MULTIZONE

CASE STUDY

APS

WEBSITE: http://www.apscontrols.org

EMAIL: analystsofpneumatic@bellnet.ca

PHONE: (905) 640-2333

DATE: 17/03/25

PREFACE

Multizone HVAC systems, illustrated on page 1, are extremely energy inefficient and often do not maintain good comfort conditions.

Properly upgraded logic has achieved energy consumption reductions of > 40% on many systems, with examples calculated by the building owners shown on pages 8 and 9, with much improved comfort in the occupied spaces.

IN ORIGINAL DESIGNS

- The hot deck (HD) plenum temperature varied directly through a reset schedule in proportion to the outside air (OSA) temperature changes. As the OSA became colder, the HD became hotter.
- The cold deck (CD) temperature was controlled to 13˚C with varied fresh air quantities in winter and with mechanical cooling in summer.
- The hot deck/cold deck dampers were modulated by individual room thermostats, mixing HD air and CD air in the rooms' supply ducts to control their rooms' temperatures.
- The fan systems typically ran 24/7, often at the same space temperatures.

ISSUES WITH THE CONVENTIONAL DESIGN

- The HD and CD control did not communicate with the zone thermostats' demand signals; therefore, did not continually know if cooling or heating was required by any of the zone thermostats.
- The actual requirement for heat varies significantly from simple reset from only OSA as presented in the graph on page 5.
- Often all zones are calling for cooling and no heat, but the HD is hot lessening the cooling capability of the zones' supply air as the zone dampers typically leak some air.
- The fans that run 24/7, typically waste electricity and heat.

ISSUES WITH PARTIAL BAS/PNEUMATIC CONTROL

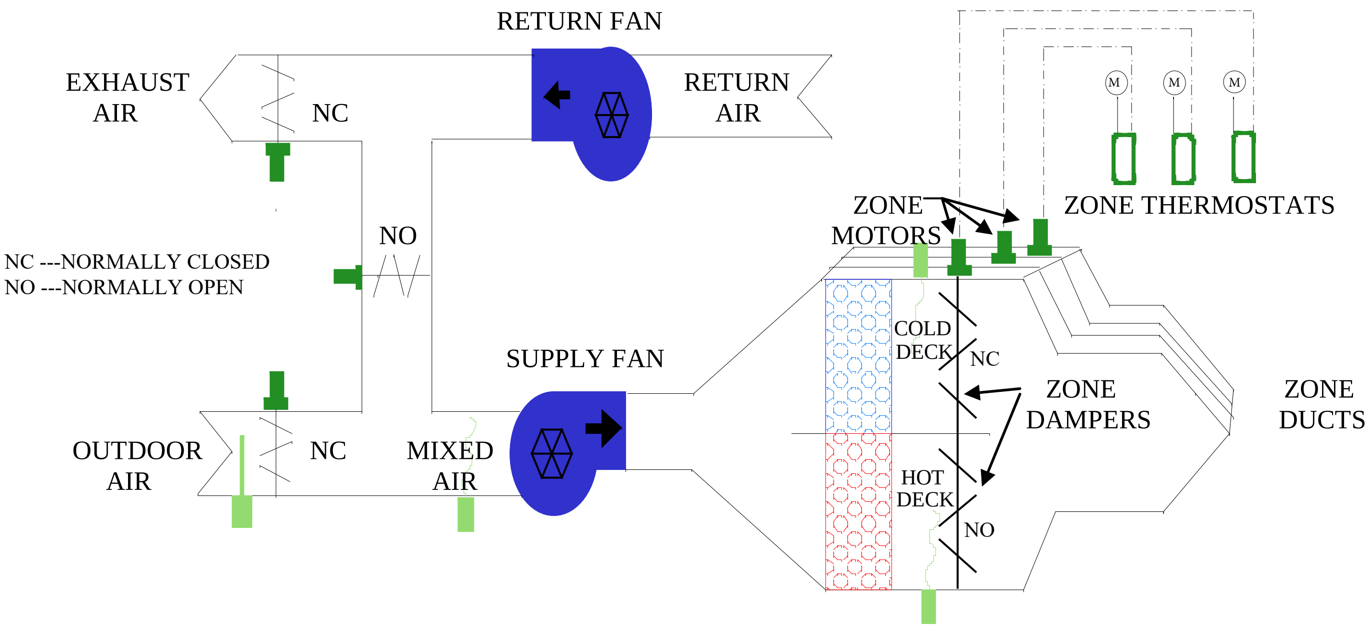
- With the BAS controlling the HD and CD and the pneumatics controlling the zone dampers, often all zones are calling for cool supply air and no heat, but the BAS is keeping the HD hot based only on OSA temperature, which is lessening the cooling capability of the zones' supply air as the zone dampers typically leak.

CONTROL LOGIC ALTERATIONS

- Gradually provide heat to satisfy the coolest zone, up to the design OSA reset schedule, after that zone has closed the CD zone damper and opened its HD zone damper and the room continues to cool down.
- Gradually provide CD cooling, down to 13˚C, to satisfy the warmest zone, after that zone has opened its CD zone damper and closed its HD zone damper and that room continues to warm up.
- If acceptable, duty cycle the system for night set back in winter from night thermostats located in the most likely area to cool fastest with the outside air, return air and exhaust air dampers in their normal position if the fans CFM values allow.
- Confirm with owner that the comfort zone range and other alterations are acceptable to their operations.

CONTENTS

THREE ZONE MULTIZONE FAN SYSTEM



MULTIZONE FAN SYSTEM

The physical arrangement of most multizones is illustrated above.

Original design caused a constant mixed air temperature of 13°C. When the outside air exceeded 21°C, the mixing dampers returned to their minimum ventilation setting.

The cold deck was controlled to 13°C constantly via the cooling coil for summer operation.

The hot deck temperature was scheduled based on outside air temperature variation. The colder the outside air temperature, the hotter the hot deck.

The thermostats blended air from the cold deck with air from the hot deck to achieve a supply air temperature satisfying the individual zone.

Modern logic knows the maximum demand for cooling and heating from all the zones. If all zone signals are within the range of the zone damper motors the thermostats are all within .5C° of set point.
This asures the heating and cooling are kept at a minimum value.
The acceptable range of temperature shift is adjustable through sensitivity (proportional band) of the zone thermostats. EXAMPLE: The heating/cooling disallows any room below 20°C or above 23°C.

If any zone opens its cold deck 100% and closes its hot deck 100%, that zone can gradually cause the cold deck temperature to be lowered.

Conversely, if any zone opens its hot deck 100% and closes its cold deck 100%, that zone can gradually raise the hot deck temperature.

The coolest demand for cold deck is limited to a minimum of 13°C and the hottest demand for hot deck is limited by an outside air reset based on the original design.

The system respects the ventilation code, receiving at least minimum ventilation during occupied mode.

The gas sections of Wendell Statton PS and West Hill C.I. in Scarborough and the Administration Office and Henry Street HS in Durham are all multizones. The energy reductions are on pages 8 and 9.

MIXED AIR

MULTIZONE COOLING DURING WINTER

Mixed air in a fan system is the body of air that is a mixture of outside air and return air from the building. Most conventional fan systems attempt to control the mixed air temperature in the range of 13°C. A certain percentage of the fresh air is required for ventilation purposes and exhaust air replacement, while fresh air beyond that percentage is required for cooling purposes only.

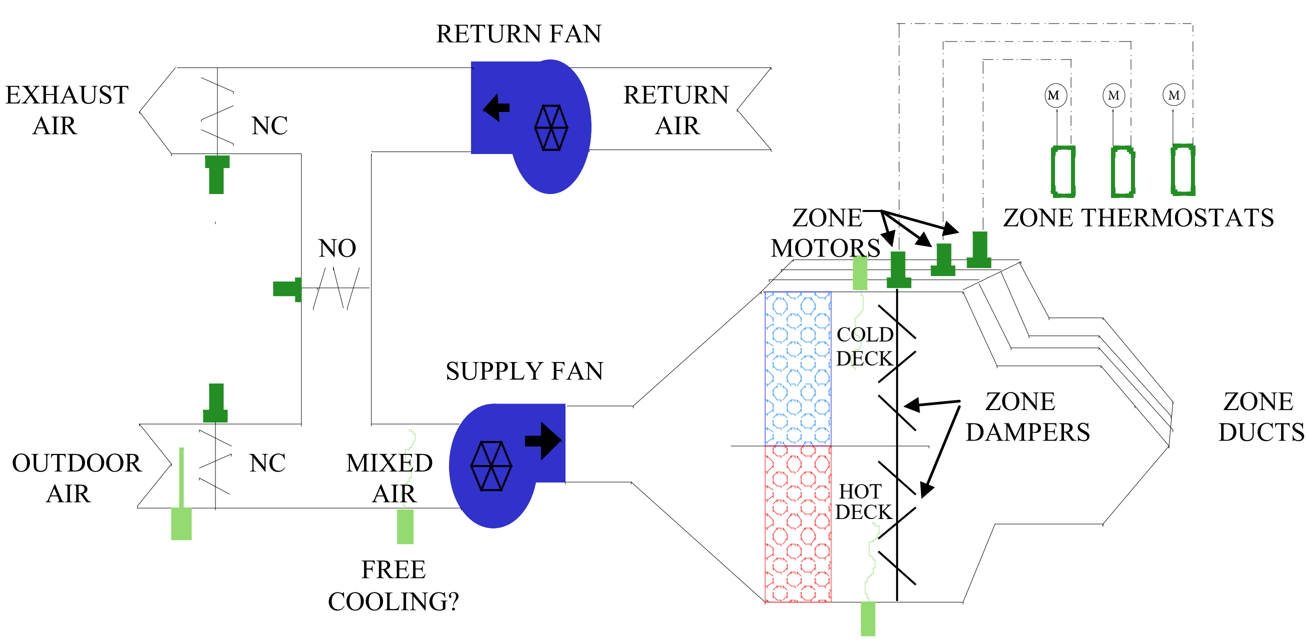
Often the mixed air is referred to as “FREE COOLING”, but is it always? Most buildings require varying degrees of cooling, even during the winter. The mixed air in the range of 13°C is the design temperature for times when the building requires maximum cooling. What happens when that amount of cooling is forced into the building and the maximum amount of cooling is not required?

The building will either become uncomfortably cold or the building system will have to add heat to compensate for the unwanted cooling.

This is similar to going home and putting a manual switch on your central air conditioner to have refrigeration active all the time. When the load for cooling is great enough to match the capability of the refrigeration unit the building will be comfortable. When the cooling load drops, you will either have to find a way to have the cooling delivered match the actual requirement or turn on your furnace to remain comfortable.

“FREE COOLING” is not “free” if the amount of cooling delivered is not required by any of the zones. This “FREE COOLING” cost is equal to the heating energy cost to correct for the over-cooling.

THREE ZONE MULTIZONE FAN SYSTEM



MULTIZONE HEATING LOGIC

Many multizone control systems determine the hot deck heating temperature based only on the outside air temperature. This is similar to allowing your furnace to run for a fixed number of minutes per hour based on the outside air temperature.

This may sound logical, but consider these heating scenarios in your own house.

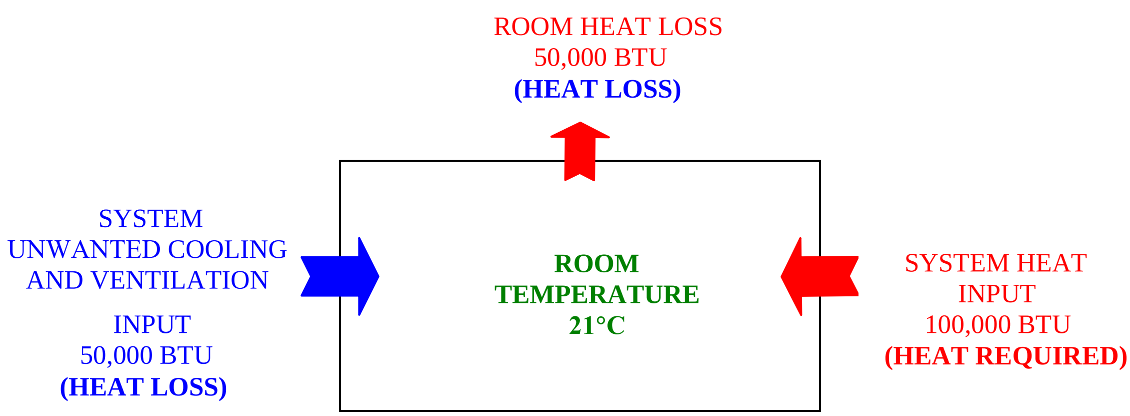
SCENARIO	OSA TEMP.	FURNACE RUN	WIND	OCCUPANCY	SUN CONDITION	ROOM TEMP.
ONE	0°C	15 MIN./HR	STILL	25 (GATHERING)	BRIGHT NOON SUN	?
TWO	0°C	15 MIN./HR	BLIZZARD	YOU ALONE	NIGHT	?

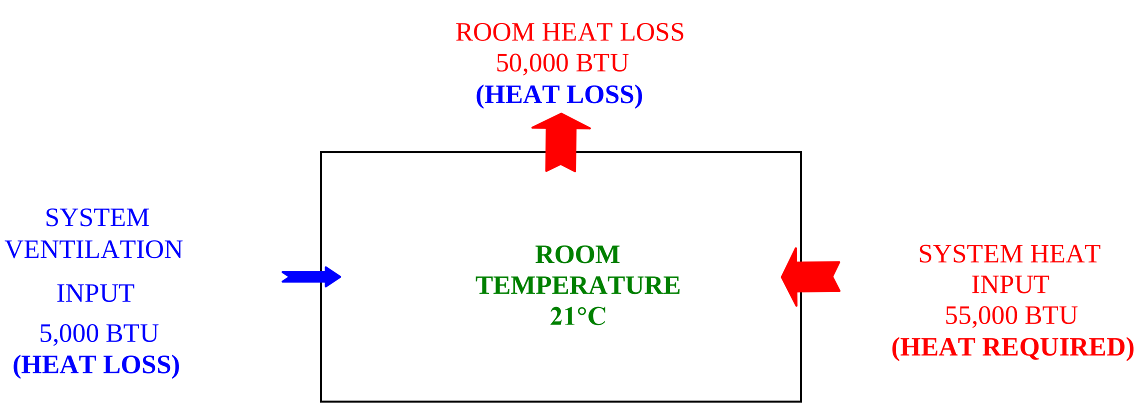
If the same heating input, based on the 0°C outside air temperature is enough to keep you warm in scenario two's conditions, the gathering will over-heat under the conditions of scenario one with the same run time based only on the outside air temperature.

The graph on page 5 illustrates a comparison of actual heating requirements of the coolest area of the building to heating requirements determined by only outside air temperature.

CO-ORDINATING THE HEATING AND COOLING

WHICH ARRANGEMENT SEEMS BETTER?





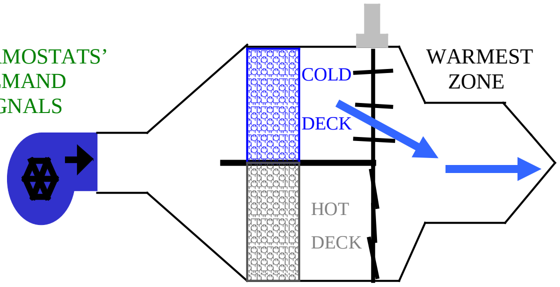
NOTE: When the hot deck, based on only outdoor air reset, is hotter than any zone requires, the cold deck must become colder to compensate for the unwanted heating.

When the cold deck is colder than any zone requires, the hot deck must become hotter to compensate for the unwanted cooling.

ZONE HEATING-COOLING SEQUENCING IN MULTIZONE LOGIC

18#

THERMOSTATS' DEMAND SIGNALS



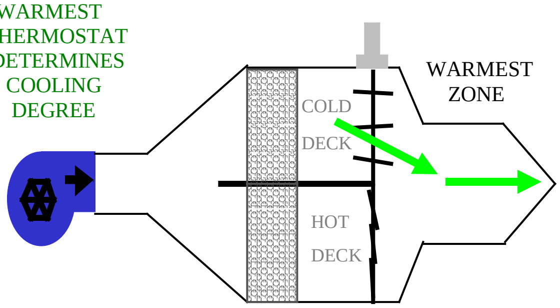
The zone thermostat with the greatest requirement for cooling modulates the free cooling in the winter and the mechanical cooling in the summer, to varying degrees, just enough to keep the served areas within the comfort zone.

The zone demanding cooling does not mix any hot deck air with the air sent to that zone during this mode of operation, allowing the least amount of cooling, in the cold deck, to maintain comfort conditions.

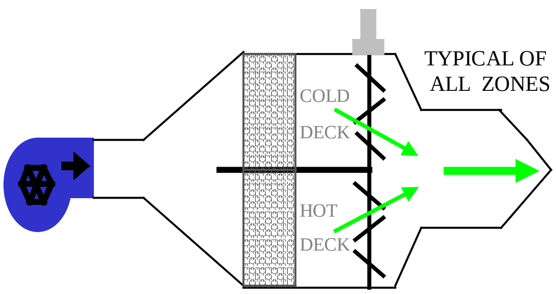
13#

At least minimum ventilation is maintained during all occupied times.

WARMEST THERMOSTAT DETERMINES COOLING DEGREE



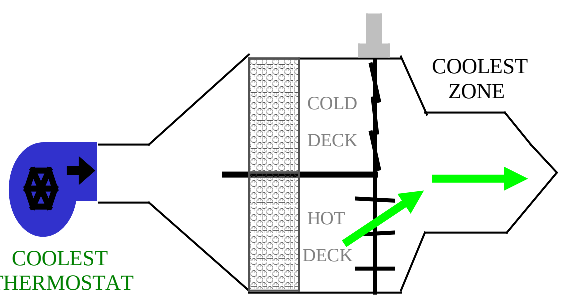
The zone thermostat with the greatest requirement for cooling modulates its zone dampers to completely close its hot deck and completely open its cold deck. At this point the cooling is still not active.



All zone thermostats are modulating their zone hot deck and cold deck dampers within their spring range; therefore, all are within one .5 C° of set point.

The hot deck is maintained at minimum heat and the cold deck for summer holds the cooling off and for winter the free cooling is off.

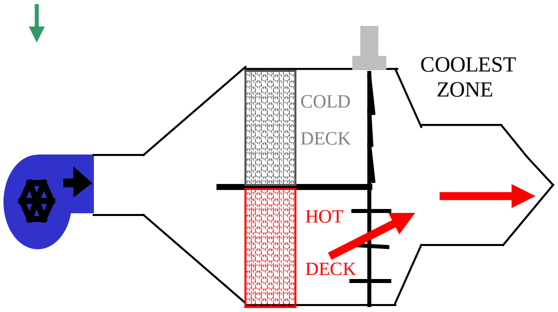
8#



The zone thermostat with the greatest requirement for heating modulates its zone dampers to completely close its cold deck and completely open its hot deck. At this point the heating is still not active.

COOLEST THERMOSTAT DETERMINES HEATING DEGREE

7.5#



The zone thermostat with the greatest requirement for heating modulates the hot deck heating valve, to varying degrees, just enough to keep the served areas within the comfort zone.

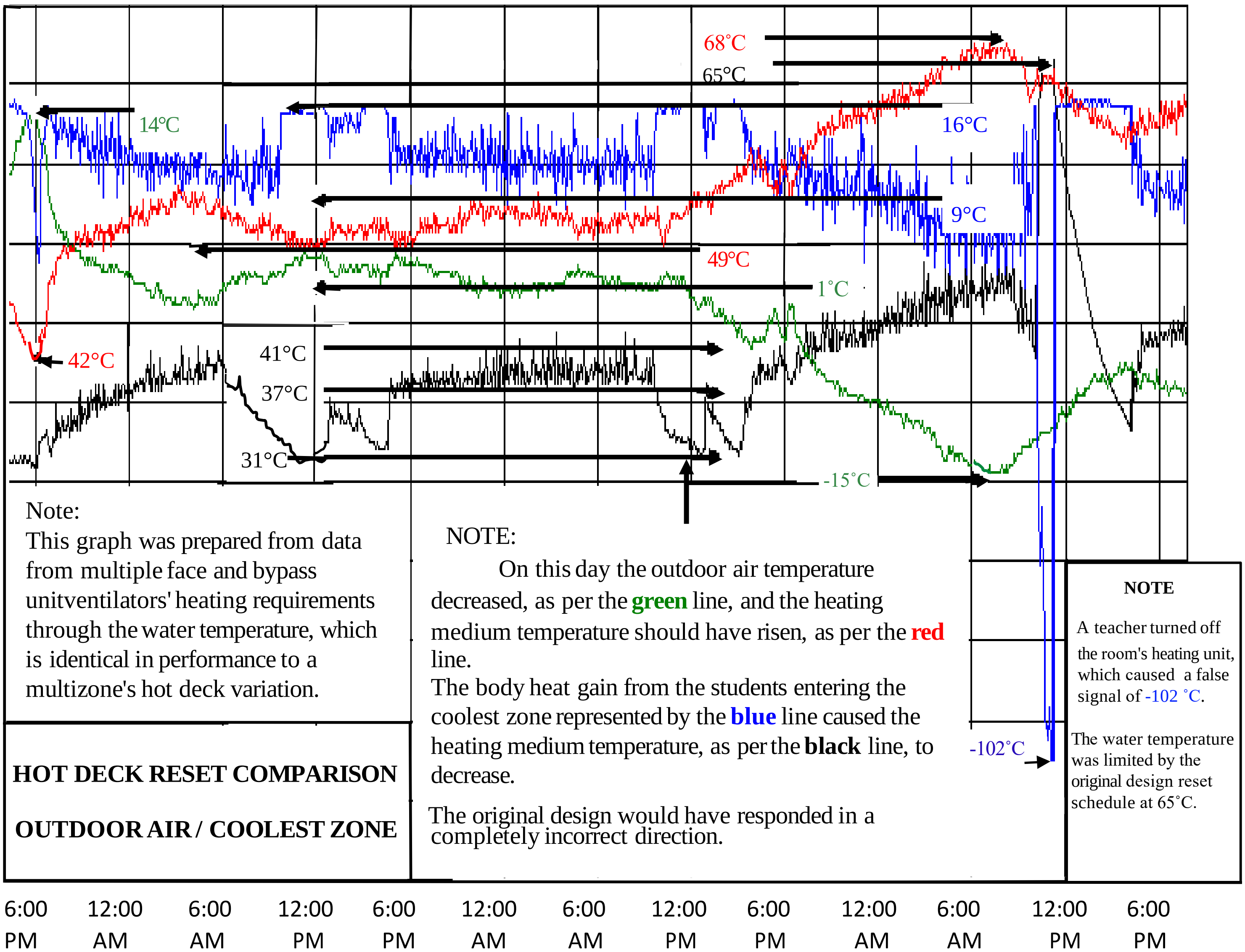
The hot deck is also limited by the outside air temperature and sometimes the return air temperature.

The zone demanding heating does not mix any cold deck air with the air sent to that zone during this mode of operation, allowing the least amount of heating, in the hot deck, to maintain comfort conditions.

2#

HEATING REQUIREMENT OF COOLEST ZONE COMPARED TO HEATING SUPPLY

BASED ON ONLY OUTDOOR AIR TEMPERATURE



This graph illustrates the heating temperature difference between resetting only from the outside air temperature and resetting from the coolest room of the area served.

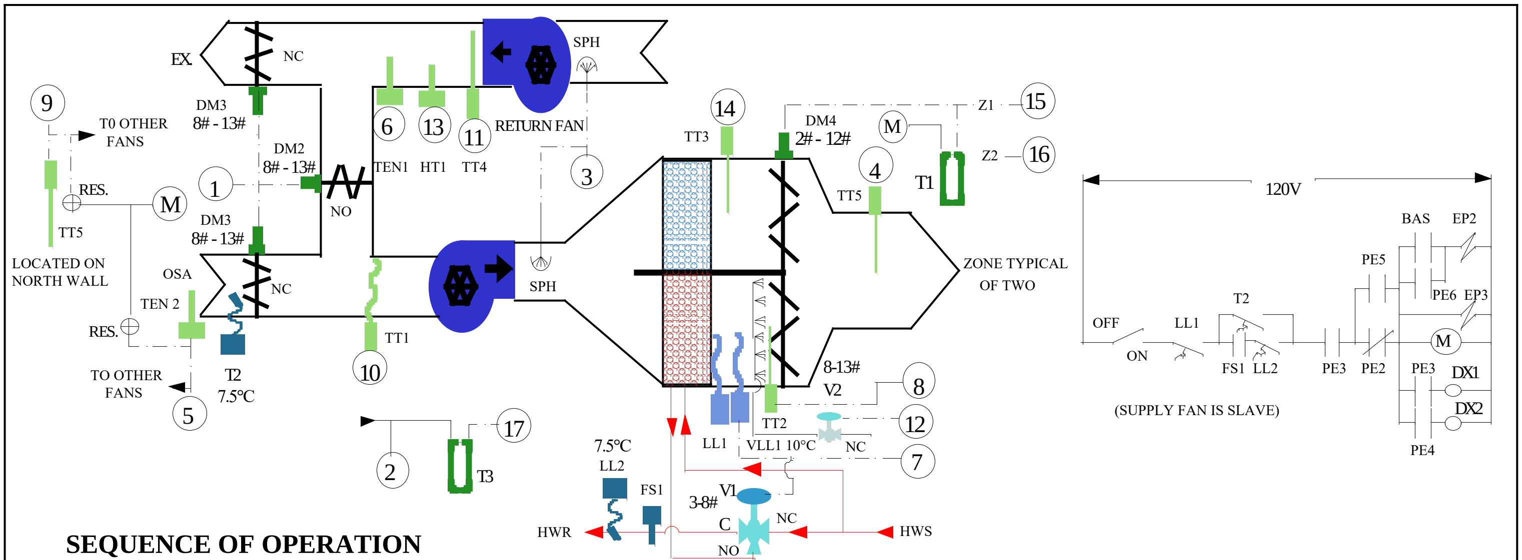
The red line illustrates the heating temperature based on the actual outside air temperature, illustrated by the green line. This is the originally designed reset schedule. The red and green lines are symmetrical.

The black line illustrates the heating temperature based on the heating requirement of the coolest area served illustrated by the blue line. This is the conservation circuit. The black and blue lines are symmetrical.

The coolest room's signal "tells" the main reset controller that the outside air temperature is warmer than the actual outside air temperature, causing the reset controller to produce heating at exactly the correct temperature to keep the coolest zone in the comfortzone.

Note that the heating medium temperature drops when the coolest school class becomes occupied in the morning: the heating temperature rises at noon when the bodies leave the coolest room: it temperature drops again when the bodies re-enter the room for the afternoon and rises again when the bodies leave for the day.

EXAMPLE RETROFITTED MULTIZONE FAN SYSTEM FROM HENRY STREET HIGH SCHOOL



SEQUENCE OF OPERATION

The BAS disables the main air to night thermostat (T3) for day operation closing pressure switch (PE2), causing the fan to run continuously. The BAS holds the dampers in the recirculation position via solenoid valve (EP2) for morning warm-up.

Zone thermostats (T1) send their signals to modulate their respective zone damper motors (DM4) and to high and low selectors (HS1) and (LS1).

HS1 sends the greater demand for cooling (higher signal) to biasing relay (BR1) which sends its signal to receiver controllers (RC3) and (RC2). RC3 senses the outside air temperature via transmitter (TT5) and sends its signal to pressure switches (PE3) and (PE4) to cycle the refrigeration when the outside air is more that 13°C. RC2 senses the mixed air temperature via transmitter (TT1) and sends its signal to enthalpy logic module (EN1). EN1 senses the outside and return air enthalpy via transmitters (TEN1) and (TEN2). EN1 sends its signal to minimum positioning relay (MPR1) which sends its signal through EP2 to modulate the mixing damper motors (DM1), (DM2) and (DM3).

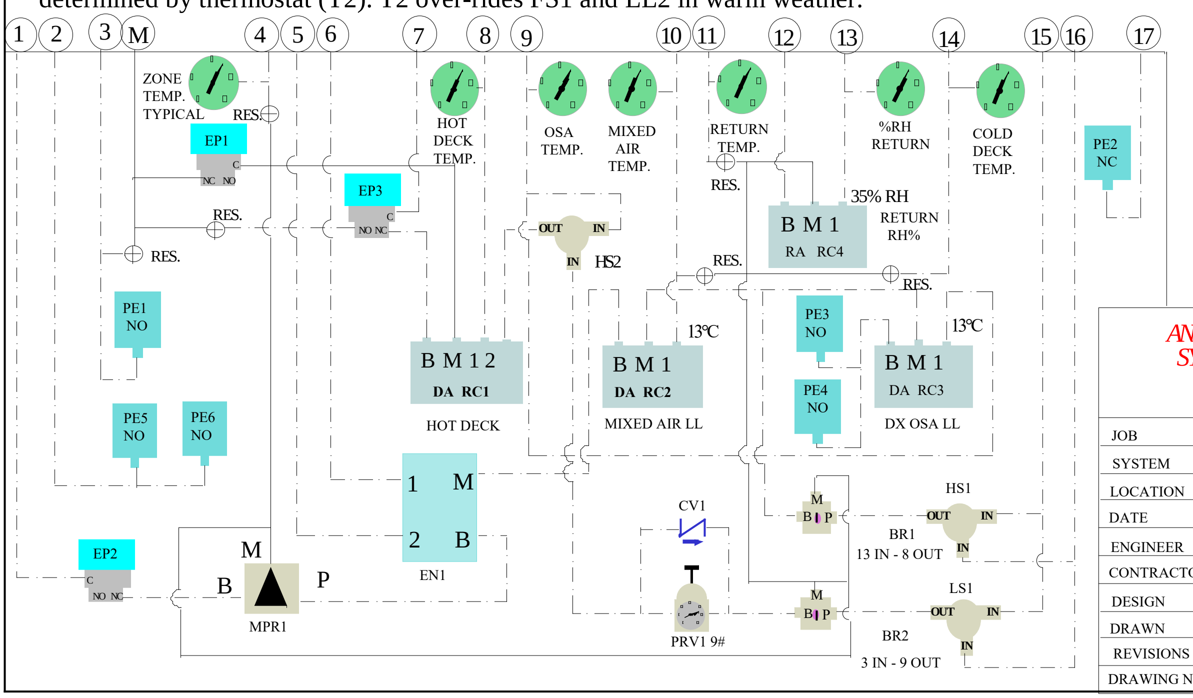
LS1 sends the greater demand for heating (lower signal) to biasing relay (BR2), which sends its signal to regulator (PRV1), which sends its signal to high selector (HS2), which also receives a signal from the outdoor air temperature transmitter (TT5). HS2 sends its signal to receiver controller (RC1). RC1 senses the hot deck temperature via transmitter (TT2) and sends its signal through solenoid valve (EP3) to modulate heating valve (V1).

At night the BAS holds the mixing dampers in their normal positions and provides main air to T3, allowing T3 to duty cycle the fan via PE2 at 14.5°C.

The mixing dampers are in their normal positions and V1 is controlled via low limit (VLL1) when the fan is off.

If the system is required for day operation at night the interval timer on drawing eight may be turned to the desired amount of time, altering the 14 PSIG night main to 20 PSIG. Pressure switches (PE5) and (PE6) close their contacts causing the fan to run continuously with day ventilation.

If low limit (LL1) senses a temperature below its set point or either sprinkler head (SPH) melts the fan system will shut down. If low limit (LL2) senses a temperature below its set point or the flow switch (FS1) senses no flow, the fan will shut down in cold weather as determined by thermostat (T2). T2 over-rides FS1 and LL2 in warm weather.



RC1 RESET SCHEDULE		
OSA	HOT DECK	LOWEST SIGNAL
-23°C	54.4°C	.9 PSIG
15.5°C	21°C	3 PSIG

ANALYSTS OF PNEUMATIC SYSTEMS LIMITED (APS)
(905) 640-2333

JOB	HENRY STREET HIGH SCHOOL
SYSTEM	CAFETERIA UNIT AHU1
LOCATION	HENRY STREET, WHITBY
DATE	MAY 29, 2008
ENGINEER	
CONTRACTOR	
DESIGN	DS
DRAWN	DS
REVISIONS	
DRAWING NUMBER	ONE OF EIGHT

AHU1

GENERAL EXPLANATION REGARDING SYSTEM LOGIC BENEFITS

ORIGINAL DESIGN PROBLEMS REGARDING ENERGY WASTE, CONTROLLING PRIOR TO THE CIRCUIT ON DRAWING ONE.

CURRENT DESIGN LOGIC IMPROVEMENTS TO SAVE ENERGY. CONTROLLING AS PER THE CIRCUIT ON DRAWING ONE

-1- The fan system ran continuously nights, days and weekends
This wasted electrical energy.

The fan system now runs continuously for day mode, but cycles on night mode only if the night thermostat senses the temperature has dropped to 14.5°C, reducing the building's heating and cooling energy consumption. When the fan is off the heating valve is controlled by a pneumatic low limit preventing the duct from over-heating to save energy and protect the coil.

-2- The hot deck (heating) temperature was varied directly in relationship to changes in the outdoor air temperature. There was no compensation for body heat load, solar heat load, wind effect, lighting effect, etc.

At times none of the zones required heating, yet the hot deck would still be very hot. All dampers tend to leak; therefore, the zones that were demanding full cooling were still getting unwanted heating.
This wasted heating energy.

The new logic holds the heating at minimum level (21°C) until at least one zone has completely closed off its cold deck damper and completely opened its hot deck damper. As that zone's signal drops, holding the zone dampers completely in the full hot deck position, the hot deck temperature is allowed to rise just enough to keep the coolest zone within the comfort zone. This assures that the minimum amount of heat is used at all times to just barely satisfy the coolest zone. The outdoor temperature establishes the reset schedule shown on the drawing, which limits the temperature in the hot deck available to the coolest zone.

-3- The mixed air temperature was controlled constantly at 13°C. This setting addressed the maximum requirement for cooling: at all other times it was too much cooling and heat had to be added to compensate for the over-cooling.
This wasted heating energy.

The minimum positioner assured at least minimum ventilation, addressing air quality concerns. (unchanged)

The fresh air enthalpy (total heat content of the air) and the return air enthalpy was compared selecting the lesser cooling load when the system was in summer operation. (unchanged)

The new logic holds the mixed dampers at their minimum ventilation position until at least one zone has opened its cold deck damper completely and closed its hot deck damper completely. As that zone's signal increases, holding the dampers completely in the full cold deck position, the mixed air temperature is allowed to drop, limited to a minimum of 13°C. This assures that the minimum amount of cooling is used at all times to just barely satisfy the warmest zone.

NOTE: IF ALL THE ZONE DAMPERS ARE MODULATING, WITHIN THEIR SPRING RANGES, THE HOT DECK REMAINS AT MINIMUM HEATING AND THE COLD DECK REMAINS AT MINIMUM COOLING. THE VENTILATION IS MAINTAINED AT THE MINIMUM VENTILATION VALUE SATISFYING THE CODE REQUIREMENTS.

THE BOARD OF EDUCATION FOR THE BOROUGH OF SCARBOROUGH

CONTROL MODIFICATIONS BY

A P S

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

NOTES: Actual Board information copied into Word.

The gas sections of West Hill C.I. and Wendell Statton Sr. P.S. were multizones.

THE DURHAM BOARD OF EDUCATION

CONTROL MODIFICATIONS BY

A P S

	ENERGY USE YEAR PRIOR TO CHANGE		ENERGY USE YEAR FOLLOWING CHANGE		ENERGY SAVINGS		ECONOMIC BENEFIT
SCHOOL	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

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

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

DM: mm
1982 01 14

Notes:

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

NOTE: The administration office did not have temperature setback or setup and the fan system ran 24/7, as it served a computer room that was sensitive to humidity fluctuations.

SUMMARY

- Conventional multizone logic wastes energy and sometimes hinders comfort control.

- Client calculated reductions in energy use have ranged from 32% to 57% with improved comfort control in all. (Pages 8 and 9)

- Blending a pneumatic system controlling the zones with a BAS program controlling the hot deck and cold deck leaves a lack of communication in the system.
  Selecting the highest and lowest pneumatic zone signals, with P/I transducers receiving those signals, allows the BAS to understand the actual requirements for heating and cooling.

- The BAS or pneumatic logic controlling the hot deck and cold deck must know:

  (1) If any of the zones require heating and to what degree to keep that zone in the comfort zone.

  (2) If any of the zones require cooling and to what degree to keep that zone in the comfort zone.

  The logic must assure that the zone calling for heat is only supplying hot deck air.

  The logic must assure that the zone calling for cooling is only supplying cold deck air.

  The demanding zones must gradually apply the minimum amount of either heating or cooling to keep the zone in the acceptable comfort zone.

- Night setback and/or night setup can be achieved by duty cycling the fan at night from properly located limiting thermostats or BAS sensors if:

  1) The fan is not required at night for people, animals, plants, etc.

  2) The fresh air, return air and exhaust dampers can be commanded to full recirculation without negative impact on ducting, the fans, building pressurization, etc.

  3) Thermal changes are not negatively impacting in any way.

  4) Humidity fluctuations through temperature changes do not have a negative impact.

- Persons in the occupied space have attempted to trick control systems to satisfy their thermal desires outside the normal comfort zone by putting bags of ice or hotwater bottles on BAS sensors or adjusting pneumatic zone thermostats.

  Two remedies applied for these actions were:

  1) A BAS solution was to have a program that senses the rate of change on sensors. If a sensor's temperature changes at an unusual rate, its signal is blocked from the program setting the hot deck and cold deck temperatures for a determined period of time, while the unauthorized thermal influence melts or cools to the actual room temperature.

  2) A pneumatic solution was to assess the probability of a signal being realistic by combining the outdoor temperature, return air temperature and the demand signal to an allowable window of probability for heating or cooling requests from the demanding zones.

- Dual duct systems are very similar with some possible correction approaches on pages 5.43A, 5.43B and 5.43C in the APS Training Manual on the WEBSITE http://www.apscontrols.org .