

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

A P S
PHONE# (905) 640-2333
FAX # (905) 640-2444
analystssofpneumatic@bellnet.ca
<http://www.apscontrols.ca>

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The data for this case study was collected in a school at two locations. One illustrates the actual temperature of the supply water required to satisfy the coolest zone served and the other illustrates the impact of supply water temperature on energy performance and comfort.

The logic presented in this report does not only apply to school buildings. It applies to any heating system with the capability of varying the primary supply water or air temperature into the occupied areas.

Systems resetting hot water or supply air only from outdoor air temperature are likely wasting heat, increasing the wear and tear on the control valves and creating discomfort, at times, in the some served areas.

The logic applies to all control systems: DDC, electronic, pneumatic and manual.

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

GRAPH #1

ACTUAL OUTDOOR AIR TEMPERATURE (°F)
ACTUAL DESIGN SUPPLY WATER TEMPERATURE BASED ON OUTDOOR RESET (°F)



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.

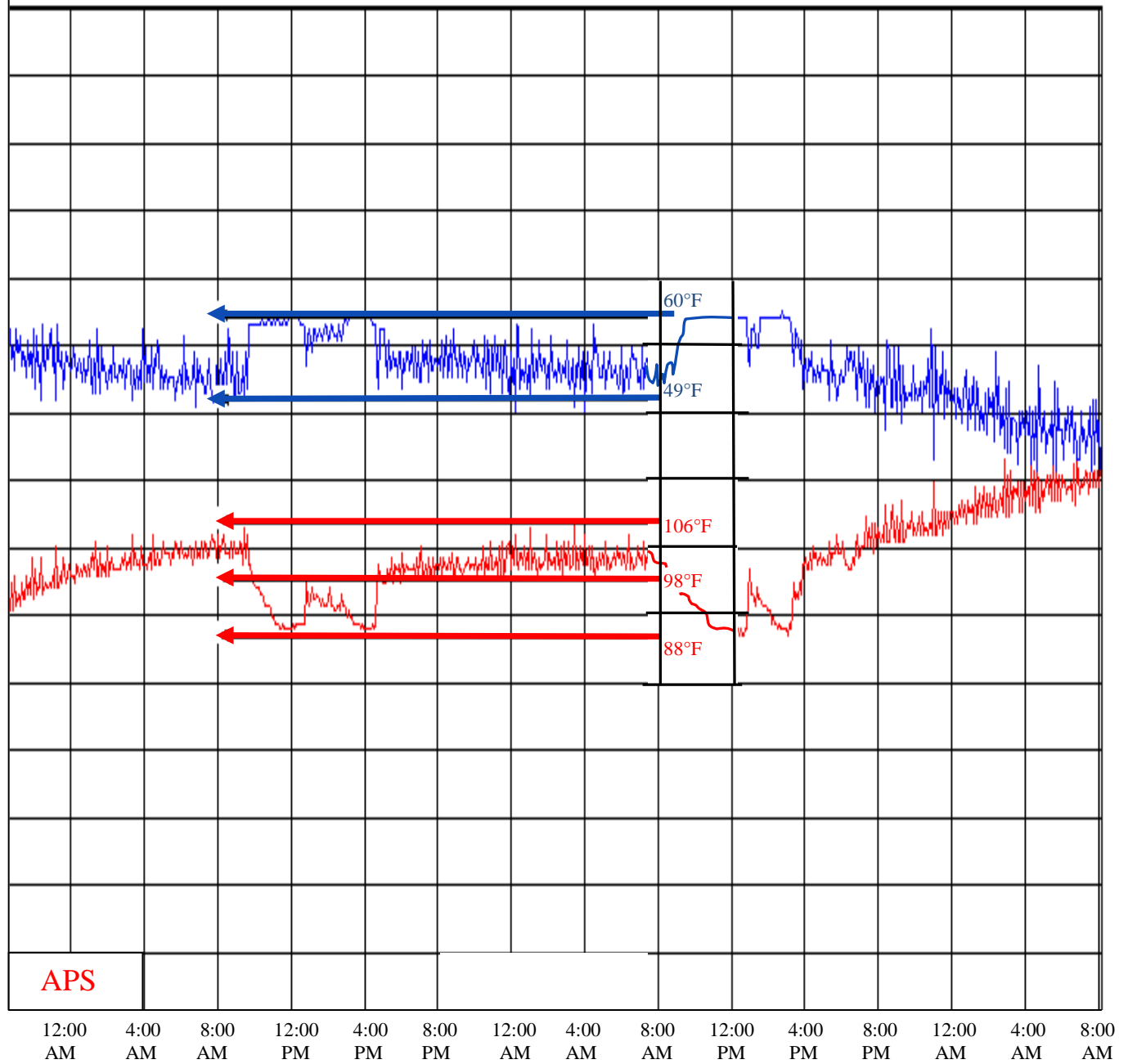
Sensing point (F) on FIGURE #2 is the location where the supply water temperature readings were obtained and sensing point (G) on FIGURE #2 is the location where the actual outside air temperature readings were obtained.

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.

GRAPH #2

ENERGY CONSERVATION DEMAND SIGNAL
HOT WATER SUPPLY BASED ON 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.**

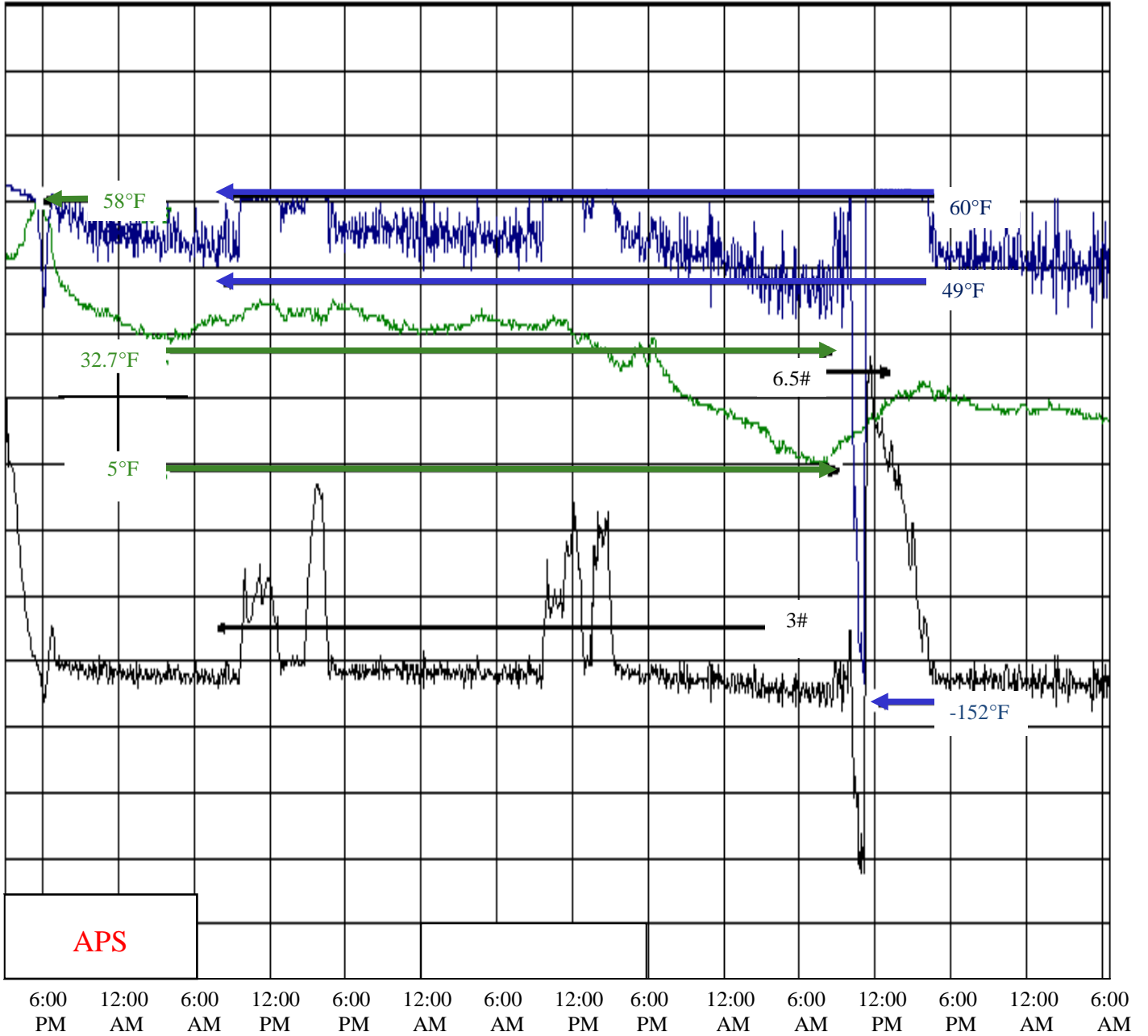
A multi-selector determines the heating requirement of the coldest room. It selects the lowest signal to indicate the true requirement for heating. Relays are used to offset the coldest room's signal such that it will create an Energy Conservation Demand Temperature Signal of 60°F any time the room has 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.

GRAPH #3

ACTUAL OUTDOOR AIR TEMPERATURE
ENERGY CONSERVATION DEMAND SIGNAL
COOLEST ROOM BRANCH SIGNAL (PSIG)



GRAPH #3

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

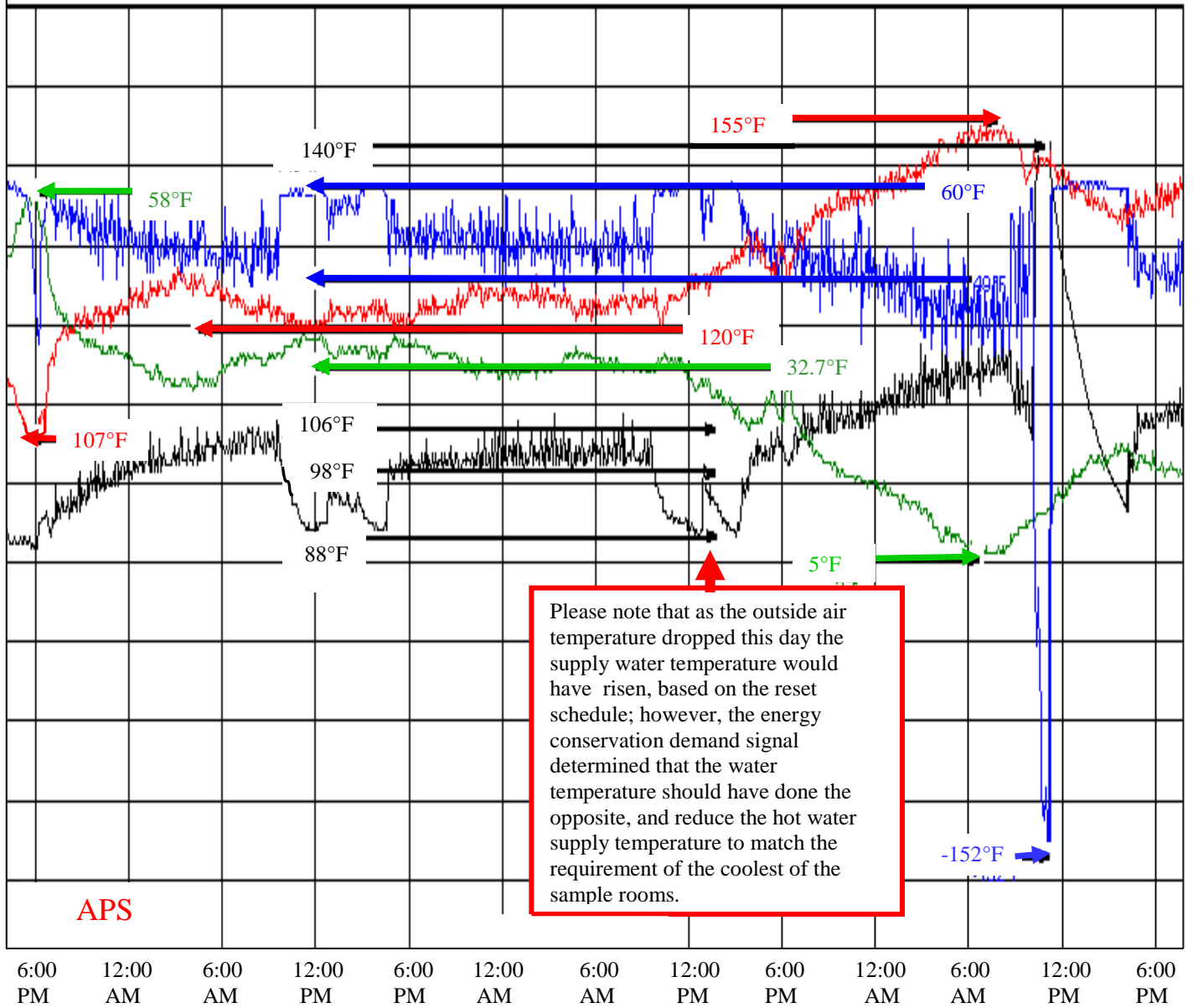
The “COLDEST ROOM BRANCH SIGNAL” is attained via a multi-selector, which produces the lowest signal of the rooms that are sampled. The coldest room signal is obtained at sensing point (H) on FIGURE #2.

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.

GRAPH #4

ENERGY CONSERVATION DEMAND SIGNAL
ACTUAL OUTDOOR AIR TEMPERATURE
HOT WATER SUPPLY TEMPERATURE BASED ON CONSERVATION DEMAND SIGNAL
HOT WATER SUPPLY TEMPERATURE BASED ON OUTDOOR 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.

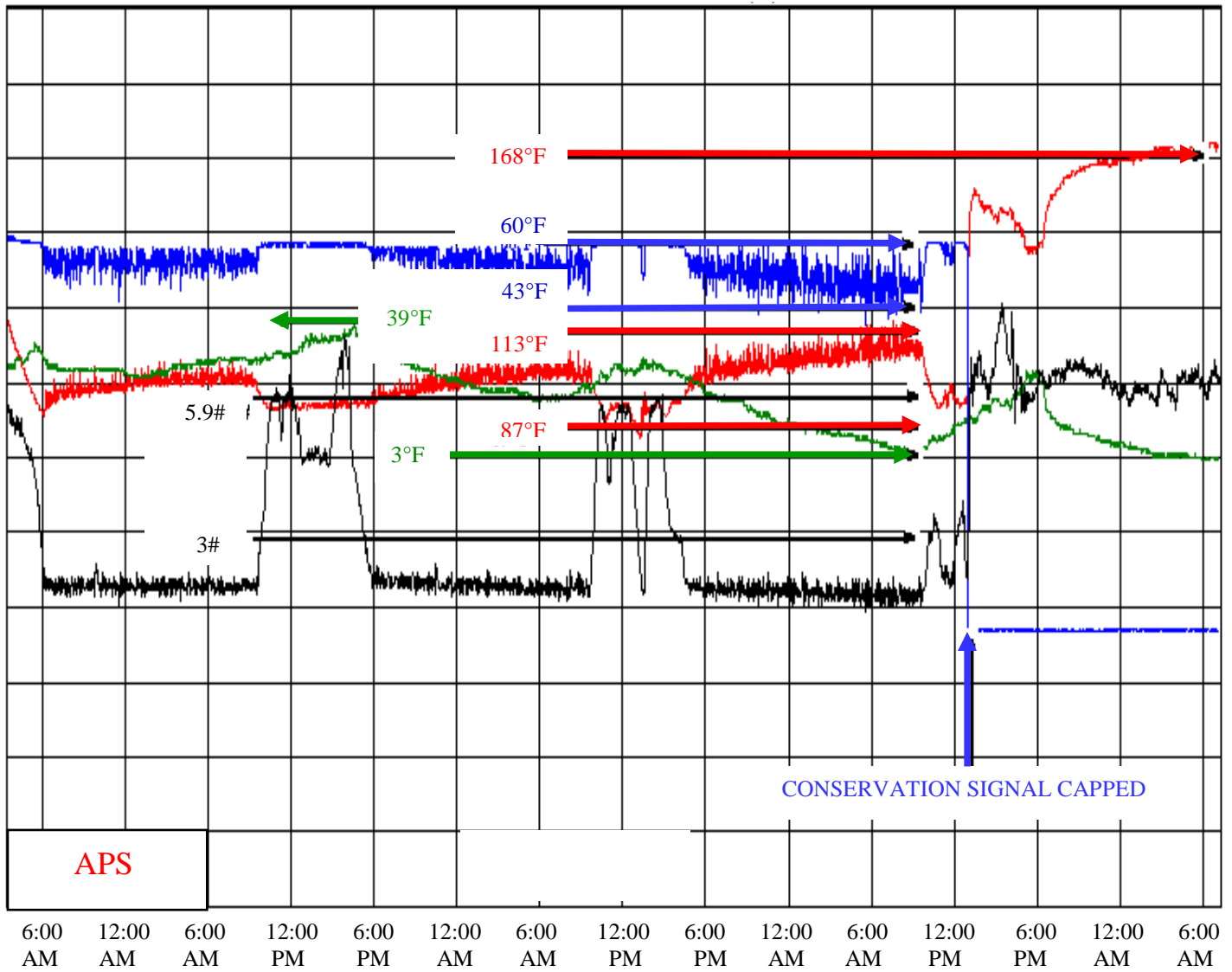
The Energy Conservation Demand Signal responds directly to the actual heating requirements of the coolest spot in the building while the outside air temperature sensor is oblivious to the building's needs and only reports the outside air temperature condition. During the afternoon of February 25, 1996 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.

GRAPH #5

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



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.**

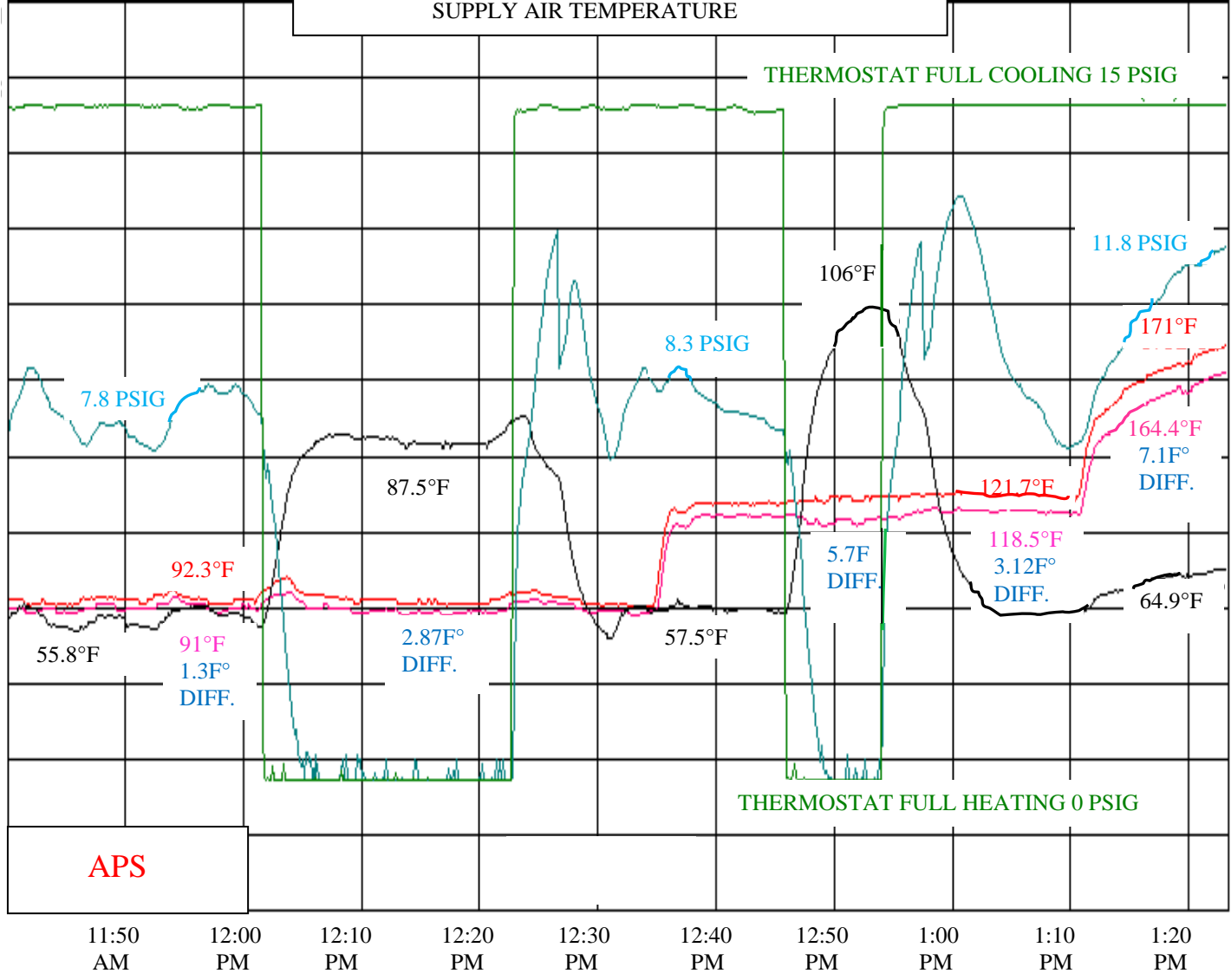
The increased cooling required is the result of heat escaping into the unitventilator.

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

POINTS ILLUSTRATED ON UNITVENTILATOR DRAWING

- THERMOSTAT BRANCH SIGNAL (PSIG)
- LOW LIMIT BRANCH SIGNAL (PSIG)
- COIL SUPPLY WATER TEMPERATURE
- COIL RETURN WATER TEMPERATURE
- SUPPLY AIR TEMPERATURE



APS

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.

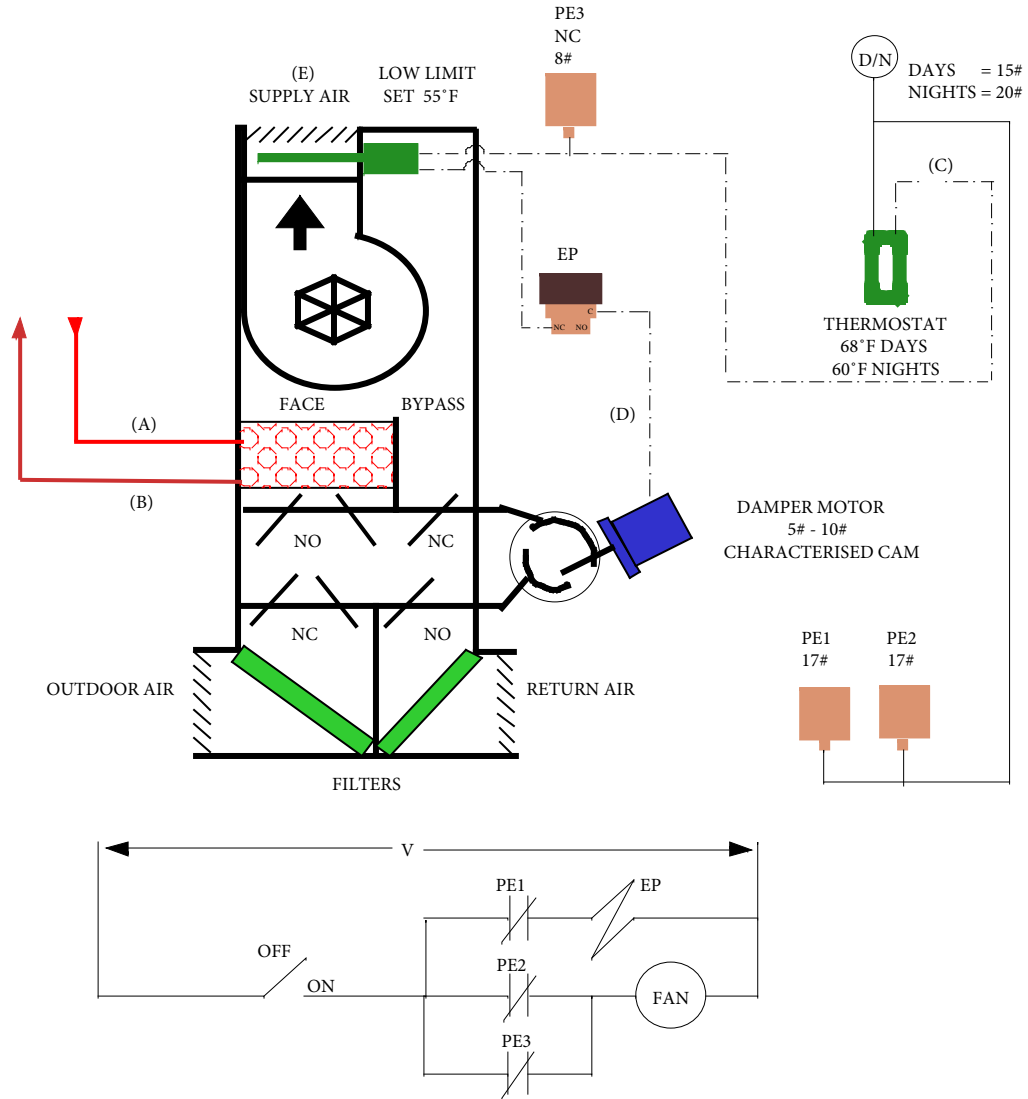
The system can be controlled equally well with either completely computer logic or completely pneumatic logic.

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.

FIGURE ONE

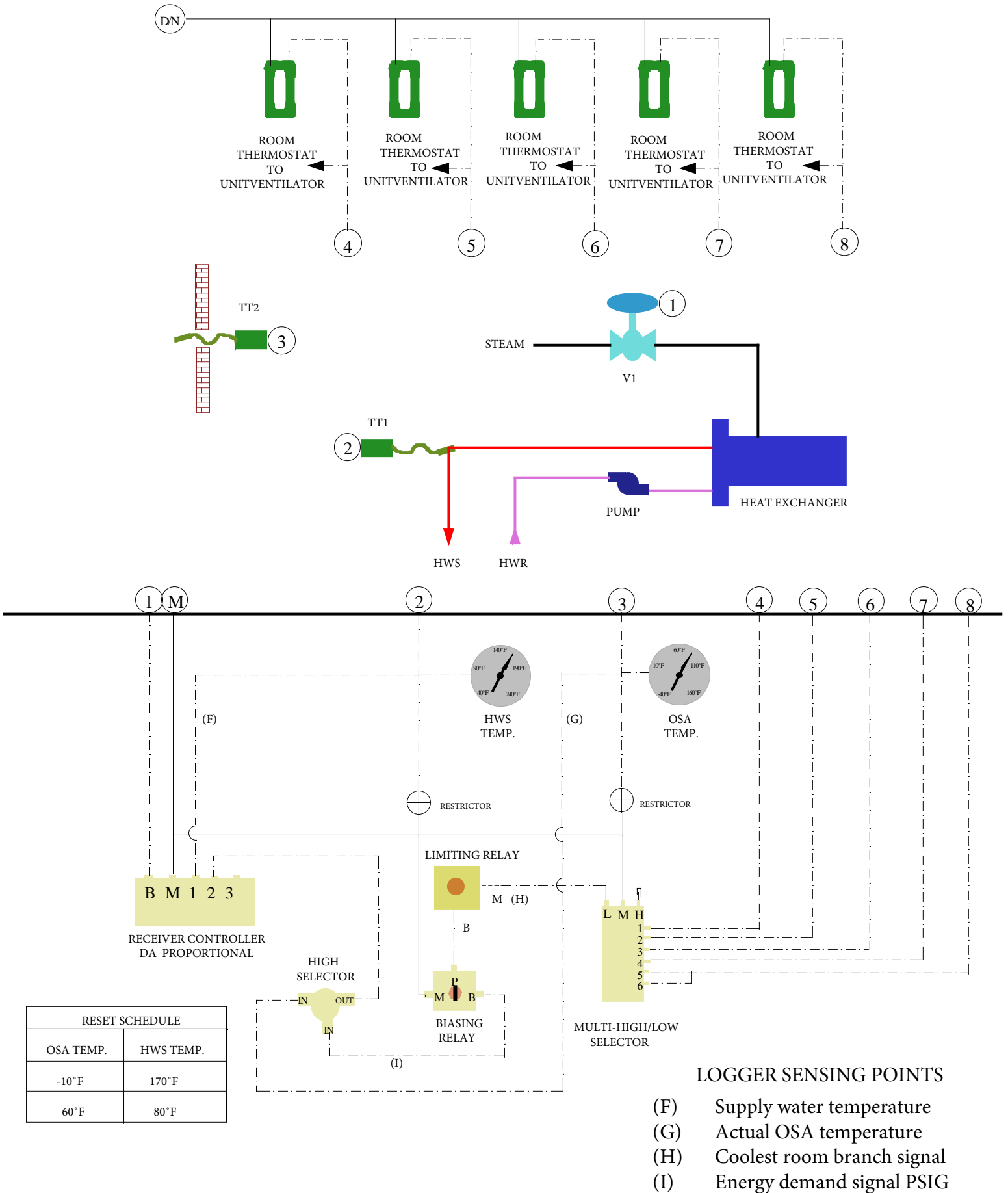


FACE & BYPASS UNIT VENTILATOR

LOGGER SENSING POINTS

- (A) Hot water supply temperature
- (B) Hot water return temperature
- (C) Thermostat branch pressure
- (D) Low limit branch pressure
- (E) Discharge air temperature

FIGURE TWO



RESET SCHEDULE	
OSA TEMP.	HWS TEMP.
-10°F	170°F
60°F	80°F

- LOGGER SENSING POINTS**
- (F) Supply water temperature
 - (G) Actual OSA temperature
 - (H) Coolest room branch signal
 - (I) Energy demand signal PSIG

VAV PERFORMANCE CASE STUDY

Analysts of Pneumatic Systems Limited

APS

PHONE (905) 640-2333

FAX (905) 640-2444

analystsofpneumatic@bellnet.ca

<http://www.apscontrols.ca>