DEHUMIDIFICATION WITHOUT RE-HEAT USING FACE AND BYPASS DAMPERS

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ABSTRACT:

Installations with chill water cooling, needing constant air volume and dehumidification, traditionally use a draw through air handling unit with a cooling coil and a re-heat coil. Dehumidification is achieved by overcooling the discharge air to wring out moisture and then re-heating it back to the desired temperature. This method works well but at the added expense of over cooling plus re-heating. A properly controlled Face and Bypass unit can deliver the same air conditions by blending return air and cold deck air with no need for re-heat. This system uses only the amount of cooling energy needed to do the job and no re-heat energy, in some cases as much as 50% less energy than the re-heat method.

INTRODUCTION:

The concept developed from the desire to reduce the installation and operating costs of air handling unit equipment for cleanrooms at Texas Instruments.

The special demands of a cleanroom require a constant high volume of circulating air as well as close pressure, temperature and humidity control. Small cleanrooms often use one air handler unit to provide all four of these requirements.

Dehumidification problem:

A higher than normal air volume to cooling load ratio results in high dehumidification costs.

Cleanrooms require large air flows through HEPA filters for particle removal. The cleanroom nominal requirements of 72° F. ± 2° and 45% Rh. ± 5% dictate a discharge dew point of 47° to 54° F. Because of the high volume of air required for particle removal, the discharge air temperature does not need to get as cold as in normal HVAC designs to remove the same amount of heat. An office area air handler may be designed around a 55° discharge temperature and normal discharge air volumes to handle it's heat load. A cleanroom air handling unit only needs 60° to 70° discharge air temperatures to remove it's heat load. The 55° discharge AHU system's cooling coil will by design remove moisture from the air as it cools. The cleanroom system's cooling coil modulated to deliver 60° to 70° discharge air will not be cold enough to do adequate dehumidification. This condition requires the control system to lower the cooling coil temperature to remove moisture while not allowing the discharge temperature to drop. This report will investigate solving this problem using a traditional re-heat unit and a face and bypass unit.

Re-heat unit:

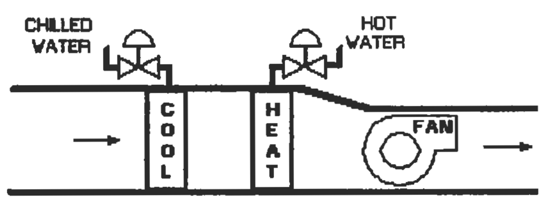

Fig.1

This system uses a draw through air handling unit to take advantage of the fan heat generated as added re-heat. It uses a mixing box section to add building air for room ventilation and pressure control. The unit has both a modulating cooling coil and re-heat coil. When dehumidification is needed all the entering air passes through the cooling coil where it is cooled down to remove the moisture needed. Then it is re-heated back to the temperature required to hold room temperature. This method of temperature and humidity control result is wasted over cooling energy and an equal amount of wasted re-heat energy. Together the wasted energy can equal more than energy actual required to do job.

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Face and bypass unit:

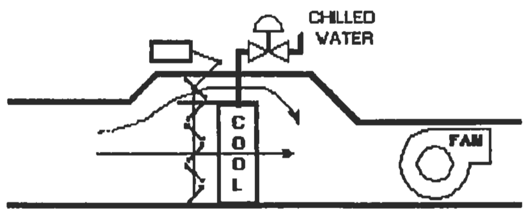

Fig.2

This system uses a draw through air handling unit to take advantage of the fan heat generated as added re-heat. It uses a mixing box section to add building air for ventilation and room pressure control. The unit has a modulating cooling coil and an additional section installed between the filter box and the coil section. This Face and Bypass section has a set of cross linked dampers that gives it the ability to flow all the air through the coil or divert any amount needed around it. The air passage around the coil is designed to have the same pressure drop as the coil so the total discharge air volume does not change when any portions of the air is modulated around the coil. When dehumidification is needed the cooling coil temperature is lowered to remove the moisture needed. A portion of the entering air bypasses the cooling coil to hold the discharge temperature needed to maintain room temperature. The result is the same temperature and humidity conditions as in the re-heat method, while using only the amount of energy required to do the job.

Technical Background

Air handling unit dehumidification characteristics

Re-heat AHU
A typical chill water air handling unit varies it's discharge temperature by modulating water flow through the coil. This gives it the ability to deliver any discharge temperature from entering air temperature down to it's design capacity.
As the discharge air temperature is lowered from entering air temperature the discharge dew point remains equal to the entering air dew point until the discharge temperature approaches it. When the discharge temperature reaches dew point the dew point will follow the discharge temperature as it is lowered. (see fig. 3)This type of air handling unit does not provide adequate dehumidification in low load high humidity conditions.

Face and Bypass Unit
A standard face and bypass unit modulates it's discharge temperature by maintaining a constant cold deck temperature and mixing it with varying amounts of entering air.As the discharge air temperature is lowered from entering air temperature the discharge dew point drops rapidly and assumes a slow chancing profile through out the normal operating range. (see fig. 3)The lowered dew point at higher discharge temperatures occurs because some portion of the total air stream still passes through the cold cooling coil, removing moisture that subtracts from the final mixture.

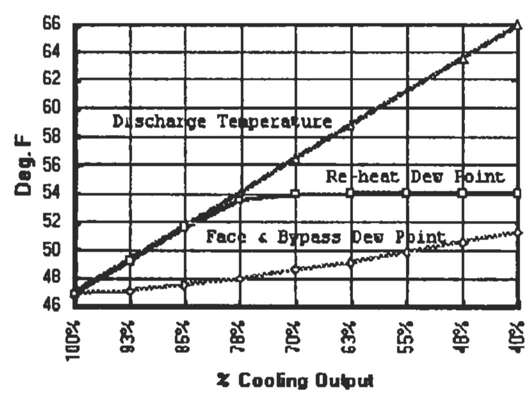

Fig.3

Psychrometric comparison

Re-heat Unit:
A Psychrometric description of the re-heat cycle shows air entering the coil at 74°db / 62°wb (D). It is a mixture of return air at 73°/ 60°wb (B) and building air at 80°db/71°wb (C).This air is then cooled down the coil profile line to the dew point needed for dehumidification 48°. This is the coil temperature 51°db/50°wb (E).Next the air is re-heated to 59°db/53°wb (F).The fan adds the final heat to bring the discharge temperature to 64°db/56°wb (G) needed to satisfy room conditions. In this 6,000 CFM model the Cooling energy needed is 202,500 BTU/Hr. and the heating energy 62,000 BTU/Hr.

A. 72°db, 59°wb Room conditions
B. 73°db, 60°wb Return conditions
C. 80°db, 71°wb Building air
D. 74°db, 62°wb Entering air
E. 51°db, 50°wb Coil temperature
F. 59°db, 53°wb Discharge temperature
G. 64°db, 56°wb Final discharge temperature

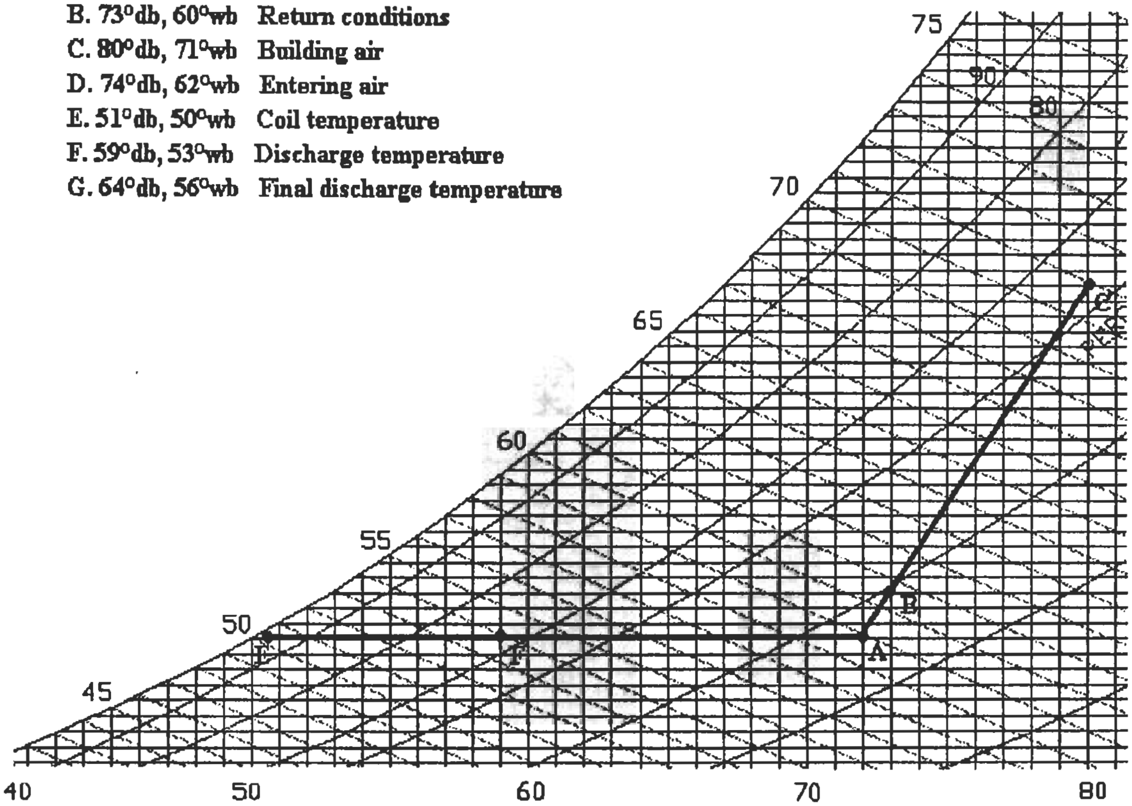

Fig.4

Face and Bypass Unit:

The face and bypass cycle shows air entering the coil at 74°db/62°wb (D).

It is a mixture of return air at 73°/60°wb (B) and building air at 80°db/71°wb (C). The cold deck temperature needed to do the required dehumidification must be calculated. A line is drawn from the room condition 72°db/59°wb horizontal to meet the saturation line. This line gives the dew point of the discharge air mixture.

In a face and bypass unit the pre-fan discharge temperature 59°db (F) is a mixture of entering air 74°db/62°wb (D) and coil temperature air (E).

The coil temperature is determined by drawing a line from the entering air point (D) through the intersection of the discharge temperature (F) and the dew point line. The point at which this line crosses the a coil profile line is the coil temperature 46°db/45°wb (E). The amount of air passing through the coil is calculated form the dry bulb ratio needed to make the mixture.

Cold deck % = (74-59) / (74-46) = 53%
53% of 6,000 CFM = 3,200 CFM

In this 6,000 CFM model the Cooling energy needed is 140,400 BTU/Hr. and the heating energy 0 BTU/Hr.

NOTE:
If the line drawn to determine the coil temperature does not cross a coil profile line at a temperature that can be achieved with the chill water available some re-heat must be used to make up the delta.

A. 72°db, 59°wb Room conditions
B. 73°db, 60°wb Return conditions
C. 80°db, 71°wb Building air
D. 74°db, 62°wb Entering air
E. 46°db, 45°wb Coil temperature
F. 59°db, 53°wb Discharge temperature
G. 64°db, 56°wb Final discharge temperature

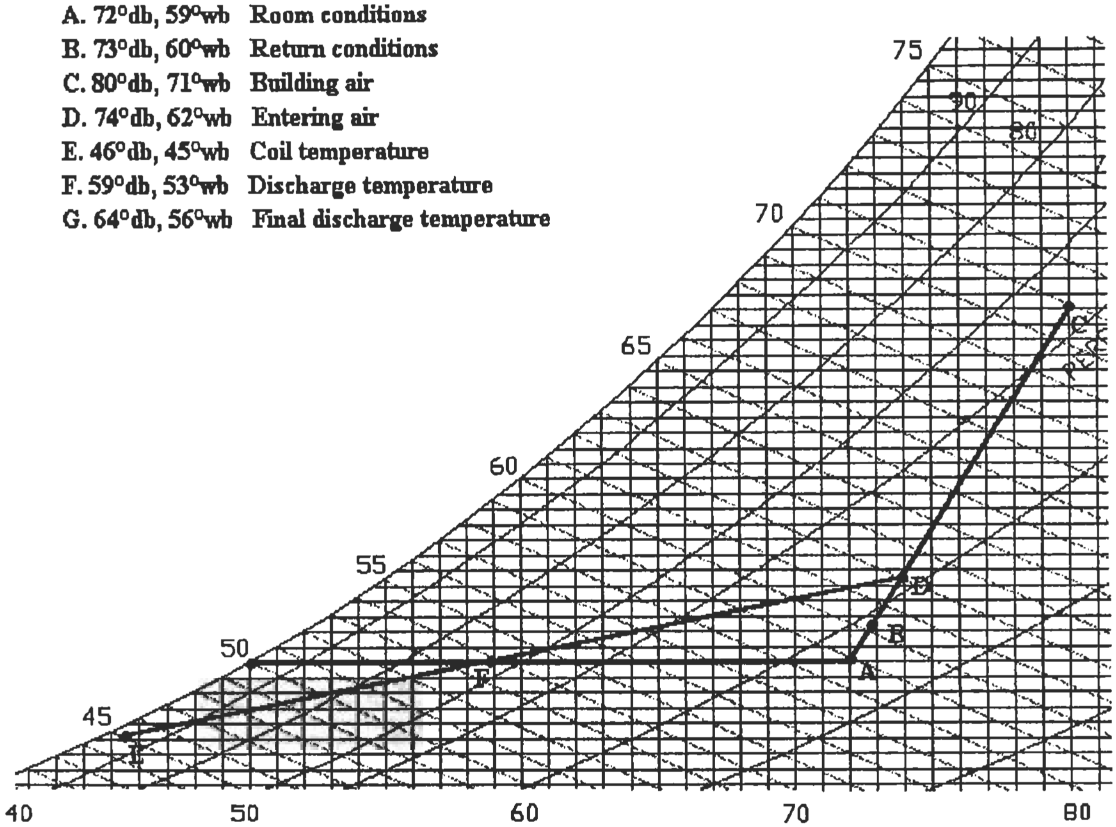

Fig.5

Graphic depiction:
These Figures show the air handling unit configurations, air paths and a scaled depiction of the dry bulb and dew point changes as air passes through the unit.

Re-heat Unit

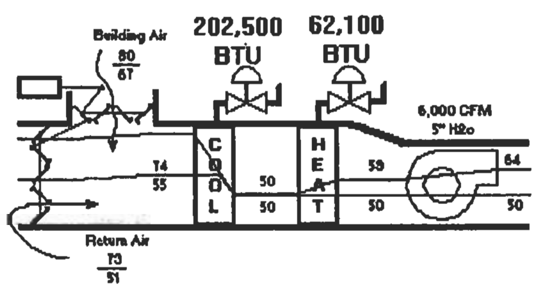

Fig.6

Face and Bypass Unit

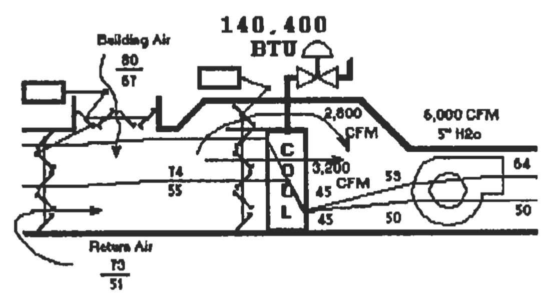

Fig.7

Case History:

Design goals:

1. Make the operation controllable and reliable.

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2. Dehumidify to room specification at lowest energy cost.
3. Make the air handling unit and controls maintainable.
4. Monitor and historically trend the systems operation.

Room specifications:

1. Class 100,000 Cleanroom 12,500 Sq. Ft
2. Temperature 72 Deg. F + or - 2 Deg. F
3. Humidity 45 % Rh. + or - 5 % Rh.

Dehumidification design conditions:

1. 6000 CFM air flow at 5" H2o static pressure
2. Heat load of 88,000 BTU's
3. 42 Deg. F cooling water at 10 PSID
4. 90 Deg. F heating water at 20 PSID
5. Summer Psychrometrics
   building air conditions 80°F 62% Rh 25% Mix
   return air conditions 73°F 45% Rh 75% Mix

Air handler design:

Pressure and ventilation requirements dictated the use of a mixing box to add fresh air from the building space. The Psychrometrics were done using the room and building air conditions and mixtures. The calculations indicated that normal dehumidification conditions could be accomplished with out re-heat. They also reviled that higher chill water temperatures, greater room or building air latent loads or high building air mixtures could possibly present conditions the face and bypass unit would not have the capacity to handle. The decision was made to install a re-heat coil as a back up measure. Under extreme conditions the unit can close the bypass damper and function at the full capacity of a re-heat unit. The cooling coil was sized for the full load of a re-heat unit. The oversize cooling coil and decreased coil face air flow helps keep the chill water differential temperature from dropping when the face and bypass unit requires a low coil temperature. This along with a lower total cooling requirement help the chill water pumping savings at the central utility plant. A vertical draw through face and bypass unit with a re-heat coil in the fan section was chosen to accommodate the space limitations of this project. This figure shows the actual configuration of the air handler as it was installed.

Face and Bypass Unit
Lay Out

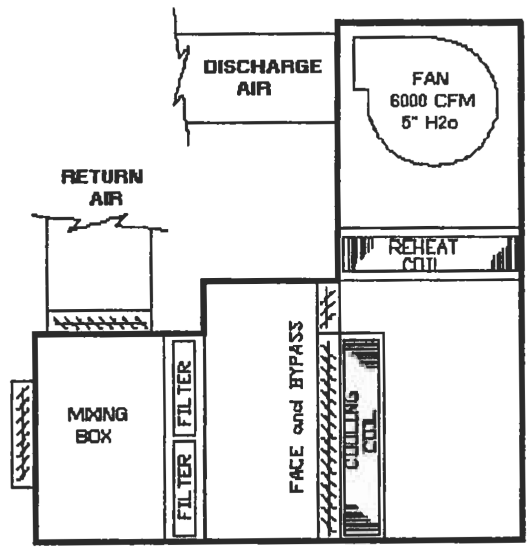

Fig.8

Controls design:
This cleanroom required close tolerance temperature control at 74°F. but allowed relative humidity to drift between the 40%Rh and 50%Rh limits. A cascade control system was chosen to help stabilize room conditions during dehumidification change over periods. This system also smoothes out sudden changes in chill water temperature or pressure from the central utility plant.

Room temperature :
The outer (room temperature) control loop uses a wall mount sensor located 54" from the floor. It changes the discharge temperature needed by adjusting the set point of the inner (discharge temperature) control loop. The discharge temperature sensor is mounted just down stream of the fan discharge. The output of this loop modulates the chill water valve to acquire the discharge temperature needed to cool the room.

Room dehumidification :

A dehumidification control loop will on a call for dehumidification take control of the chill water valve away from the duct temperature loop and begin to modulate the cold deck to the colder temperature needed for moisture removal. The duct temperature begins to drop and the duct temperature loop responds by modulating open the bypass damper to reestablish control. The dehumidification control sequence involves to main control loops that interact with each other. The face and bypass dampers effect the amount of air flowing through the cold deck which effects it's temperature and the cold deck temperature effects the amount of air the face and bypass dampers modulates around the coil.

Room humidification :

A separate humidity control loop gave the advantage of specific loop tuning for the steam humidifier used in this installation rather than tuning for the whole humidification system. It also provided an individual set point to create an energy conserving humidification / dehumidification dead band.

Room pressure :

A room pressure control loop modulated the building air damper to hold a slightly positive pressure in the room.

Backup dehumidification :

The concern that under extreme conditions the dehumidification cycle could require the face and bypass damper to limit the amount of air passing through the cooling coil to such a small amount that it could not function needed to be addressed. In this event the face and bypass damper would reverse and begin to modulate back open to the coil. The duct temperature would begin to fall and the duct temperature control loop would begin to modulate the re-heat valve. The entire sequence reverses as dehumidification requirements subside.

DDC Control:

The tuning of cascaded control loops, interacting temperature and dehumidification control loops, the backup dehumidification sequence and the desire to monitor and trend the system performance pointed to a Direct Digital Control System. Pneumatic actuation was chosen for it's reliability, cost and customer preference.

Monitoring:

The DDC control system helps provide monitoring capabilities. Below is a screen print out made on 01/26/94 of the cleanroom air handling in the dehumidification mode. It shows the air handling unit face damper open 76.5% to the cooling coil and the re-heat valve 0% open. It farther shows the duct steam humidifier 0% on and the building air make up damper 100% open. Temporary wall construction in the area prevents the room from pressurizing. The room set points at this time are 74° deg. 48% Rh. and .05" H2o. The screen also shows the room temperature at 73.9° relative humidity 48.8% and room pressure .05" H2o. all within specifications.

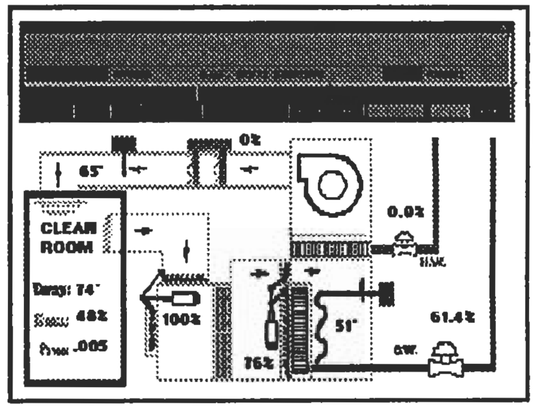

Fig.9

Results:

The biggest concern for system has been it's controllability. The room load changes dramatically from full operation of the equipment with as many as 10 people to all off and no occupants. The control system has been able to adjust to these difficult load changes with out upset in the room conditions. The unit has proven to be stable during humidification to dehumidification changeover. The temperature is being held within + or - .75 Deg. and humidity is being held within + or - 1 % Rh. The units' capacity to dehumidify was tested to it's maximum this summer when the building makeup air damper went 100% open for more than three months to make up room pressure loss during wall construction. The room held temperature and humidity specifications during the entire period and never used the back up re-heat feature. The buildings monitoring system was used to both tune the loops and trend the units performance. The Cleanroom has been operating with this system since February 1992 and has never needed the back up re-heat coil and never failed to keep the temperature and humidity within specifications.

This project was done on a normal cleanroom project control budget and did not have funding for added instrumentation to show actual savings.

CONCLUSION:

Re-heat dehumidification is least efficient at low load conditions. Face and bypass has it's highest percentage savings at these conditions.

The previous Psychrometric calculations were bases on a 6,000 CFM unit with entering mixed air conditions of 74°db / 62°wb. A comparison made with identical load room load conditions and lower entering air conditions of 72°db / 61°wb shows the increased percentage savings.

74°db, 62°wb

Cooling BTU's		
Re-heat Unit	202,500	
Face & Bypass	140,400	
Delta	62,100	30%
Heating BTU's		
Re-heat Unit	62,100	
Face & Bypass	0	
Delta	62,100	100%
Total BTU Savings	124,200	45.9%

72°db, 61°wb

Cooling BTU's		
Re-heat Unit	167,000	
Face & Bypass	94,500	
Delta	72,500	43%
Heating BTU's		
Re-heat Unit	72,500	
Face & Bypass	0	
Delta	72,500	100%
Total BTU Savings	145,000	59%

Lower operating cost than re-heat system. If re-heat coil is eliminated lower initial cost can be realized from the elimination of the coil and associated hot water piping.

With proper controls set up and loop tuning the system has proven to be stable under all conditions. Two smaller projects have been installed in the last year using the face and bypass system. Both have operated through the summer with out problem.

Considerations:

Psychrometric study done to determine system capacity and savings.

Adequate coil selection for dehumidification.

Proper control valve sizing.

DDC controls make the loop tuning and monitoring.

Thorough controls set up and commissioning to insure stability.

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