heat from the supply water passing through the unit. This is 240% more unwanted heat escaping into the air stream than on the conservation circuit.

When the supply water temperature was raised to 171.5°F, to simulate a typical supply water temperature without a secondary loop, the unitventilator, which was on full cooling, was losing 7.1F° of heat from the supply water. This is 546% more unwanted heat escaping into the air stream than on the conservation circuit.

The low limit branch pressure increased from 7.8 PSIG on the conservation circuit to 8.3 PSIG on the original reset schedule to 11.8 PSIG on the high temperature water supply. The damper motor has a spring range of five to ten pounds. The actual outside air temperature at the time of the readings was 27°F. **While on the high temperature water the unit had to drive to 100% outside air and still could not get the supply air temperature below 64.9°F. The escaped heat caused a 37.9F° temperature gain in the supply air temperature with the unit on full fresh air.**

## COMFORT

The low limit branch signal had to gradually increase as the supply water temperature was increased to compensate for the greater amounts of unwanted heat escaping into the unitventilator. **The low limit finally lost control in its attempt to provide cooling and the room over-heated while the thermostat and the low limit were both producing signals to demand full cooling.**

**NOTE:** When the thermostat was demanding full heat while on the conservation circuit the water differential was 2.8F°. When the thermostat was demanding full cooling on the high temperature water, the water differential was 7.1F°. The system used 247% more heat when on cooling with the high temperature water than it used when on full heating with the conservation circuit.

## GENERAL

**On any heating system where the level of heat is to be determined by the actual requirement of the space, it is imperative that the control point which sends a signal to the main plant to demand heating levels also controls the local device which regulates the heat into the local area.** It is a very common error to have computer points in several classrooms to scan the building for the greatest demand for heat while having local thermostats controlling the flow of heat to the rooms. This can create a situation where the computer is demanding full heat to satisfy a room where the thermostat is set to not allow the heat to enter the room.

The system can be controlled equally well with either completely computer logic or completely pneumatic logic.

If you choose to use computer logic, each of the room thermostats in the sample rooms has to be replaced with a transducer to control the valve (or the valve can be replaced with an electronic modulating valve) and the software has to be able to determine the room with the greatest requirement for heating. The software then has to coordinate the supply of heat with the position of the local control valve in the coldest room.

If you choose to use pneumatic logic, you will tee into the existing branch lines of the sample room thermostats and often run them to a multi-low selector. A biasing relay will likely be used to establish an Energy Conservation Demand Temperature Signal.

The safety of the building occupants, the mechanical equipment and the building must be the first concern to a designer making changes to save energy. It is the responsibility of the designer to know every potential problem area for each system and address each one in a logical manner. No two buildings are exactly the same; therefore, no two conservation circuits are exactly the same.

Respecting our common environment, on which we all depend, you may reproduce this report and use it for training purposes, if you wish.

**THE DURHAM BOARD OF EDUCATION**  
**CONTROL MODIFICATIONS BY**  
**A P S**

SCHOOL	ENERGY USE YEAR PRIOR TO CHANGE		ENERGY USE YEAR FOLLOWING CHANGE		ENERGY SAVINGS		ECONOMIC BENEFIT
	ELECTRIC	FUEL	ELECTRIC	FUEL	ELECTRIC	FUEL	SAVINGS
ADMIN.	575,040	767,690	469,120	597,192	105,920	170,498	\$4,641.00
GENERAL VANIER	1,847,200	4,584,768	1,520,720	4,127,945	326,480	456,823	\$13,480.00
HENRY ST. HS *	1,049,9162	2,772,563	961,263	2,671,423	88,653	101,138	\$3,385.00
O'NEILL CVI	949,025	2,294,845	886,925	2,236,678	62,100	58,167	\$2,219.00
DUNBARTON HS	1,686,500	3,376,841	1,586,086	3,001,606	100,414	375,235	\$6,962.00
G.L. ROBERTS HS	1,129,996	2,433,187	1,001,192	1,338,622	128,804	896,565	\$13,914.00
SOUTHWOOD PARK PS	820,080	NO FUEL	554,640	NO FUEL	265,440	NO FUEL	\$6,503.00

- \* - CHANGES WERE IN EFFECT FOR 3 MONTHS.
- ALL CONSUMPTION VALUES ARE IN KILOWATT-HOURS.
- DOLLAR VALUES ARE 1981 FUEL COSTS

TOTAL SAVINGS	\$51,104.00
TOTAL COST	\$42,340.00
PAYBACK 8 MONTHS, 1 WEEK	

DM: mm  
 1982 01 14

Notes:

- Actual chart of School Board's data copied into Word.
- Administration and Henry St. are multizone systems.
- Southwood Park PS is electric baseboard and electric reheat.
- General Vanier SS, O'Neill CVI and Dunbarton have a variety of HVAC fan systems, but no multizones.
- G.L. Roberts HS was VAV with perimeter heating only controlled via indoor/outdoor reset from one main valve.

**THE BOARD OF EDUCATION FOR THE BOROUGH OF SCARBOROUGH**

4.3

**CONTROL MODIFICATIONS BY**

**A P S**

SCHOOL	UTILITY	ANNUAL REDUCTION	1979 UTILITY COST	UTILITY SAVINGS **	\$	IMPROVEMENT COST	PAYBACK YR.
MILITARY TRAIL JR. PS	GAS	31.1%	9,863	2315	4,073	4,072	1
	ELECTRIC	20.9%	11,217	1758			
JACK MINER PS	GAS	20.4%	14,338	2194	4204	3,287	0.8
	ELECTRIC	17.8%	15,059	2010			
ALEXMUIR JR. PS	GAS	29.5%	7,308	1617	3515	2,699	0.8
	ELECTRIC	24.6%	10,285	1898			
SILVER SPRINGS PS	GAS	37.8%	6,425	1822	3,973	1943	0.5
	ELECTRIC	36.6%	7,835	2151			
WENDELL STATTON SR. PS	GAS	57.6%	10,221	4415	10,114	5300	0.5
	OIL	19.5%	16,463	3210			
	ELECTRIC	22.6%	14,684	2489			
TIMBERBANK PS	GAS	17.1%	8,142	1044	2,784	2110	0.8
	ELECTRIC	22.1%	10,499	1740			
WEST HILL C.I.	OIL	8.1%*	46,552	3771	24,419	36,370	1.5
	ELECTRIC	10.9%*	51,974	4249			
	GAS	51.8%*	42,211	16,399			
				TOTALS	53,082	55,781	1.05

- \* - PART YEAR ONLY

- \*\* - GAS AND ELECTRIC @ 75% OIL @ 100%

JRM/sc June 18, 1981

**LETTER FROM SCARBOROUGH BOARD ACCOMPANYING CHART ABOVE**

Gentlemen:

During early 1979 control improvements were carried out by your firm on a number of our schools. These schools are listed on the attached schedule which indicates the savings that have been achieved.

For clarification purposes, it should be noted that:

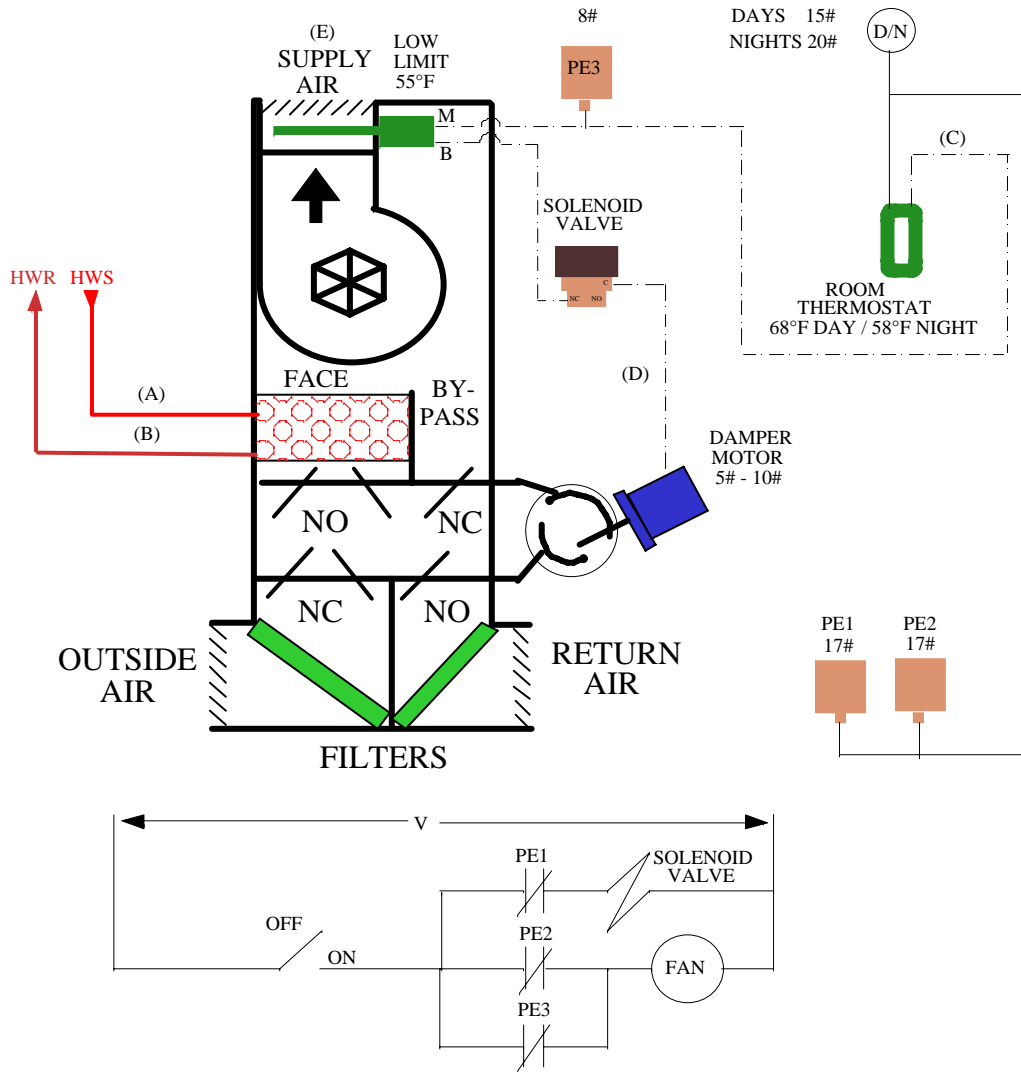
- a) no allowance has been made for the fact it was 4.7% colder in 1980 than in 1979.
- b) The utility costs are 1979 actuals and no allowance has been made for escalation.
- c) The majority of the savings are undoubtedly higher as the modifications were not in effect for the entire year.
- d) We have assumed only 75% of the actual gas and electricity savings because of the sliding scale rate structures.
- e) Approximately \$17,000. Is included in the cost of improvements at West Hill Collegiate for other work that was performed at the time aimed primarily at improving poor environmental conditions.

It is almost needless to say that we are very pleased with the results and the manner in which they were carried out.

Yours very truly  
J.R. Mazanik

**NOTE: Actual Board information copied into Word.**

**FIGURE #1**



**SENSING LOCATIONS**

- (A) HOT WATER SUPPLY TEMPERATURE.
- (B) HOT WATER RETURN TEMPERATURE.
- (C) THERMOSTAT BRANCH LINE PRESSURE.
- (D) LOW LIMIT BRANCH LINE PRESSURE.
- (E) DISCHARGE AIR TEMPERATURE.

**FACE & BYPASS UNIT VENTILATOR**

**FIGURE #2**

