

SINGLE

ZONE

CASE

STUDY

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## SINGLE 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.

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 four 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 design was altered, as per drawing three, by a representative of another large control company.  
We identify the design and commissioning problems.  
The energy performance relationship is illustrated.  
The performance of this arrangement is graphically illustrated from data collected before we altered any controls.
- (4)- Drawing four is the same as drawing three except the preferred energy use relationship is illustrated.
- (5)- Drawing five illustrates the control arrangement that will achieve the same common sense control you concluded in your manual operation on drawing one.  
The performance of this arrangement is graphically illustrated.
- (6)- An energy use comparison is drawn via the two performance graphs.  
The 49.74% energy reduction enjoyed relates to the specific load conditions.  
Based on practical experience, the alterations applied to this system normally produce reductions in the range of 15% to 25% annually.
- (7)- Remember, if the control system is not making the same common sense, device positioning 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 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 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 temperature is lower than the building temperature.

ACTION FLOW SHEET

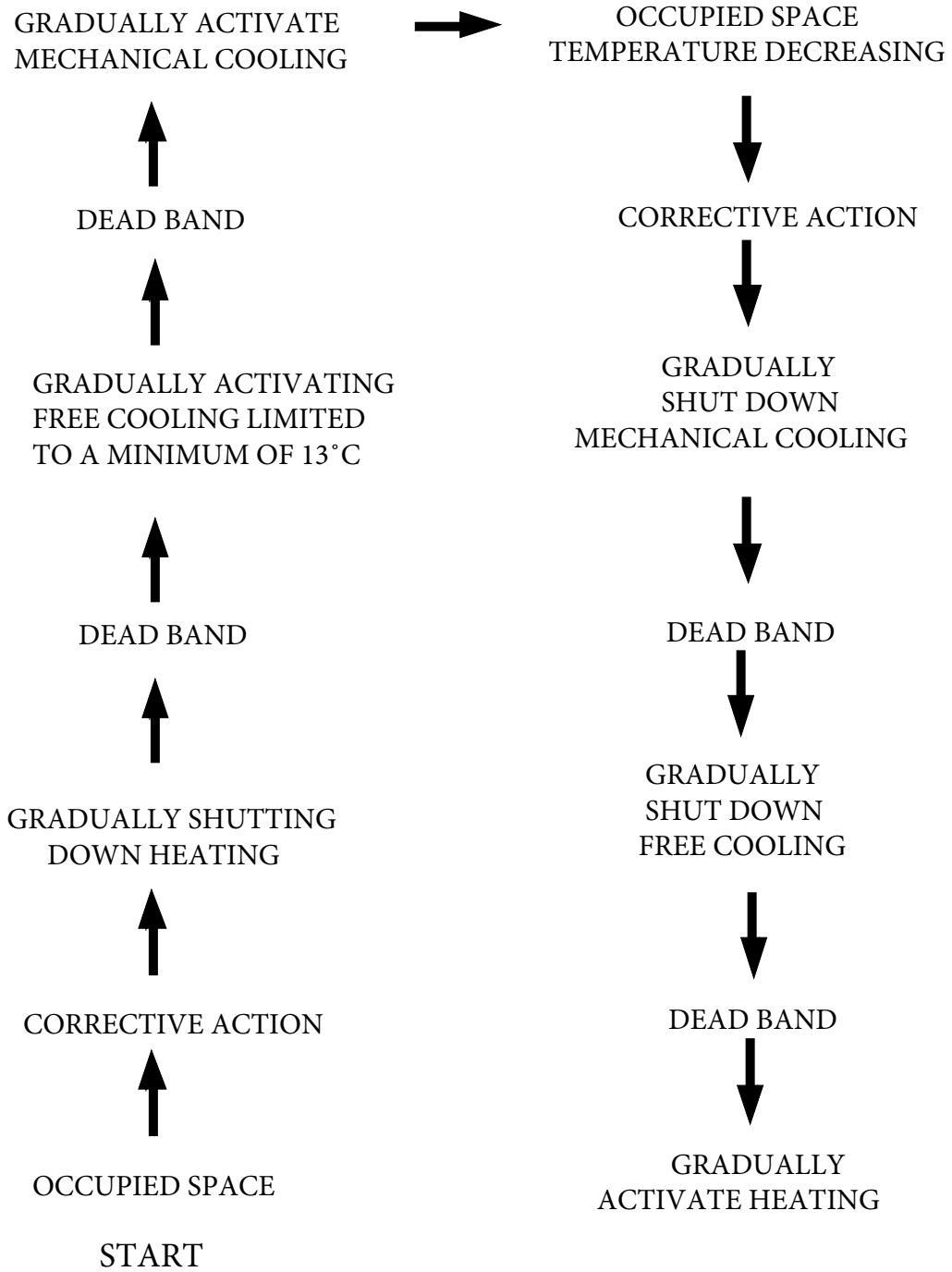


FIGURE 1

## MANUAL OPERATION DRAWING ONE

### **VENTILATION**

The manual 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.

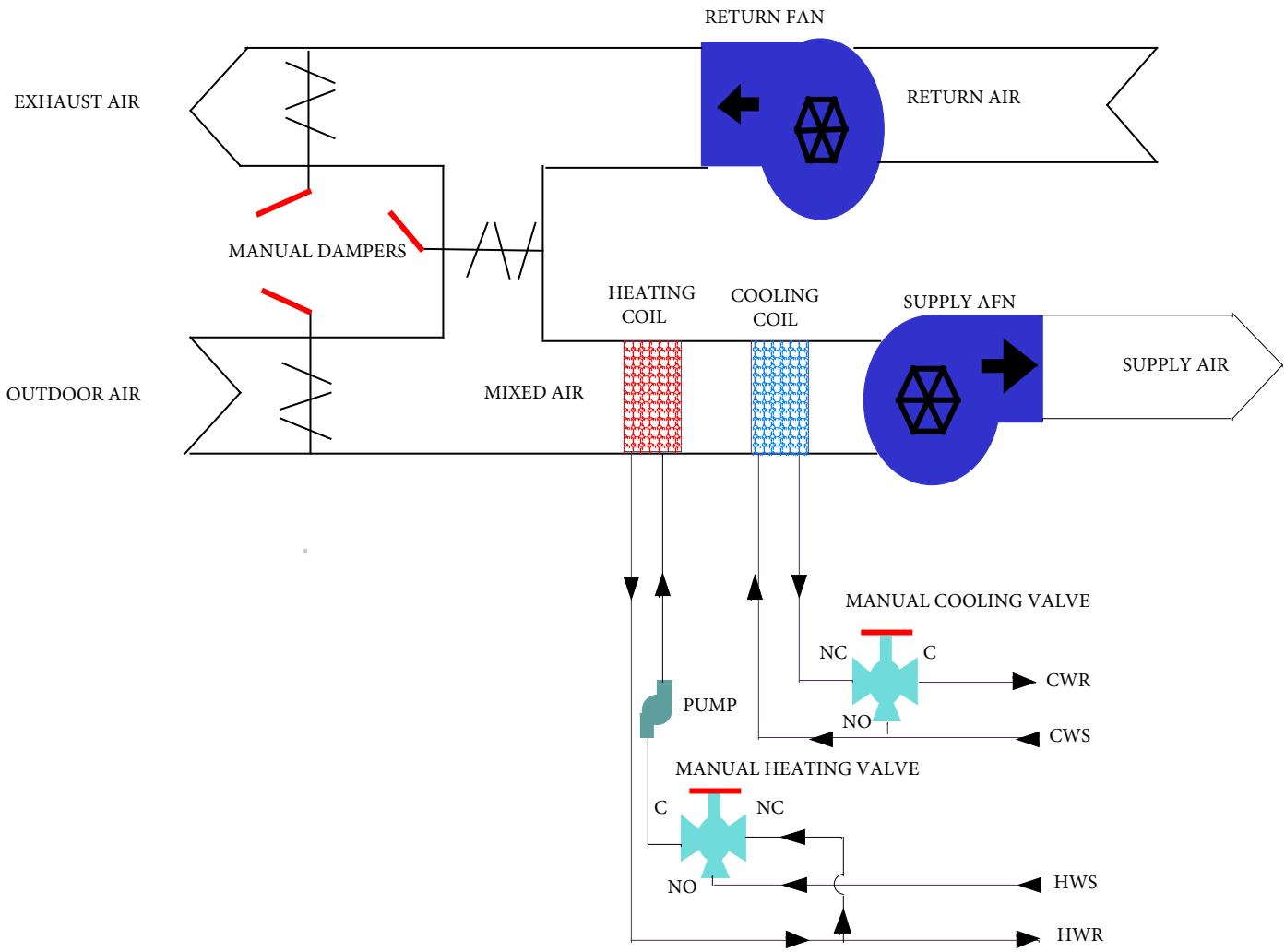
Shut down the fan at unoccupied times if it is not required.

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

### **TEMPERATURE CONTROL**

- 1- If the occupied space is thermally satisfied, keep the heating valve closed to the heating coil, keep the cooling valve closed to the cooling coil and leave the manual dampers in the minimum ventilation position.
- 2- If the occupied space starts to become cool, hold the manual dampers in the minimum ventilation position, keep the cooling valve closed to the cooling coil and open the heating valve to the heating coil only enough to hold the occupied space within the thermal comfort zone.
- 3- When the occupied space starts to become warm below 13°C outside.
  - Gradually reduce the quantity of hot water entering the heating coil. If the heating valve is completely closed off to the heating coil and the occupied space continues to increase in temperature, keep the heating valve closed to the heating coil, adjust the manual dampers to gradually reject the warm return air and bring more cool outside air into the occupied space.
  - Do not allow the mixed air to drop below 13°C.
  - Do not starve the supply fan or create a high discharge pressure on the return fan.
  - If the air temperature after the heating coil drops below 5°C in any area of the coil, shut the fan down to prevent freezing of the coils.
- 4- When the occupied space starts to become warm above 13°C outside:
  - Follow the procedure outlined in "3". If the outside air can not cool the occupied space, gradually open the cooling valve to the cooling coil just enough to keep the occupied space 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 ONE



## DRAWING TWO

### ORIGINAL DESIGN

The original design logic was typical of many systems designed and installed in the past sixty years.

A return air controller modulated the heating valve (V1) and the chilled water cooling valve (V2) in proper sequence as the means of controlling the occupied space temperature. The heating valve closed completely before the cooling valve allowed any chilled water flow through the cooling coil.

This part presented no problem relating to the system logic.

A mixed air controller modulated the mixing dampers (D1) and (D2) to maintain a constant 58°F upstream of the heating coil. An outside air high limit controller overrode the mixed air controller, preventing free cooling when the outside air temperature exceeded 70°F. A minimum positioning relay (MPR1) assured at least minimum ventilation when the fan system was active.

The outside air high limit could be upgraded to an enthalpy function, comparing the total cooling load of the outside air to the total cooling load of the return air. This loop selects the air stream with the lesser load reducing the workload on the cooling coil.

The minimum positioning relay could be upgraded to a carbon-dioxide sensor or VOC (Volatile Organic Compound) sensor better addressing the occupied space contaminant load.

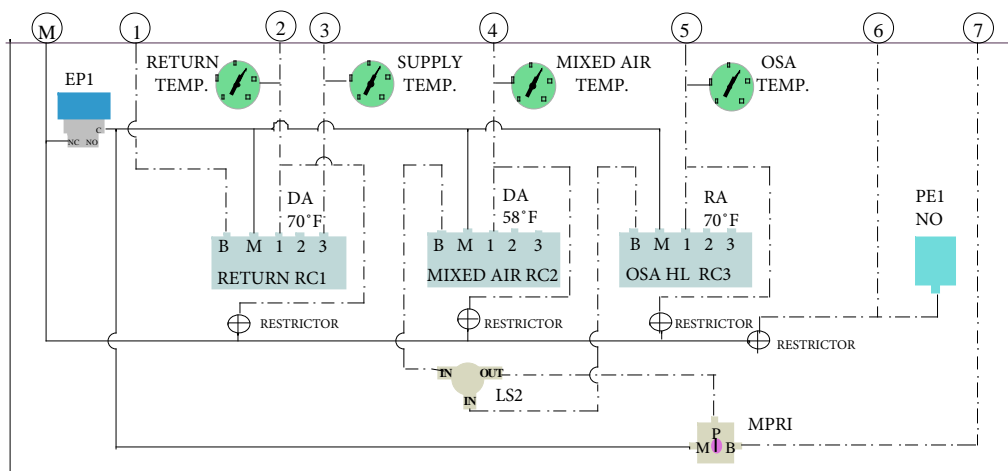
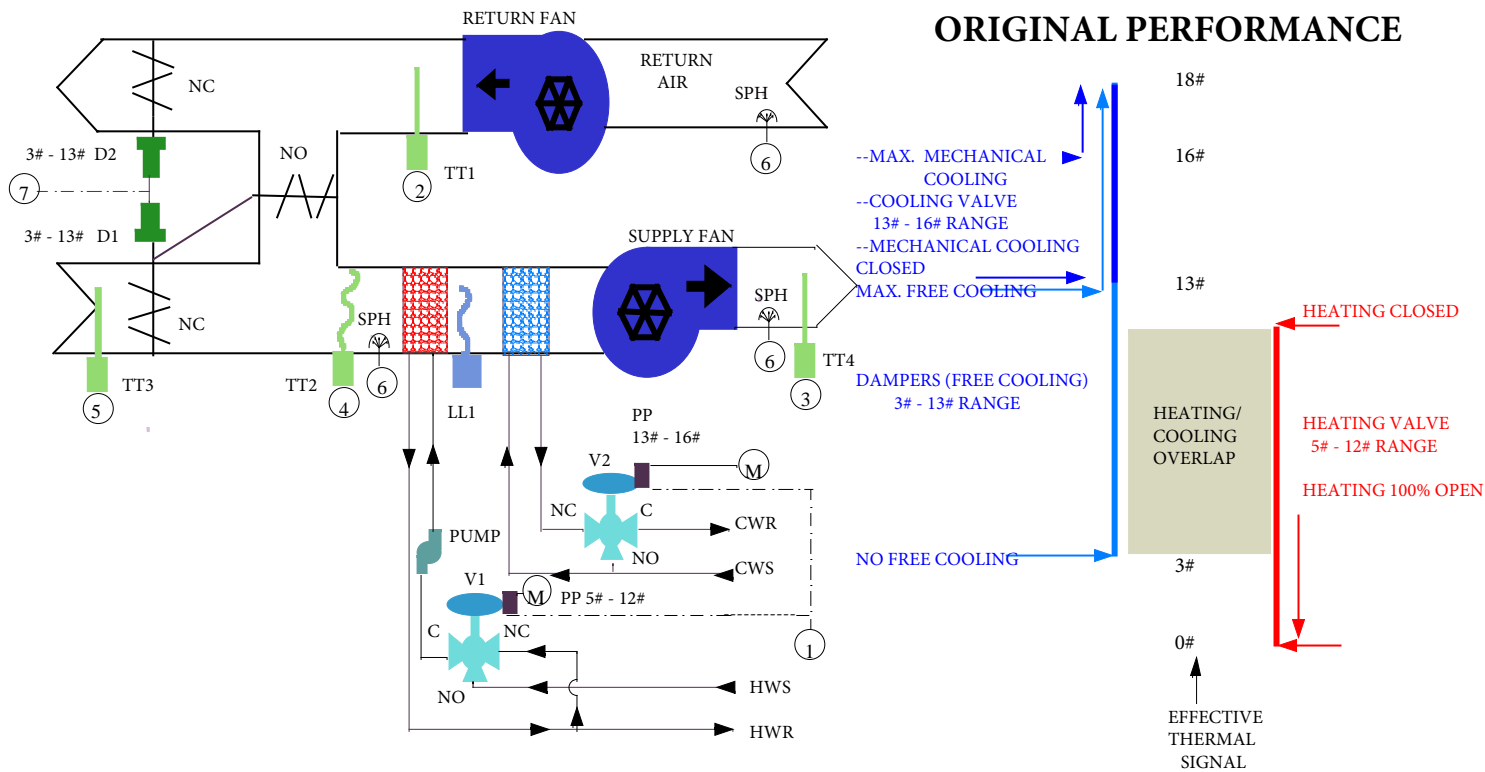
The mixed air design caused the "free cooling" to be active all the time the fan ran. The 58°F mixed air design intended to address the free cooling requirements when the space required its maximum amount of cooling. **At all other times heat had to be active to compensate for the over-cooling of the mixed air.** This is similar to opening the windows in your house and then turning on your furnace to compensate for the cold air coming through the windows. If you just closed the windows, the furnace would be required at a lesser rate.

Drawing two illustrates the overlap of free cooling and heating. The total BTU quantity of unwanted free cooling had to be matched with an equal BTU quantity of heating only to address this problem with the control logic. Additional heat was required to address the normal building heat losses of the occupied space.



# DRAWING TWO

## ORIGINAL PERFORMANCE



DRAWING THREE  
SYSTEM AS WE FOUND IT

Another contractor altered the control logic, as illustrated in drawing three.

The control contractor attempted to address two problems regarding the original design.

(1) They allowed the return air controller access to the mixed air loop.

The conservation intent was correct, but the application made no difference. The two mistakes occurred when they selected the biasing relay and commissioned that relay. The first error was selecting a biasing relay with a 1:1 ratio that can not squeeze the ten pound damper function between the heating and cooling valves where there is only a one pound span available. The second error observed caused the biasing relay signal to be advanced to the dampers rather than retarding the signal.

In theory the changes caused a greater over-lap of free cooling and heating; however, at a practical level the system performed exactly as the original design.

(2) The second alteration performed was installing a gradual switch in the occupied space, allowing the occupants the option of raising or lowering the return air set point.

This caused problems as the gradual switch had a blind dial with only six dots. The set point impact range was 42F° (7F° per dot) while the occupants thought each dot represented 1F°.

The two intended improvements were both valid points; however, the implementation of both actually had an over-all negative impact on control of the occupied space.

Graph one, at the back of this report, illustrates the system's energy performance as we found it. Graph two, at the back of this report illustrates the system's energy performance after we corrected the over-sights in logic.

Attempting to equalize the load, we deliberately chose time slots for both graphs that were at night, eliminating solar impact and human activity variation. The times chosen experienced identical average outside air temperatures. Other unknown factors caused the space to require 81.6°F supply air during data collection for the first graph and 70.66°F for the second graph. *During the period of the first graph, the system would have required 49.75% less heat attaining the 81.6°F supply air temperature if it employed the logic present for the second graph.*

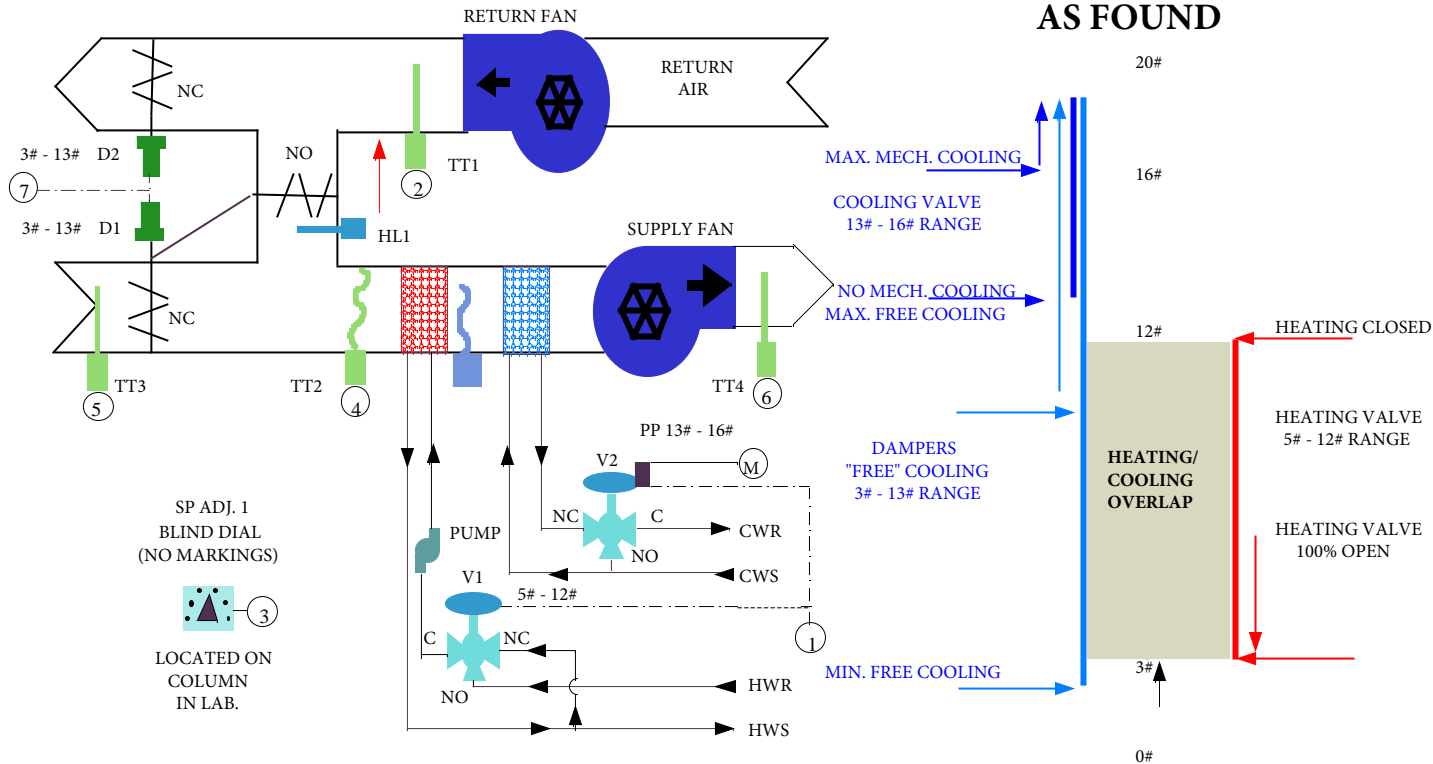
The system, as we found it, brought in an average of 74.86% fresh air, causing the return air controller to open the heating valve an average of 41.4%. In comparison the system as it now stands brought in an average of 27.4% fresh air, causing the return air controller to open the heating valve an average of 3.4%.

The old system over-cooled the mixed air and then activated the heating coil to compensate for the unwanted cooling. The new system logic allows the controls variable use of heat in the return air that has already been purchased.

# DRAWING THREE

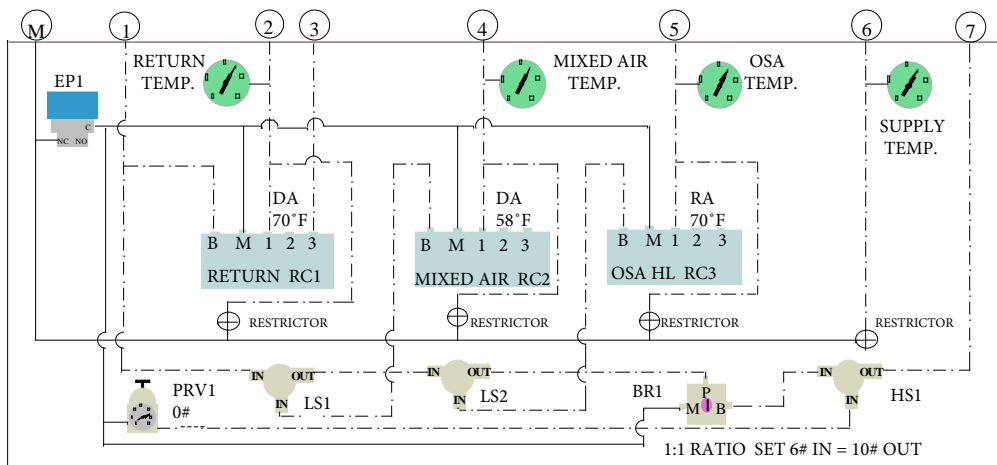
NOTE: TT1 SHOULD BE MOVED UP STREAM OF RETURN FAN PREVENTING FAN HEAT GAIN.  
 HL1 SHOULD BE MOVED TO DISCHARGE OF RETURN FAN AVOIDING DEAD AIR LOCATION.

## AS FOUND



NOTE;  
 BR1'S BIAS CAUSED A  
 THEORETICAL  
 NEGATIVE VALUE.

EFFECTIVE  
 THERMAL  
 SIGNAL



DRAWING FOUR  
PREFERRED PERFORMANCE CHART

Drawing four is the same as drawing three with the exception of the performance chart at the upper right corner. The chart on drawing three illustrates the actual performance as we found the system and Drawing Four illustrates the performance chart of the desired sequence of operation.

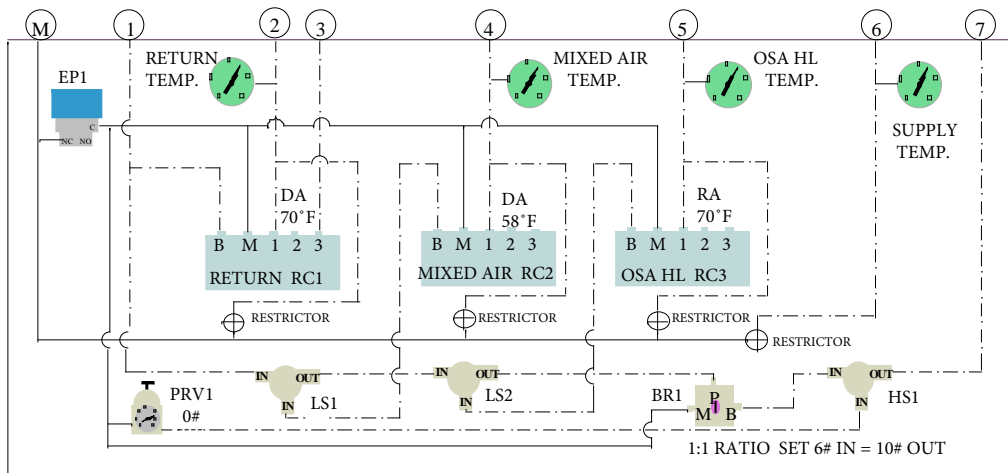
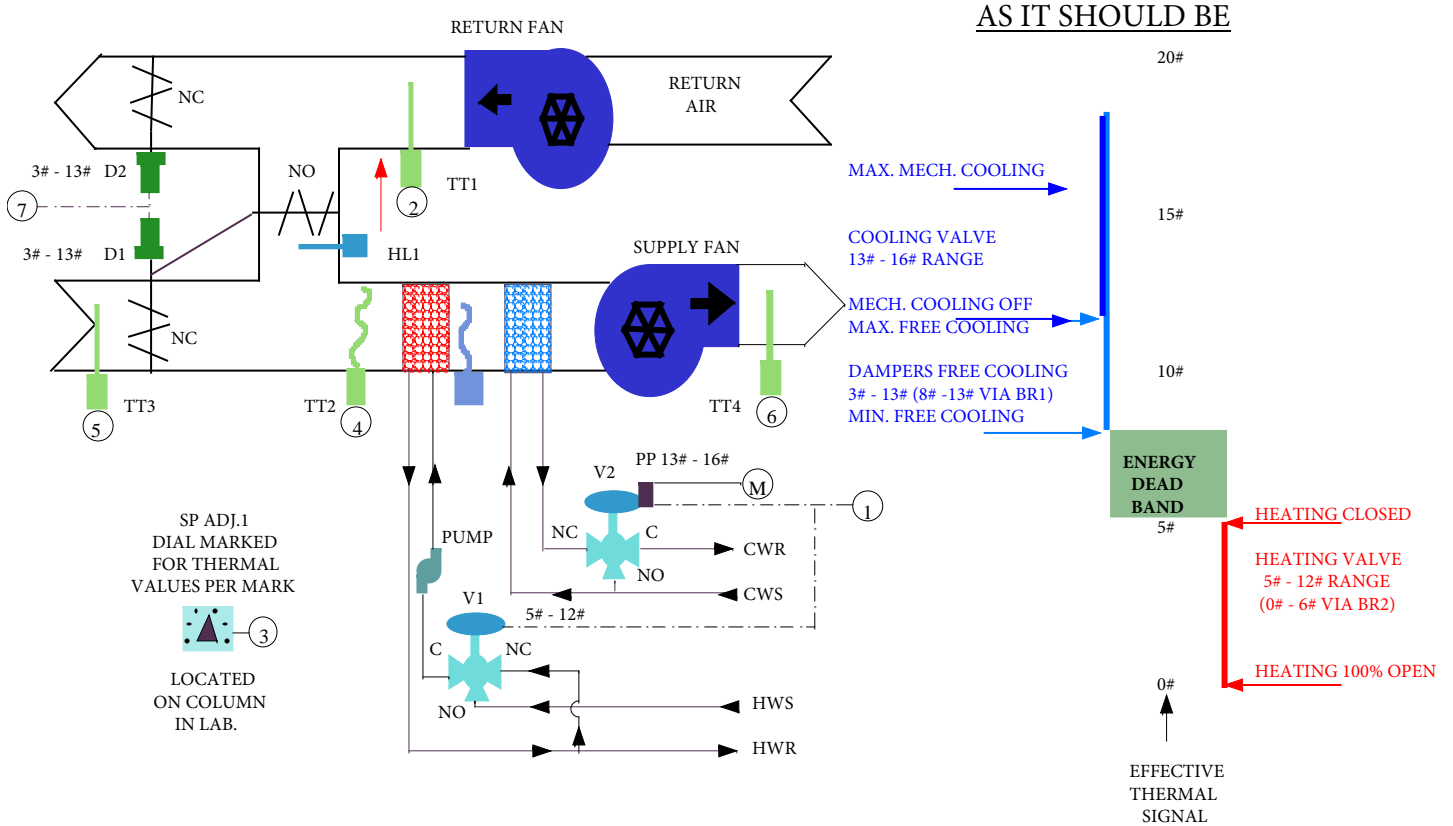
Two other points worthy of note are the locations of the return air temperature transmitter (TT1) and the electric high limit (HL1).

The electric high limit replaced PE1 and its associated sprinkler heads (SPH) in the original design. The original design was well arranged regarding sensing for high temperatures. The location of HL1 could hinder the device from sensing a high temperature if the building were on fire. If the outside air temperature were between 55°F and 70°F, the dampers would drive to full fresh air as the fire warmed the return air. HL1 would be sheltered from sensing the fire while the system fed the fire with oxygen.

TT1 senses the heat gain from the return fan. Up stream of the return fan is a better location for sensing the return air temperature.

# DRAWING FOUR

NOTE: TT1 SHOULD BE MOVED UP STREAM OF RETURN FAN PREVENTING FAN HEAT GAIN.  
HL1 SHOULD BE MOVED TO DISCHARGE OF RETURN FAN AVOIDING DEAD AIR LOCATION.



DRAWING FIVE  
SYSTEM AFTER LOGIC CORRECTIONS

Drawing five illustrates the control arrangement now controlling on site with the sequence of operation.

The performance chart illustrated on drawing four is achieved by this control system.

The high limit (HL1) is moved to sense the return air temperature at all times.

TT1 is moved to sense the true return air temperature.

It is interesting to note that the same number of instruments were required to achieve the logic system in drawing five as the first conservation attempt, as illustrated in drawing three.

GENERAL

The enthalpy circuit was not installed at the time of writing this report.

The minimum ventilation is being controlled as per the original design at the time of writing this report.

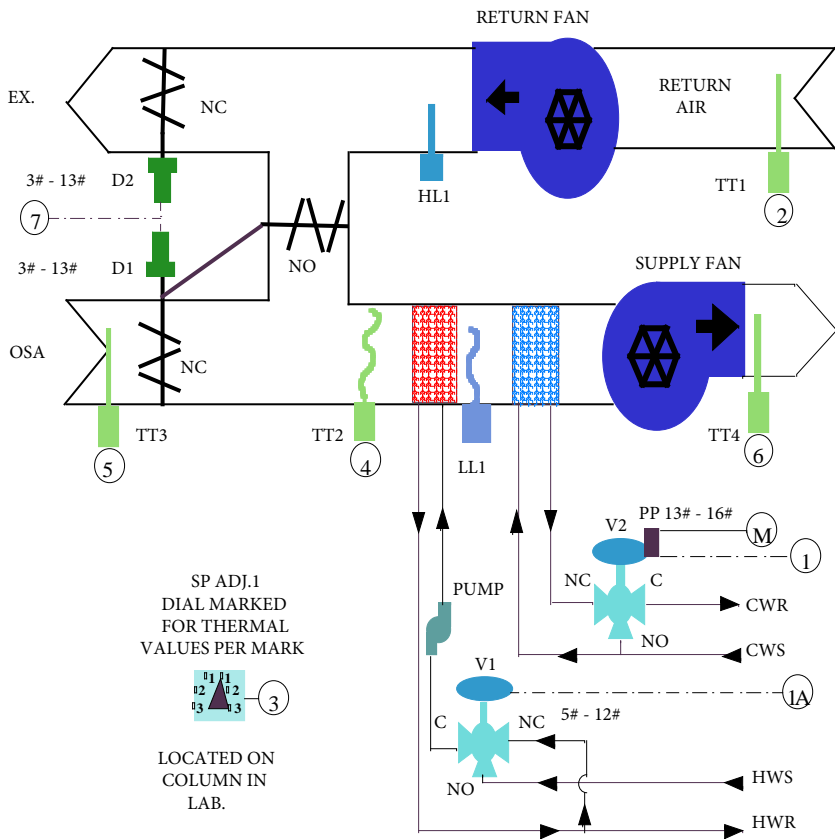
Two potential opportunities relating to energy reduction that required further investigation are:

-1- The fan could possibly be duty cycled, at unoccupied times, to a night set back temperature. This would save energy relating both to the heating and the electrical consumption.

-2- The minimum ventilation rate is 27% on the fan as it is currently running. The return fan has inlet vanes currently set at a fixed point. If the exhaust fans run intermittently, the opportunity may exist to reduce the minimum ventilation rates automatically based on the pressure differential from the laboratory to atmosphere.

This case study is the approach employed for one system in one building. The responsibility rests on the individual designer using any techniques presented in this report. The focus must remain on the safety and well being of the building occupants and the building. The only energy available for savings is the energy consumed by illogical control.

# DRAWING FIVE



## SEQUENCE OF OPERATION

- The fan runs continuously to suit the laboratory operations.
- Solenoid valve (EP1) passes control air to the fan controls when the fan is running.
- Receiver controller (RC1) senses the return air temperature via transmitter (TT1) and receives a set point demand from (SP ADJ 1). RC1 sends its signal to biasing relays (BR1) and (BR2) as well as to cooling valve (V2). The instrument arrangement causes the heating valve (V1) to close first, then the free cooling via damper actuators (D1) and (D2) is maximized and then mechanical cooling is employed via V2 on a call for cooling.
- BR1 sends its signal to high selector (HS1) which also receives a signal from regulator (PRV1) to assure the system of at least minimum ventilation while the fan is running.
- Receiver controller (RC3) senses the outside air temperature via transmitter (TT3). RC3 passes its signal to receiver controller (RC2) only when free cooling is available, based on the outside air temperature to economize on mechanical cooling. RC2 senses the mixed air temperature via transmitter (TT2). RC2 limits the mixed air to a minimum of 58°F.
- Turn down ratio relay (BR3) is set to limit the range of set point demand from the laboratory.
- If low limit (LL1) senses a temperature below its set point on any one foot of its element the fan will shut down. If high limit (HL1) senses a temperature above its set point the fan will shut down. Both LL1 and HL1 require resetting after being tripped.

