MULTIZONE

ZONE CASE

STUDY

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MULTIZONE ZONE CASE STUDY

The intent of this case study is to allow an understanding of a significant problem relating to the Heating, Ventilation and Air Conditioning (HVAC) industry. The issue addressed involves simultaneous heating and cooling, due to poor design, installation and commissioning of control systems. This paper's intent is promotion of a thorough understanding relating to the problem, enabling one to address similar situations as they are encountered.

This case study reflects a relatively simple conservation circuit. More complicated circuits may assess the probability of a thermostat demand signal being false by looking at the outside and return air temperatures, as well as the thermostats' demand signals.

A significant quantity of greenhouse gas (GHG) enters our atmosphere directly relating to poor control arrangements as illustrated in this case study.

This case study is presented in these steps:

(1)- The fan system is considered manual as illustrated in drawing one.
What are you manually controlling?
What are your target conditions?
How would you logically adjust the operations?

(2)- The original design is illustrated in drawing two.
We identify the design problems.

(3)- The conservation circuit is illustrated in drawing three.

(4)- Graph #1 illustrates the original design heating and cooling function performance relative to varying outside air temperatures.

(5)- Graph #2 illustrates a comparison of original design cooling levels and actual cooling requirements of the warmest zone on the system.

(6)- Graph #3 illustrates a comparison of the original design heating levels and the actual heating requirements of the coolest zone on the system.

(7)- **Remember, if the control system is not making the same common sense, device poitioning decisions as an intelligent person, with identical information input, there is something wrong with the control system!**

DRAWING ONE

If charged with the responsibility of manually controlling the multizone fan system illustrated in drawing one, what considerations exist?

(1) What are you required to achieve?

-(A)- A **healthy living environment** for occupants where the supply air is being directed.

-(B)- A **comfortable environment** in the same location.

-(C)- The most **efficient energy performance**.

(2)What components do you have to achieve your desired results?
What are the functions of each of the components?

-(A)- A supply air fan and a return air fan.

The function is to force the supply air into and draw the return air from the occupied space.

-(B)- A heating source controlled via a manual heating valve.

The function is to provide heat to the system at varying quantities.

-(C)- A mechanical cooling source controlled via a manual cooling valve.

The function is to provide mechanical cooling at varying quantities.

-(D)- Manual zone mixing dampers enabling you to blend the hot deck air and the cold deck air.

The function is to satisfy individual zone thermal requirements.

-(E)- Manual dampers enabling your selection of fresh air to varying degrees and rejecting air from the building to varying degrees.

The function is **two fold**.

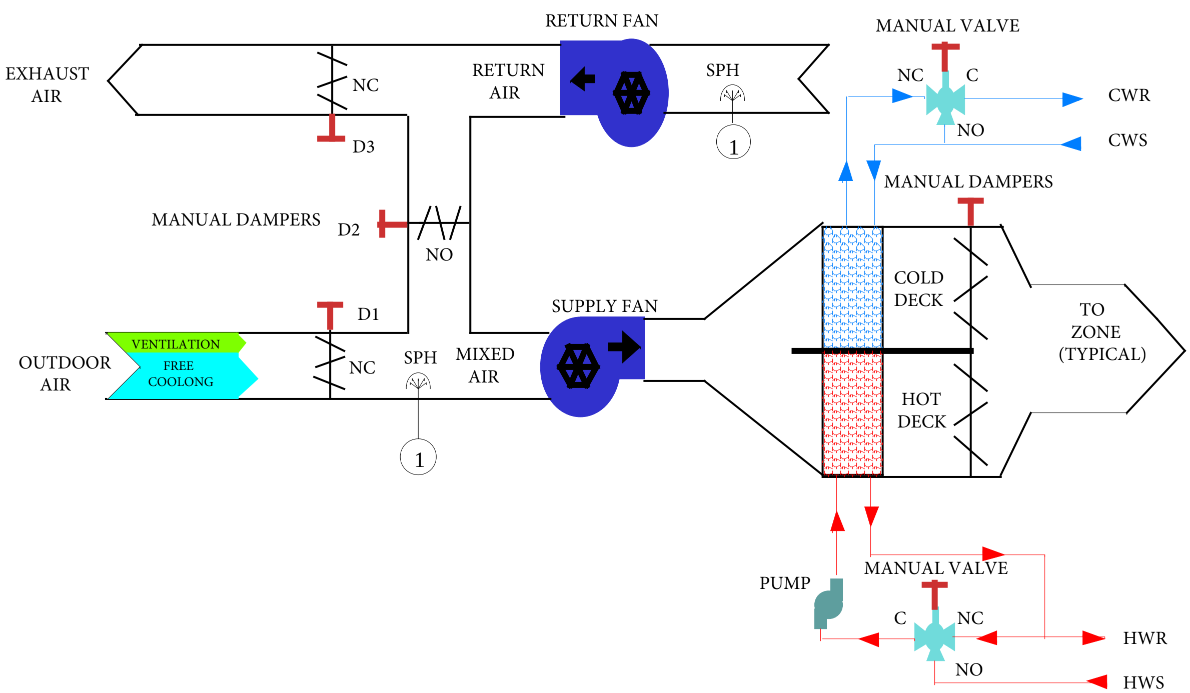
-1- Provide at least minimum ventilation based on the greater demand of either the building code relating to human occupancy or provide exhaust air replacement relating to building operations.

-2- Provide ventilation in excess of minimum ventilation requirements to achieve cooling when the outside air provides cooling benefit.

NOTES

DRAWING ONE

MULTIZONE MANUAL CONTROL



MANUAL OPERATION DRAWING ONE

VENTILATION

The manual mixed air dampers are manually adjusted to allow at least minimum ventilation at all times the space is occupied, addressing the greater of occupancy rates or exhaust fan air replacement quantities.

Shut down the fan at unoccupied times if it is not required.

Adjust the manual dampers to full recirculation at unoccupied times if there is no danger of collapsing the ductwork or creating another problem.

Duty cycle the fan at unoccupied times from a set back thermostat if this suits the system.

TEMPERATURE CONTROL

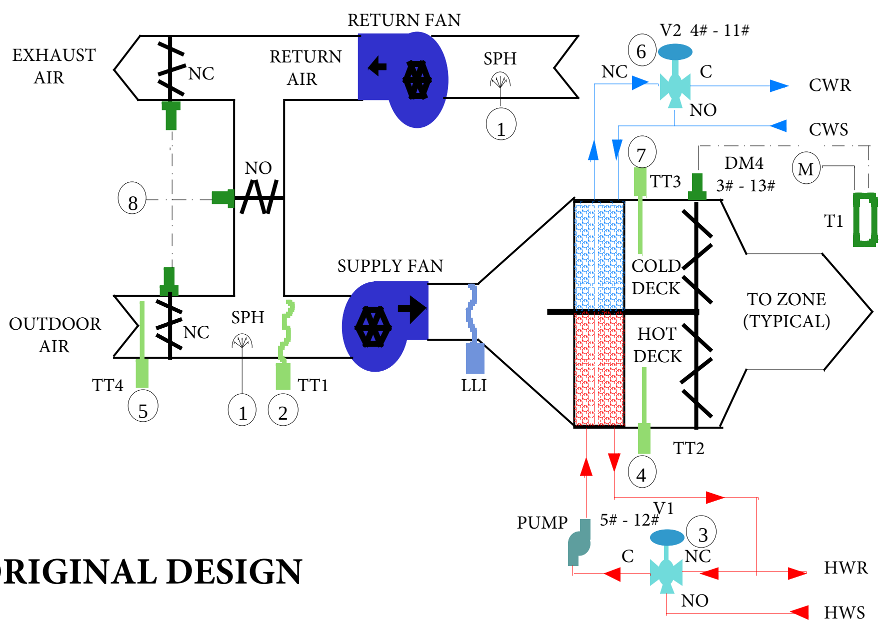
-1- If the all the zones are thermally satisfied, keep the heating valve closed to the hot deck coil, keep the cooling valve closed to the cold deck coil and leave the manual mixed air dampers in the minimum ventilation position.

-2- If any zone starts to become cool, adjust that zone's manual zone dampers to full hot deck and no cold deck. Then increase the hot deck temperature **just enough** to keep that zone within the comfort zone.
- Adjust the other zones' dampers to blend hot and cold deck air to satisfy each zone's particular thermal requirement.

-3- If any zone starts to become warm when the outside air is below 55°F, adjust that zone's manual zone dampers to full cold deck and no hot deck.
- Gradually open the fresh air damper and exhaust air damper while closing the return air damper.
- Do not allow the mixed air to drop below 55°F.
- Do not starve the supply fan or create a high discharge pressure on the return fan.
- Adjust the other zones' dampers to blend hot and cold deck to satisfy each zone's particular thermal requirement.
- If the air temperature after the heating coil drops below 38°F in any area of the coil; shut the fan down to prevent freezing of the coils.

-4- When any zone starts to become warm above 55°F outside:
- Follow the procedure outlined in "3". If the outside air can not satisfy the warmest zone, gradually open the cooling valve to the cold deck cooling coil just enough to keep the warmest zone within the thermal comfort zone.
- When the outside air becomes less efficient to cool than the return air from the occupied space, return the manual dampers back to the minimum ventilation position.

DRAWING TWO



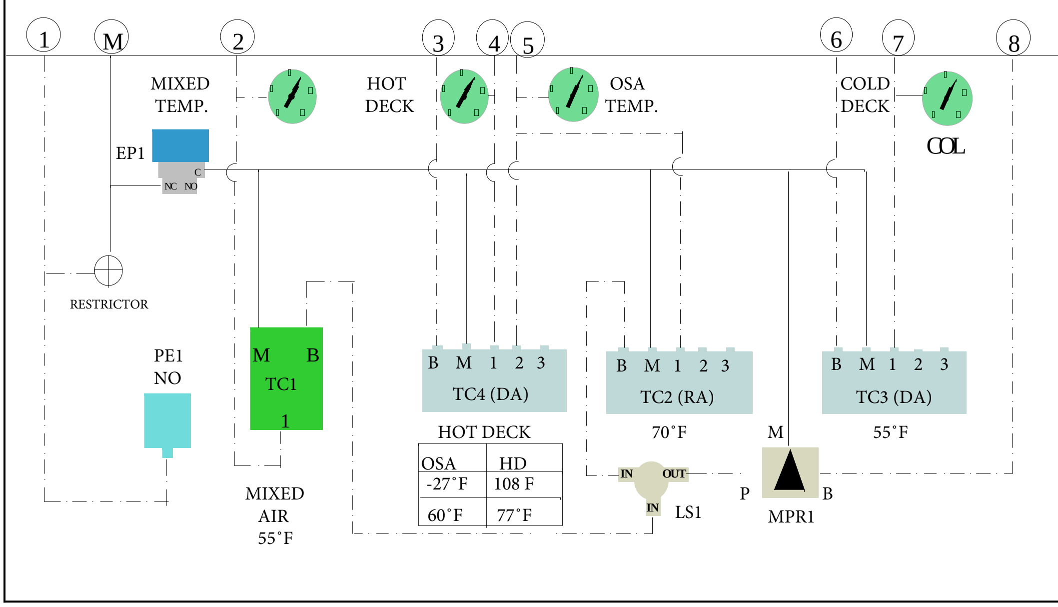
ORIGINAL DESIGN

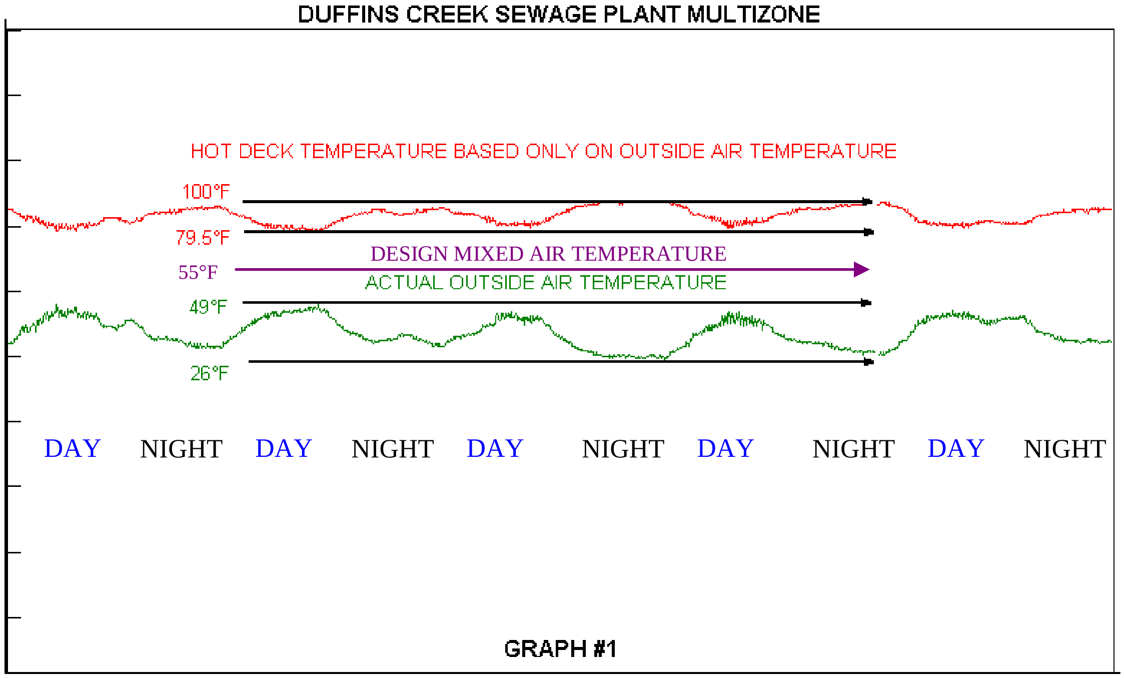
SEQUENCE OF OPERATION

The cold deck is always maintained cold. Outside air is used in winter and the cooling valve (V2) is used in summer.
The hot deck is always maintained hot, to varying degrees, based only on the outside temperature.
The thermostats modulate their respective zone damper motors, mixing hot and cold air, attaining the desired supply air temperature to satisfy the zone requirements.

BASIC LOGIC PROBLEMS

The cold deck temperature will satisfy the maximum cooling requirement the system will experience; therefore, it is too much cooling for all other conditions.
The hot deck temperature will satisfy the maximum heating requirement the system will experience at each specific outdoor temperature; therefore, it is too much heating for all other conditions.
The system produces cooling and heating, at times, when no zone requires either.
The system runs during unoccupied times.





ORIGINAL DESIGN TEMPERATURE GRAPH FOR HOT DECK AND COLD DECK

This graph illustrates the relationship between the temperature of the hot deck air and the outside air temperature. The hot deck becomes warmer as the outside air becomes cooler, at a fixed ratio, set in the hot deck controller.

On drawing two you see that the control loop controlling the hot deck does not communicate with the space heating requirements. The loop simply produces the degree of heating required for the maximum anticipated heating requirement of the occupied space. There is no compensation for load variations in the occupied space.

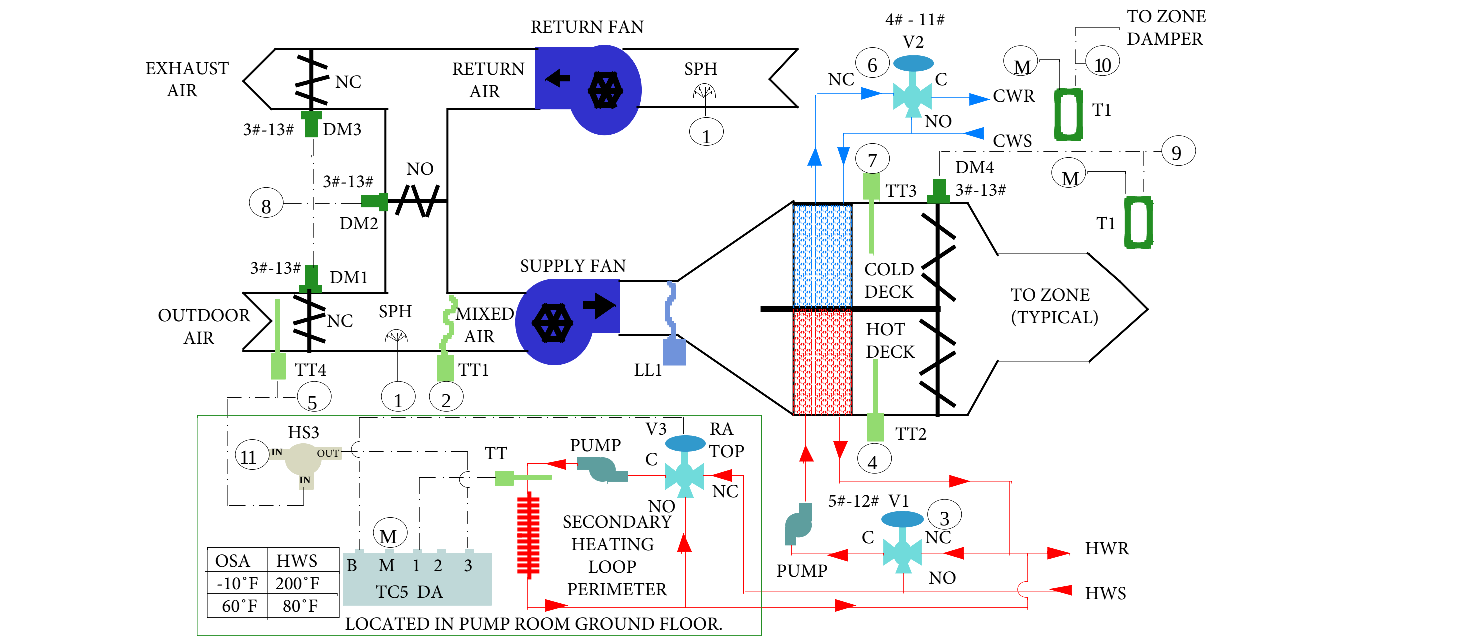
The graph also illustrates the mixed air temperature (cold deck temperature in the winter).

On drawing two you see that control loop controlling the mixed air does not communicate with the space cooling requirements. The loop simply produces the degree of cooling required for the maximum anticipated cooling requirement of the occupied space. There is no compensation for load variations in the occupied space.

This arrangement of ignoring the actual requirements of the zones tends to inject too much heat into the system. The system has to introduce extra cooling to compensate for the portion of the heat that is not actually required to address the heat loss.

At a domestic level, this is similar to running your furnace 60% of the time while the building heat loss only requires the furnace to run 50%. The house would over-heat unless you either reduced the run time to 50% or opened your windows to compensate for the extra heat generated by the excessive heat production. You would keep your windows closed and reduce the furnace run time. Most multizone systems actually follow the other path, bringing in extra cooling to get rid of the excess heat.

DRAWING THREE



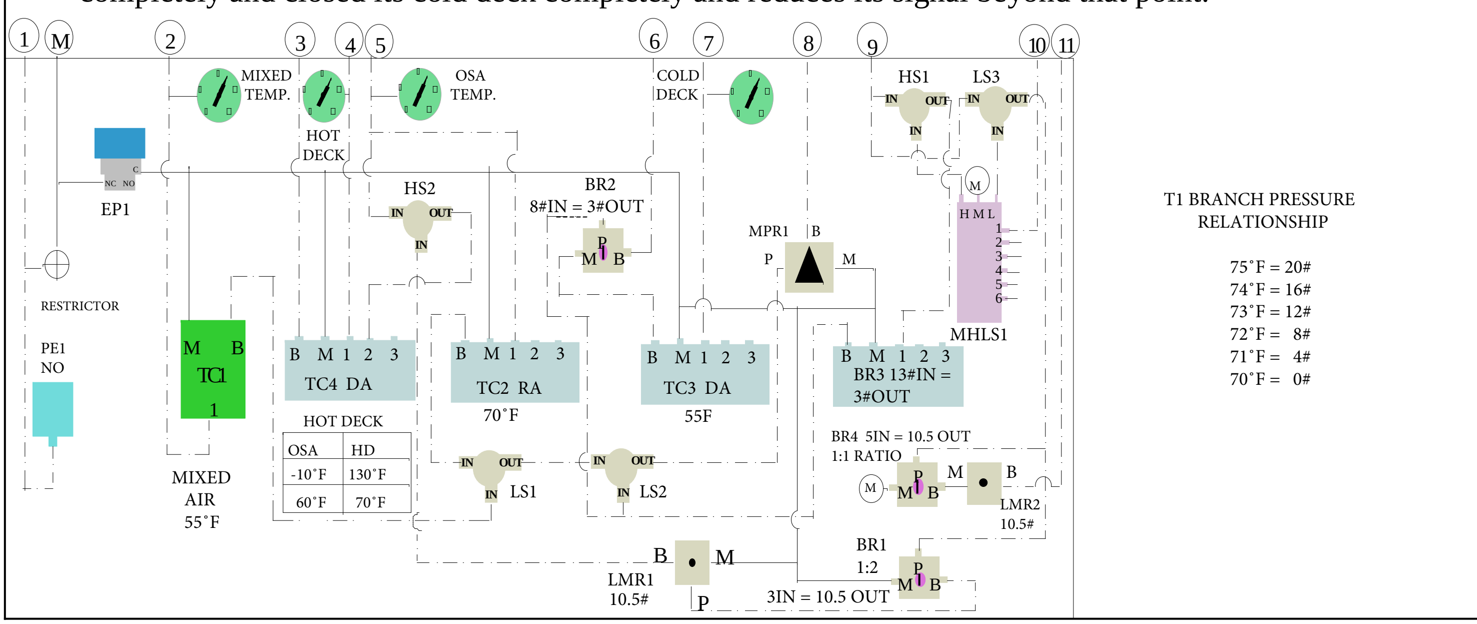
LOGIC OF OPERATION

The controls look at all the thermostat signals determining the greatest demand for heating and cooling via MHLS1, HS1 and LS3. If all thermostats are modulating their respective zone dampers the system "knows" that all zones are within 1F° of set point. Under this condition, the cold deck is controlled to minimum cooling and the hot deck is controlled to minimum heating.

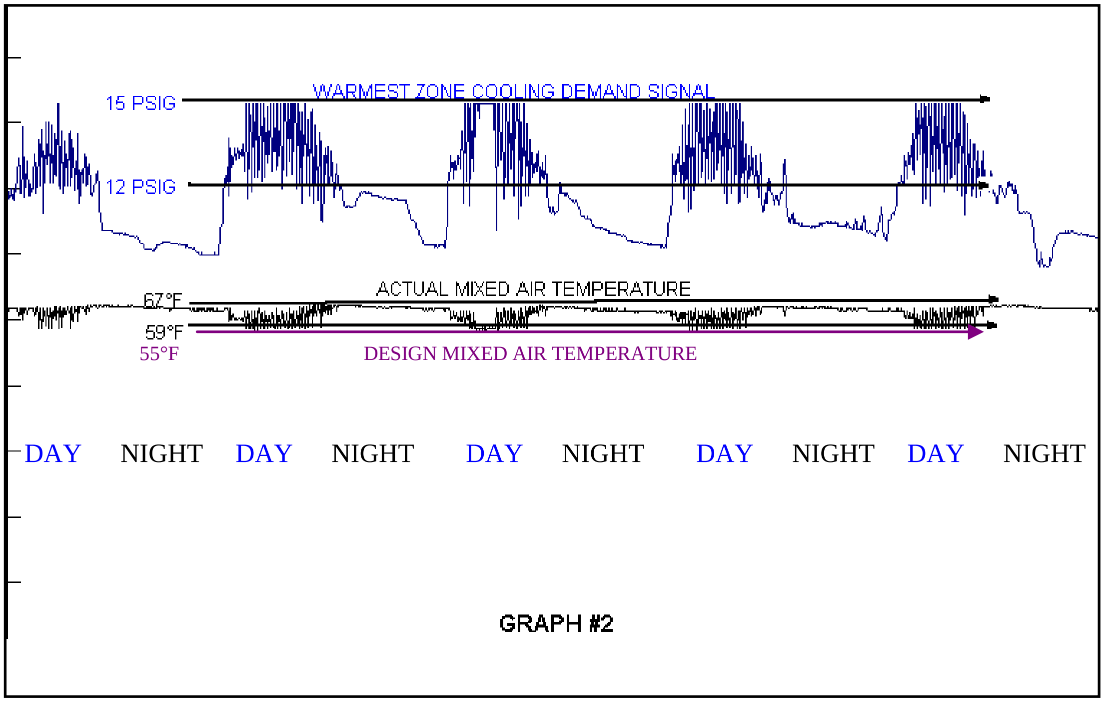
Any thermostat may lower the cold deck temperature limited by TC1 and TC3. The warmest thermostat "tells" the fan controls via the logic relays that at least one thermostat has closed off its hot deck completely and opened its cold deck completely. As the highest signal rises the cold deck will gradually become cooler.

The dampers return their minimum position when the outside air is more difficult to cool than the return air via TC2.

Any thermostat may raise the hot deck temperature, limited by TC4, after it has opened its hot deck completely and closed its cold deck completely and reduces its signal beyond that point.



DUFFINS CREEK SEWAGE PLANT MULTIZONE



GRAPH #2

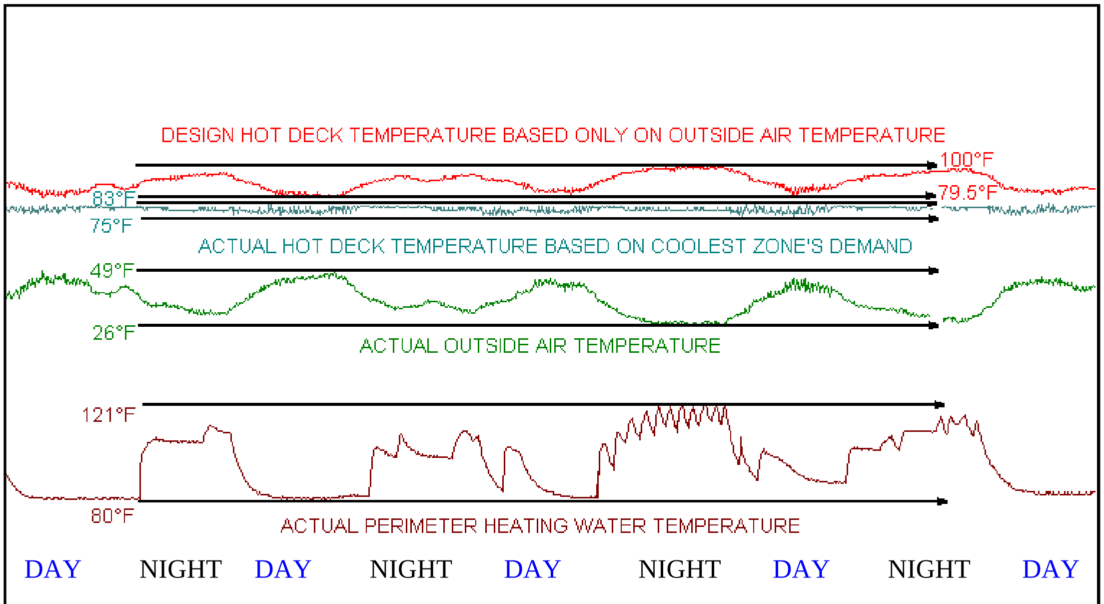
This graph illustrates the relationship of the requirement for cooling by the warmest room to the actual mixed air temperature. (The mixed air temperature is the cold deck for winter operation.) The mixed air temperature based on original design is also illustrated.

On drawing two you see that control loop controlling the mixed air does not communicate with the space cooling requirements. The loop simply produces the degree of cooling required for the maximum anticipated cooling requirement of the occupied space. There is no compensation for load variations in the occupied space. Drawing three shows the communication between the zone with the greatest requirement for cooling and the cooling functions on the fan system.

The graph shows that the warmest zone's cooling requirements increase during the day when the outside air temperatures are higher and heat gains from lights, bodies, solar gain, etc. are present. When the warmest zone signal is at 12 PSIG or below there is no requirement for cooling; therefore, the mixed air loop provides only enough fresh air to satisfy the ventilation demands, addressing air quality requirements. When the warmest zone's signal exceeds 12 PSIG the system "knows" that zone has its cold deck damper completely open and its hot deck damper completely closed. With this assurance that the demanding zone will not mix hot deck air with the requested cooling, the cold deck is gradually cooled as the warmest zone's signal approaches 15 PSIG. The mixed air temperature is limited to a minimum of 55°F.

The average actual mixed air temperature of the total points logged, on the illustrated graph is 65°F. The original design maintained the mixed air at a constant 55°F. Based on a fan volume of 15,000 CFM the original design would have used 162,000 BTU/HR more than the new conservation circuit.

DUFFINS CREEK SEWAGE PLANT MULTIZONE



GRAPH #3

HOT DECK AND PERIMETER HEATING COMPARISON FROM ORIGINAL DESIGN TO CONSERVATION CIRCUIT.

This graph illustrates a comparison of the design hot deck temperature, as per drawing two, to the actual hot deck temperature required, as per drawing three, by the coolest zone demand for heat. The actual temperature required in the perimeter heating, based on the demand from the coolest zone, is also presented.

The average actual hot deck temperature over the five day period was 79.5°F. The average hot deck design temperature was 90.2°F. The conservation circuit trimmed an average 10.7F° off the hot deck design temperature. This reduction in hot deck temperature, which provided only enough heat to satisfy the coolest zone, allowed the mixed air temperature to be raised to an average of 65°F, which provided only enough cooling to satisfy the warmest zone. The mixed air design temperature was 55°F.

The average perimeter heating water temperature was 95.2°F. The average perimeter heating water design temperature was 119°F. The conservation circuit trimmed an average 23.8F° from the design perimeter heating water temperature.

<u>GENERAL</u>

Multizone fan systems often present the most potential benefit relative to the dollars spent on retrofit. Pages 6.44 and 6.45 illustrate savings achieved in the Durham Board of Education and the Scarborough Board of Education.

We normally expect heating reductions ranging from 30% to 50% on multizone retrofits. The range depends on the condition of the system before we touch the controls.

Dual duct systems with mixing boxes at the individual zones require the same logic changes as multizones. Dual duct systems are more expensive to retrofit, as the zone signals have to be run back to the main fan control panel. Multizones have the zone signals at the fan from the original installation.

No two systems are completely identical. This case study illustrates the approach taken for this individual building. When applying this logic to another building, you must consider the safety of the occupants, building systems, etc.